NWT Apprenticeship Support Materials

Science

* *Module 1 – Foundations*
* *Module 2 – Science Development*
* *Module 3 – Special Topics*

Reading Comprehension

Math

P A R T N E R S

SNAP LAKE DIAMOND PROJECT
De Beers

Aurora College

Northwest Territories Education, Culture and Employment

Skills Compétences Canada
Northwest Territories Nunavut

Genesis Group Ltd.

Canada

Alberta Advanced Education
Apprenticeship and Industry Training

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The Apprenticeship Support Materials Project has been a true partnership. The challenge has been to develop a set of study materials, which covers every competency in the "Entrance Level Competencies for Apprenticeship Programs" developed by Alberta Advanced Education, Apprenticeship and Industry Training. These study materials although written for Northerners using northern examples, issues and problems, are appropriate for any individual entering the trades. The goal is to equip Northerners for the Trades Entrance Exam as well as to support them through the apprenticeship process.

The following partner organizations have all contributed to the development of these materials:

De Beers Canada Mining Inc. – Snap Lake Diamond Project
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Author

Thomas O'Connor M.A., Education Consultant with the Genesis Group Ltd., is the author of the NWT Apprenticeship Support Materials.

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Module One: Science Foundations

Table of Contents

Introduction

This curriculum is designed for independent study. It can also be used to support study groups, one on one tutoring, and classroom lessons. It has three modules that will cover all five levels of the Alberta list of science competencies required for the trades entrance examination.[1] **A curriculum for Math and for Reading Comprehension** is also available to provide a complete resource for trades entrance exam preparation in the Northwest Territories.

Supplementary Topics

In addition, **supplementary topics,** for example atomic structure, some chemistry, and formulas used to solve problems in applied situations, are included as options for further study.

The supplementary topics are based on alternative lists for trades entrance competency and expand the knowledge base for apprenticeship.[2] These topics are found in many pre-trades science courses at colleges and technical schools. Footnotes connect these topics with the required material.

Competency:

an ability that can be demonstrated

1 See Appendix A: Trades Entrance Requirements from the Alberta Trades Entrance Curriculum.

2 Supplementary topics include some NWT Department of Education pre-trades topics from past exams and science curriculum normally covered in high school physics and chemistry courses.

Introduction

Math Foundations are Required

All trades entrance candidates are expected to understand the competencies covered in the first four modules of the math curriculum. The science curriculum makes use of the math skills covered there. You may decide to study math and science together.

The trades entrance examination is based on a competency based approach. This means that **what you know- not how you learned it,** will be assessed. It also means that **only what you need to know for entrance into a specific trade will be assessed.**

When you choose a trade to prepare for, you need to know how much of the science curriculum will be on your trades entrance exam. Each version of the exam is designed for a specific group of trades. Contact the NWT Apprenticeship branch to learn what exam levels are required for a specific trade.

Exam Levels 1 and 2
You need to understand Science – Module 1 – Science Foundations

Exam Levels 3 and 4
You need to understand Science – Module 2 – Science Development as well as Module 1.

Exam Levels 5
You need to understand Science – Module 3 – Special Topics as well as Modules 1 and 2.

Organization of Content

Examples are the Focus

In this curriculum guide, examples with explanations are the primary tool used for review. Background for each competency is also given with a brief overview of what you need to know. Before any examples are given, the main ideas in each topic are explained and "need to know" information is summarized in rules and definitions.

You may want to skip the background given on a topic and go right to the examples to see how well you do. You can always go back to the theory if you find you need it. Study the text boxes titled: 'what you need to know about' and these will give you the main points for exam preparation.

There are three study guides for trades entrance science. Each module assumes that you understand the material covered in the previous module.

Module 1
Science Foundations (required for all trades, and all Exam Levels).

Module 2
Science Development (requires module one and adds material required for trades that need Exam Levels 3 and 4).

Module 3
Special Topics (requires Modules 1 and 2, and adds material required for Exam Level 5).

Your choice of a trade will determine how many of the three science guides cover the material that will be on your trades entrance exam.[3]

For example, an oil burner mechanic candidate in category B may need to study Module 2 – Science Development. An electronics technician candidate may need to study Module 3 – Science Special Topics. Both will need to know Module 1 – Science Foundations in Section One. The three sections of the curriculum build on each other.

Contact the NWT Apprenticeship branch to learn what exam levels are required for a specific trade.

3 This curriculum follows the Alberta list of competencies in science. In some cases, levels are combined in the curriculum but may be separated in the number of levels described as necessary for a trade. For example, this curriculum groups all level 3 competencies with level four, because a roofer who only needs level three competencies according to one grid, may be tested on level four competencies as well because they are not separated in the master list of competencies prepared by the Alberta Department of Apprenticeship and Industry Training. By following the Alberta list of competencies, this curriculum supports apprenticeship goals by erring on the side of potentially including more, rather than less, material in each category.

Introduction

NWT Apprenticeship Support Materials
Exam Level Requirements

Exam Levels 1 & 2	Exam Levels 3 & 4	Exam Level 5
Reading Comprehension	Reading Comprehension	Reading Comprehension
Math I, II, III, IV	Math I, II, III, IV	Math I, II, III, IV, V
Science I	Science I, II	Science I, II, III
Curriculum Sources:	1. Alberta list of Trades Entrance Competencies 2. Education, Culture and Employment Grid of Trades Entrance Competencies	

For example, the material in Module 2 – Science Development on heat transfer assumes that you already know the foundation material on temperature and heat found in Module 1. In Module 3 – Special Topics relating heat to waves and energy are covered. These topics assume that you already understand the material on heat and energy covered in Modules 1 and 2.

Pre-Test Yourself

Each module of the science curriculum ends with practice exam questions that you can use to assess yourself before and after you study the material in a module. The recommended strategy is to 'work backwards'. Take some of the practice questions for the highest level you are responsible for. For example, if you are in category B, try some questions at the end of Module 2 – Science Development. If you get the score you want, you should get a similar score on the exam for trades in category B.3

The results will guide you to the place in the curriculum where you should begin your review. The Practice Exam Questions are the same kinds of questions that you will find on your trades entrance exam. They are in multiple choice format. An answer key identifies the part of the curriculum that explains how to answer each question. Many candidates for the exam find that they need to start with Module 1 to review science foundations. Many people find that review goes quickly, but that new learning takes more time.

Use the laminated card provided to cover the answers and explanations that are given below each question as you work on the examples in this guide.

Organization of Topics in Each Section

The emphasis in trades is on using science to solve practical problems quickly and correctly. Each topic in this curriculum guide includes

1. Background and theory
2. Examples with explanations
3. Practice Exam Questions with answers

This curriculum guide outlines competencies, but does not provide detailed lessons, as for example in a science textbook. If you need more instruction on a particular competency, you may find these and other resources helpful.

Introduction

The steps given to explain how to solve problems are written as if you were talking to yourself, or thinking out loud. Read every sentence carefully, there are no wasted words if you are learning a competency for the first time. The right approach is to start slow: think carefully through each explanation. If you get this part right, you will be able to solve all of the problems in the competency area.

If you turn to a competency required for your exam and don't understand the explanation, you can read the earlier sections that lead up to it. The competencies are covered in a logical order from simple to more complex concepts and problems. **Each topic builds on what came before.** Many people find it helpful to read through the overview for each competency area before going to the specific competencies they need. **Key concepts are introduced when they are first needed.** For example, the concept of density is introduced in Module 1 and then applied later on to problems dealing with buoyancy in Module 2. The basic concepts of heat and temperature are introduced in Module 1 before they are developed in problems on heat transfer and change in the volume of materials in Module 2.

Science Competencies for Trades Entrance

This curriculum is not the answer for everyone seeking to enter a trade. For some people trades entrance science requires only a quick review of what was learned in school. For others, including those who had unsuccessful learning experiences in school, this curriculum will give an opportunity to learn science competencies used in trades for the first time.

In both cases, independent study requires discipline, commitment, and motivation, as well as good literacy skills. If you have needs that cannot be met by this resource, there are programs available to help you. See your advisor, career councillor, or educational institution for assistance. Ask them to guide you to a resource that will help you. You may decide to work on this curriculum with a tutor or in a study group guided by a teacher, or you may decide that your best option is to enroll in a college course in pre-trades science.

You can do the practice exam questions at the end of each Module to see how much work you need to do. The Practice Exam Questions at the end of each Module are the same kinds of questions that you will find on your trades entrance exam. They are all in multiple choice format.

There are six major competency areas in science for trades entrance. Each area contains a series of competencies that are spread out in the three Modules of the curriculum

1. Matter and Structure
2. Fluids (Liquids and Gases)
3. Heat and Temperature
4. Basic Machines
5. Electricity, Circuits and Motors
6. Light, Waves, Fields and Energy

Don't waste time!
Only learn what you need to know.

Competency:
An ability that can be demonstrated

Within each area, study material is provided for the exam levels appropriate for the module . Some competency areas are not covered in a module. Other areas are developed from one module to the next, for example, the structure and properties of matter are discussed in increasing detail as the modules progress. Keep a pencil and paper handy as you work through the curriculum. There are many definitions and diagrams for you to repeat for yourself on paper and to use as self-test items.

Unit 1

Matter

Topic 1 – States of Matter

Basic questions about the structure of our physical world include, what is matter made of? What are the properties of matter? Knowledge about matter is useful in any trade. Changing raw material into a desired form is work done on matter. The structure of matter refers to the properties of matter.

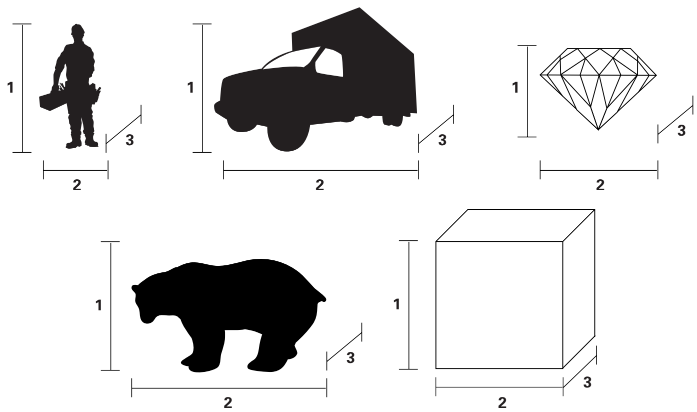
Structure describes how something is put together. When we build something or design something we choose materials that are appropriate. Properties of matter include melting points, freezing points, density (i.e. mass/volume), buoyancy, elastic limits, the ability to conduct or not to conduct electricity, and to block or bend light waves.

Density, volume, and elastic limits for materials are described in the topics that follow because each refers to a property of matter that is useful for the many kinds of calculations required in the productive work of a trade. For example, a tank must be designed with the density of the liquid it will contain in mind, because liquids have different weights for the same units of volume. For example, a liter of water weighs more than a liter of alcohol. A thin walled tank might hold a volume of alcohol, but break apart if it is filled with water. The shape of the tank will also be important.

Unit 1 – Matter

Topic 1 – States of Matter

Matter is the name given to what we can touch, weigh, and feel resistance from if we try to move it. Matter has size that we can measure. **Mass, length, width, and height are dimensions** that describe the size and shape of a material object. All material objects have three dimensions.



A man, a truck, a diamond, and a bear each have three measurable dimensions that correspond to length, width, and height. Well designed objects require decisions about the relative sizes of these three measurements. Design factors, such as stability, mobility, speed and strength (ability to withstand stress and strain), help to determine the shape and size of both man-made objects and living organisms.

> **Linear measurements are measurements of a straight line**
>
> **Area and volume are based on linear dimensions**
>
> Area of rectangles = length x height
>
> Volume of rectangular solids = Area x width

The **area and volume** of material objects can be calculated when we know the linear dimensions of an object.[4] The simplest measurable parts of an object are its length, height, and width (or thickness). These are primary dimensions of matter. Area, volume and other properties of matter are calculated (i.e. derived) from linear dimensions.

In many trades a raw material (matter) is changed into something useful. The work that is necessary to achieve desired changes is based on a scientific understanding of matter and its properties. We can build boats by understanding the principles of buoyancy and flotation. We service brakes by using hydraulic principles, and we heat our homes by designing systems that burn fuel and change matter into energy.

4 See Math – Module 4 – Measuring Time, Shapes and Spaces, for a discussion of area and volume as well as measurement. The problems on the Science exam assume that you have covered the math core (first four modules) that are required for all trades.

Unit 1 – Matter

Topic 1 – States of Matter

Matter is "Stuff"

Think of physical objects, both large and small and you will be thinking about matter. The properties of matter are the same for all objects, no matter how different they are in other respects. The earth is a material object, and so is a hair growing on your head. The atom is an example of matter, as is a stone. Scientists study the properties of matter and the changes that can occur in matter.

Matter can appear as a gas, liquid, or solid. These three states are available to matter, and changes in temperature and pressure can cause changes in state. For example, lowering the temperature of water changes it from the liquid state to a solid state when it becomes ice. These states are also referred to as **phases.**

Basic Properties of Matter

Mass = how much matter is in an object. Mass is related to the amount of force required to get an object to move.

Weight = the force exerted by gravity on an object's mass.

Volume = the space contained by an object.

Density = the ratio of units of mass to units of volume.

Buoyant Force = the upward force on an object that is equal to the weight of the fluid displaced by the object.

Phase Changes are Physical Changes

It is important to understand that a phase change does not change what something is made of. For example, oxygen is still oxygen when it appears as oxygen gas, oxygen liquid, or solid oxygen. Changes in temperature and pressure can cause phase changes. For example, when water freezes in changes from its liquid phase to its solid phase.

Unit 1 – Matter

Topic 1 – States of Matter

Matter can appear as a gas, liquid, or solid. Matter is either an element, a compound made up of elements that are chemically combined, or a mixture of elements and compounds. These are called physical substances as opposed to forces or energy.

Gases and liquids are referred to as fluids because they assume the shape of any container, and flow. When matter changes its state, for example from a gas to liquid in condensation, a physical change is involved.[5] When matter changes its composition, for example from iron to iron oxide (rust), a chemical change is involved.[6]

What You Need to Know for the Exam

Solids:

Have a fixed shape and volume because their atoms and molecules vibrate but do not move around. The atoms of a solid are packed closely together.[7]

Examples:
A piece of wood, a cube of sugar, a crowbar.

Liquids:

Do not have a fixed shape but do have a definite volume. Liquids will take the shape of what they are contained by. A litre of water is still a litre when it is in a tall cylinder or when it is in a large bowl. The atoms and molecules of a liquid can move around but stick together when flowing.

Examples:
Molten steel, water, syrup.

Gases:

Have no definite shape or volume. Gases will spread out to evenly distribute their molecules and atoms throughout the volume of the space they are contained by. There is a lot of space between molecules of a gas and very little attractive force between them. The smaller the space, the closer the molecules will be to each other, and vice versa.

Examples:
The breath you exhale, the air in a tire, the neon gas in a neon light, the gases that make up the atmosphere.

The number of atoms or molecules in a substance does not change when its physical state changes. For example, the mass of the water in an ice cube will be the same after the ice cube melts.

Gases and liquids are both fluids

5 See Unit 3 – Heat and Temperature for more on condensation.

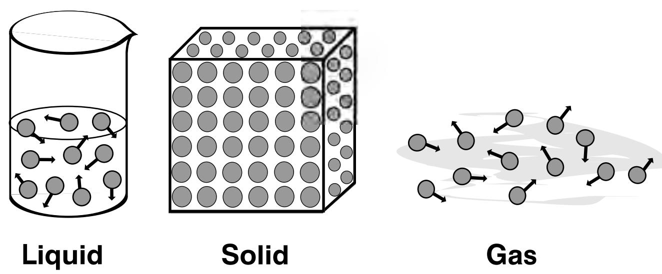
6 See Supplementary Topic 2 – Molecules.

7 See Supplementary Topic 1 – Atoms and Elements and Supplementary Topic 2 – Molecules.

Unit 1 – Matter

Topic 1 – States of Matter

A solid has definite shape and volume. A liquid has a definite volume without a definite shape. A gas has neither definite shape nor volume.



Unit 1 – Matter

Topic 1 – Practice Questions

Question 1
Which kind of matter has no definite shape or volume?

a) liquids
b) gases
c) solids
d) fluids

Answer: b

Question 2
When matter changes its state, what happens to its mass?

a) it increases
b) it decreases
c) it remains the same
d) it gets hotter

Answer: c

Question 3
Which unit is used to measure mass?

a) kilogram
b) Newton
c) pound
d) foot

Answer: a

Question 4
Which phase of matter has molecules and atoms packed most tightly together?

a) liquid
b) gas
c) solid
d) ice

Answer: c

Unit 1 – Matter

Topic 1 – Practice Questions

Question 5

A liquid is poured from a cylinder into a bowl. What happens to its volume?

a) it doubles in size
b) it is halved
c) it doesn't change
d) it changes phase

Answer: c

Unit 1 – Matter

Topic 2 – Force

Background

Matter is a physical substance as opposed to force or energy. The application of a force causes effects on matter that we can measure. In science, **a force is the name we give to the cause of motion and of changes in shape in material objects.**[8] We cannot see a force but we can see the effects of a force. A force has direction as well as magnitude (the amount or size of the force). A nail goes into a board because a hammer applies a force of 50 lbs to the head of the nail, a leaf blows because the wind applies a force to it in a certain direction, and a sponge changes shape when we squeeze it because a force is applied to the sponge at many points at the same time.[9] In each of these examples the effect is **the result of an unbalanced force** being applied.[10]

If an object can successfully resist a force being applied to it, it won't move. When a nail is hammered with enough force, the force of the hammer exceeds the opposing force of the nail's resistance due to the friction between it and the wood that it penetrates.

Force is measured in units called pounds (and its related units and subunits) in the imperial system, and Newtons and its related units in the S.I. system.[11] Notice that weight is a measurement of force. A 50 lb weight will exert a fifty pound force.

8 A more complete account of force is given in Science – Module 3 – Special Topics. Newton's laws of motion provide the framework for understanding force as any action that can cause an object to accelerate.

9 Forces are vector quantities. Vectors are reviewed in Math – Module 5 – Special Topics and used in Science – Module 3 – Special Topics.

10 If the sum of the forces acting on an object equal zero, then the object won't move. The forces will balance out. Mathematically: $\sum F = 0$

11 See Math – Module 4 – Measuring Time, Shapes and Spaces.

Topic 2 – Force

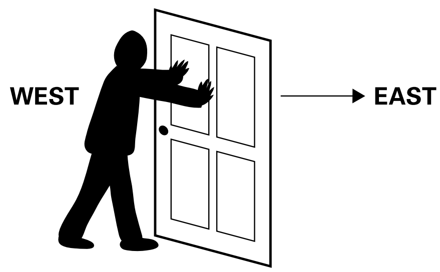
The conversion factor for units that measure the magnitude of a force are:

1 Newton (N) = 0.225 lb

1lb = 4.45 N

A complete description of a force will also show what direction it is applied to.

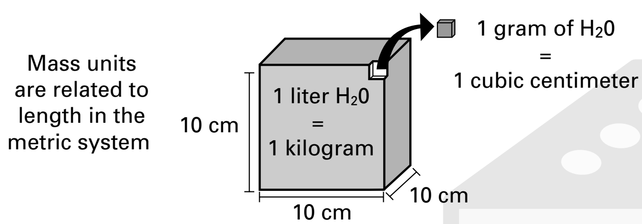
Example:
Applying 10 pounds of force to open a tight door.



This door will only budge eastward if the applied force of 10 lbs is greater than the opposing force of friction holding the door shut.

The Newton Measures the Force of Gravity on an Object (Weight)

Gravity is the attractive force between objects, and it is measured with metric units for mass. Sir Issac Newton (1642-1727) developed the mathematics to describe gravitational force. His name has been given to the basic S.I. (international unit) for force, the Newton (N). It takes 9.8 Newtons to lift 1 kilogram from the earth's surface. The S.I. units of mass are the gram and its multiples: the kilogram, decagram, and tonne.



You need to remember:

One **Newton (N)** approximately equals the **force** of the earth's gravity on 100 grams. It takes about 9.8 newtons to lift 1 kg. The Newton is a unit of force that measures the force due to gravity.

The gram (g) is an S.I. unit of mass but is also used to describe the weight of 1 cubic centimetre (= 1 millilitre) of water at sea level.

Units of weight are also units of force and
The Newton (N) is an S.I. unit of weight
The pound (lb) is an Imperial unit of weight

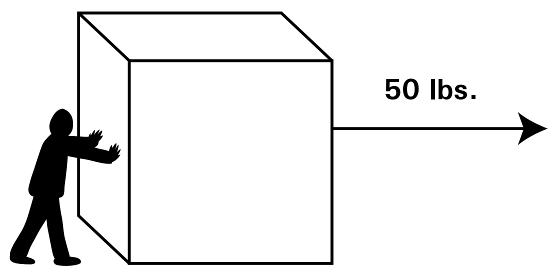
Topic 2 – Force

Kinds of Forces

When a lever is used to pry open a crate **a mechanical force** is applied. When gravel is sprinkled on bare ice, a **frictional force** will be applied to the soles of a walker's shoes. When a magnet attracts iron filings, a **magnetic force** is being applied to the filings, When an object falls to the ground, a **gravitational force,** the earth's gravity, is being applied to the object. When a tree ignites from a lightning strike, an electrical force is being applied that heats the wood in the tree to the point of combustion. In every case the effects of a force acting on an object are observed, not the force itself. **A force can be thought of as a 'push or a pull' for most trades-related purposes.**

Three Things You Need to Know About Force

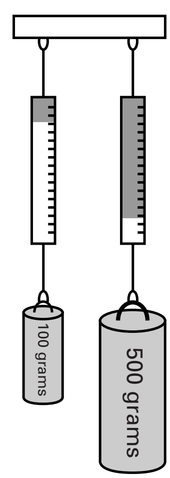
1) **A force has direction and magnitude** and can be represented by an arrow, called a vector. The tail, not the arrowhead, is put on the object being acted on by a force.



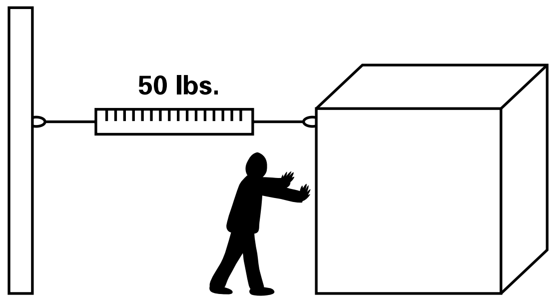
This person is pushing a crate with 50 lbs of force in the direction shown by the arrow.

2) **A spring scale can measure a force** by comparing the amount the spring moves when it lifts or pulls a standard object to the amount it moves when it lifts or pushes any other object. This method works because the spring will move the same amount when equal weights are hung from it. Scales are **calibrated** this way.

You can see how the spring is stretched 5 times further when the weight is five times heavier. This is because the force of gravity is greater on heavier objects because they have more mass as explained below.



If we want to measure the amount (ie. magnitude) of the push given to the crate by the person in the diagram, we could attach a spring scale to the wall and to the crate. As the person pushes, the spring will stretch and show how many pounds of pressure are being applied to the crate. In this example the scale, calibrated in pounds, would read '50 pounds'. Notice that the scale does not tell us the direction of the force, only its magnitude. Compass directions or other methods for describing direction are needed for that.[12]



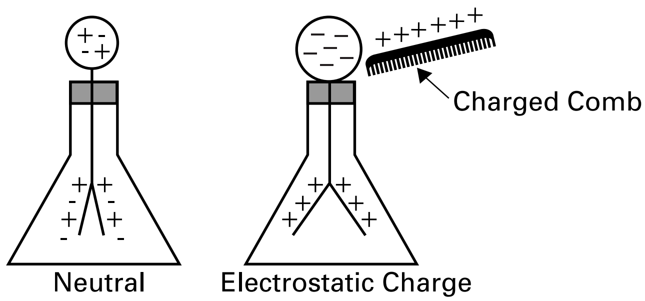
3) There are five forces:

a) Mechanical:
Collisions are examples of mechanical forces at work. Objects in motion can apply force to other objects that they come into contact with. Hitting a baseball, driving in a nail, and using a crowbar involve mechanical force. Spring scales can measure mechanical forces.

b) Gravitational:
A fundamental property of matter is gravitational force. Objects have mass and attract each other in a relationship based on how much mass they have and how close they are to each other. The force due to the earth's gravity is responsible for making objects near the earth's surface fall to the ground in a line directed at the earth's center of mass. Spring scales can measure gravitational force.

c) Electrostatic:
A fundamental property of matter is electric charge. Positive and negative charges exist as forces in nature. Like charges repel and unlike charges attract. The effects of electrostatic force can be seen when a rubber comb attracts small bits of paper after combing hair, or when you get a shock after rubbing your shoes on a carpet and then touching a doorknob. Electrostatic charges can be measured by seeing how far apart two thin metal leaves move apart when a charge is applied to the conducting rod they are suspended from. This device is called an electroscope.

[12] See Science – Module 3 – Special Topics for more on vector analysis where trigonometry is used to describe the direction of a force.



d) Magnetic:
Magnetic forces act between magnetic materials. Lodestone, aka magnetite, is a magnet found in nature that will attract iron and other magnetic materials. Magnetism and electricity interact, and electromagnetic forces result from surrounding a magnetic material, for example an iron rod, with an electric current running through a copper wire. This creates an electromagnet. Magnets have a north and a south pole, unlike poles attract and like poles repel. A compass needle is moved by the earth's magnetic field. The amount of 'dipping' by a metal needle, free to rotate, can be used to measure magnetic force.

d) Frictional:
The force of resistance to motion found between materials in contact with each other. Friction is also a force of resistance in a fluid (gases and liquids) called its viscosity.

Topic 2 – Practice Questions

Question 1
The Newton is a measure of:

a) volume.
b) weight.
c) mass.
d) force.

Answer: d

Question 2
When an unbalanced force is applied to an object what will happen?

a) The object will shrink.
b) The object will float.
c) The object will move or change shape.
d) The object will fall.

Answer: c

Question 3
Friction can be reduced by:

a) using more effort.
b) decreasing the area of contact between two objects.
c) using a lubricant.
d) all of the above.

Answer: c

Question 4
What force is involved when a rubber comb attracts small pieces of paper after being rubbed with a cloth?

a) Magnetic force.
b) Gravitational force.
c) Friction.
d) Electrostatic force.

Answer: d

Topic 2 – Practice Questions

Question 5

A spring scale can be used to measure:

a) pushing and pulling forces on objects.
b) mass.
c) electrostatic force.
d) magnetic force.

Answer: a

Topic 3 – Friction

Friction is a force that resists motion where there are surfaces in contact. It takes more force to move a ten pound weight across a sandpaper surface than it does to move the same object across a glass surface. In both cases, the force of friction has to be overcome for a stationary object to move, but the force of friction is much greater on the sandpaper surface.

Friction is the force that opposes an applied force. When a body is in motion on a surface, or in contact with other substances, friction is responsible for slowing the object down.[13]

Friction is also found in fluids and gases, but here we will focus on friction between solid objects in contact with each other. Friction is a fact of life that forces us to do more work than would be necessary in a frictionless world.

> **Friction between surfaces produces heat (thermal) energy.** Rubbing your hands together produces heat from the force of friction that opposes the applied motion of your hands. The more pressure between your hands, and the faster you rub them, the greater the heat produced.

When you push a heavy object you experience resistance due to the opposing force of friction. When this resistance is overcome, the object will begin to move, a certain amount of heat is produced, and the surfaces wear down, or erode. Parts in machines need replacing when friction wears down surfaces that contact each other, for example bearings in a wheel or rings around a piston.

> **Remember:**
> The greater the force of friction that must be opposed in order for motion to occur, the greater will be the heat produced when motion begins.

Friction and Area of Contact

It is important to understand that friction between two bodies does not depend on the size of the area of contact. A brick standing on end or on its face will require the same amount of force to overcome static friction.

When an object moves on a surface, **sliding (kinetic) friction** is involved. The force of sliding friction will depend on how smooth the surfaces are. A heavy object can be easily moved on ice but not on the ground or on a floor made of wood. The nature of the surfaces involved matters.

13 We can say that the energy of motion is dissipated by the opposing force of friction.

Friction can be reduced but not totally eliminated.
Lubricants, smooth surfaces, and the use of rollers, wheels or ball bearings will reduce friction between surfaces.

Lubrication lowers the coefficient of friction
When a lubricant is used, the surfaces in contact become more able to slide over one another. The force of friction is reduced.[14] A number, called the coefficient of friction, can be determined for any material to compare the force due to friction between materials.

Friction is Not All Bad

Sometimes friction produces an advantage. For example, the ability of a screw to 'bite' into wood is due to the friction between the metal and the wood. The fact that we can walk on pavement easily, but with difficulty on ice, is due to the greater force of friction on pavement.

[14] Science – Module 2 – Science Development, discusses the meaning and use of coefficients of friction to evaluate materials.

Topic 3 – Practice Questions

Question 1

The maximum force of static friction is equal to:

a) the force that will start an object moving on a surface.
b) the force that combines load and distance.
c) the work needed to overcome the force of friction.
d) the weight of the object.

Answer: a

Question 2

The measurement of friction for various materials tell us:

a) which materials have no friction.
b) which materials are better lubricants.
c) how much force is needed to overcome friction.
d) how much pressure will be produced by friction.

Answer: c

Question 3

What does lubrication do to the amount of friction?

a) Decreases it.
b) Increases it.
c) Doesn’t change it.
d) Depends on pressure.

Answer: a

Question 4

Which situation requires more force to oppose the force of friction on a horizontal surface?

a) Getting a block of wood to start sliding across a table.
b) Keeping a moving block of wood sliding on a table in motion.
c) Lifting a block of wood from a table.
d) Lifting a block of wood onto a table top.

Answer: a

Unit 1 – Matter

Topic 4 – Gravity and Weight

Background

Gravity Causes Weight

We know there is a force of gravity because it takes effort to lift something from the Earth's surface. We can also show that any mass will exert an attractive force on other objects around it. The larger the mass the greater the force of gravity it exerts. **Weight measures the effect of the force of gravity on an object.** In the trades, weight is measured with pounds in the imperial system, and with mass units, ie. Gram, kilogram etc. in the S.I. system.

Gravity is a fundamental property of matter. Matter can be divided into smaller and smaller parts. Atom means literally 'not divisible' in classical Greek. The idea of atoms was around in 500 B.C., long before modern science succeeded in proving their existence and measuring their properties. Today, scientists continue to explore the nature of matter by further dividing the parts of the atom into subatomic particles.

A Practical Implication for Trades

Weight measures the force exerted by gravity on a mass, and **in practical terms weight and mass will measure the same on the earth's surface**.

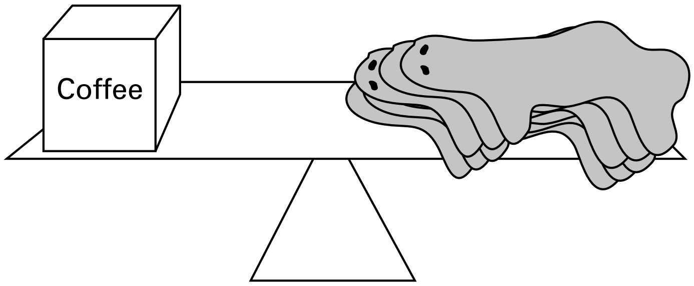
Matter that we handle in the trades is either an element or a compound formed from elements. There are 118 elements listed in the periodic table of the elements. Of these only about 46 occur in nature. These include many metals, carbon, gold and oxygen. The remaining elements can only be separated from compounds in a laboratory or industrial process.

Measuring Mass

A balance beam allows an object's mass to be compared with a standard mass or with another object's mass. Equal mass on each side balances the scale. A balance beam can tell us when two masses, possibly of very different shapes (i.e. dimensions), are equivalent. This kind of measuring can be done in different places to show equivalence of mass. This method allows us to see that a sack of coffee and a pile of beaver hides can be equal in mass because the force of gravity acting on each side is the same when the beam balances. We can see this without knowing the weight of the items on each side.

Unit 1 – Matter

Topic 4 – Gravity and Weight



For Greater Clarity…

If the beam balances at sea level, it will also balance on a mountain top 3 miles above the earth's surface, and on the moon, where the force of gravity due to the moon's mass is only one sixth of the force of gravity on the earth's surface. The force of gravity will have the same effect on masses that are equal when they are placed near each other in any location.

The weight of objects (i.e. the magnitude of the force due to gravity), however, will be different depending on where we are. It turns out that all mass exerts a gravitational force, but larger masses exert larger gravitational forces, and a large mass, for example the earth, will attract smaller objects to itself, for example people, without any noticeable counter-attractive force by the smaller object playing a role.

Matter Must Have Mass and May Have Weight Depending on Where It Is.

You may be surprised to learn that the weight of an object can vary, but its mass does not. In outer space, far from any gravitational field, objects will have no weight, but they will still have mass. **Mass is a more basic idea than weight.**

A More Detailed Explanation:

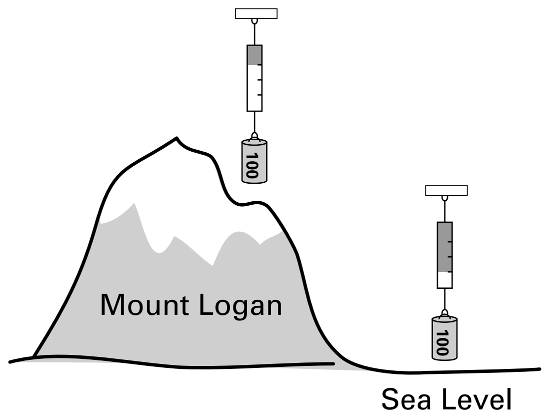
Weight describes only one property of mass in a gravitational field. Weight is the force exerted by gravity on mass. Weight becomes less the higher we are above the earth's surface, but mass remains the same. This is because the strength of the earth's gravitational field decreases with distance away from the centre of the earth.

100 grams of salt will weigh slightly less at 10,000 feet above sea level than in Yellowknife, but it will still be salt, and still contain the same amount of salt.

Topic 4 – Gravity and Weight

A Spring Scale Reveals How Weight Changes with Altitude

A difference in weight can be measured by a spring scale at different altitudes. The same mass will pull the spring towards the ground slightly more at sea level than at 10,000 feet higher. This happens because the force of gravity weakens as we go further away from the earth's centre of gravity. Gravity is a force that decreases with distance.



For Greater Clarity…

Mass can also refers to the total number of atoms in an object. The location of an object doesn't change the number of atoms in it. Historically, weight was measured before the concept of mass was understood. Measurements of weight allowed people to compare the heaviness of objects on the earth's surface.

We can **measure gravity as the attractive force between objects.** Any mass will attract any other mass. Even a small mass will exert gravitational force on its neighbours. All objects contribute and respond to gravitational forces of attraction. A relatively large mass such as the earth, attracts us to its surface. We have mass and the earth has mass. It takes work to overcome gravity every time we stand up on earth, but on the moon it would take only one sixth the effort, because the moon has less mass than the earth.

Unit 1 – Matter

Topic 4 – Gravity and Weight

A mental experiment can show that mass stays the same- even in weightless conditions of outer space

We attract the earth to ourselves just as the earth attracts us to its surface, but the contest is unequal because the earth has more mass than we do. Its gravitational field is so much greater than our own that we only feel a one way pull.

If we travel in a spaceship, the force exerted by earth on our ship will decrease as the distance from the earth's surface increases. If we carry a truck on our spaceship, it will have the same mass in space as on the earth's surface, and it will also have the same dimensions and volume.

However, the truck will not weigh anything if it is outside a gravitational field. This is why we speak of a gravitational field, within which, the strength of the gravitational force that determines weight is measured. The truck's weight is determined by (i.e. is a function of) the distance between the earth and the spaceship. The closer to the earth, the more the truck will weigh. Normally, when we talk about what something weighs, we mean its weight at sea level. **At sea level the mass and the weight measure the same. One kilogram, a mass unit, has an equivalent weight of 2.2 pounds.**

Summary

What you need to know: the difference between weight and mass
The idea of weight is a special case of the more general idea of mass. Mass measures the amount of matter in an object that can be acted on by the force of gravity. On the earth's surface, the mass of an object is measured by the force that gravity exerts on it. However, we measure mass by referring to its weight in everyday life on the earth's surface. Mass and weight are different concepts but turn out to be equal quantities at the earth's surface.

Topic 4 – Practice Questions

Question 1

The weight of an object increases when:

a) it comes closer to the earth's surface.
b) it leaves the earth's surface.
c) it changes its shape.
d) it gets colder.

Answer: a

Question 2

One Newton measures:

a) the force of the earth's gravity on 100 grams.
b) the force of one pound of water.
c) the weight of a cubic centimetre.
d) the force of gravity.

Answer: a

Question 3

A balance beam on the moon shows that a moon rock and a radio balance each other. What can be said about their weight?

a) They are weightless.
b) The radio weighs more than the moon rock on the earth's surface.
c) The moon rock weighs more than the radio on the earth's surface.
d) The moon rock and the radio will weigh the same on the earth's surface.

Answer: d

Topic 4 – Practice Questions

Question 4

When a very large object is weighed on the ground and again on top of a high mountain, what will be true?

a) The object will increase its mass.
b) The object will weigh more on the mountaintop.
c) The object will weigh less on the mountaintop.
d) The object will decrease its mass.

Answer: c

Question 5

Which statement is true

a) Mass and weight measure the same at the earth's surface.
b) Mass is always greater than weight.
c) Mass is always less than weight.
d) A person will have less mass on the moon.

Answer: a

Topic 5 – Force and Motion: Solid Objects

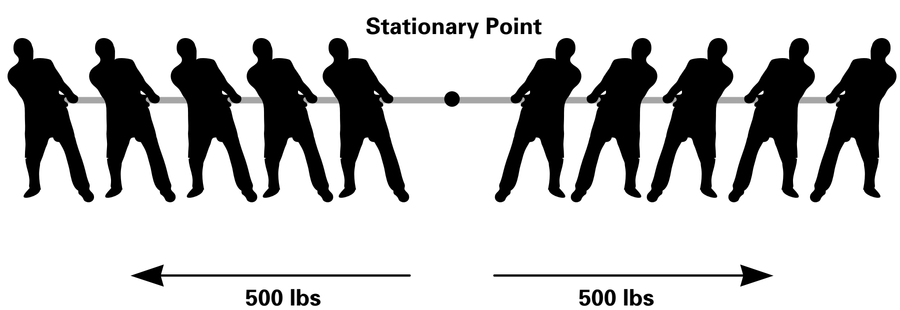
What You Need to Know About Objects, Motion and Force

Motion includes both speed and direction and:

1. When opposing forces balance out there is no motion or change in motion.
2. When opposing forces on an object do not balance out, there is motion or a change in motion, or a change in shape.
3. Objects in motion will remain in motion with no change in their speed or direction unless an outside force acts on them.

Background

Motion is caused by a net unbalanced force.[15] If there is no unbalanced force acting on an object, it will not move. It is in **equilibrium**. When something moves its location changes.[16] An object that is not moving has no net force acting on it, but it may have several opposing but equal forces acting on it. For example, in a tug of war tremendous force can be applied to a point at the middle of the rope, but the point will not move as long as the opposing teams pull with equal force.



All of the forces acting on an object balance out when it is stationary.

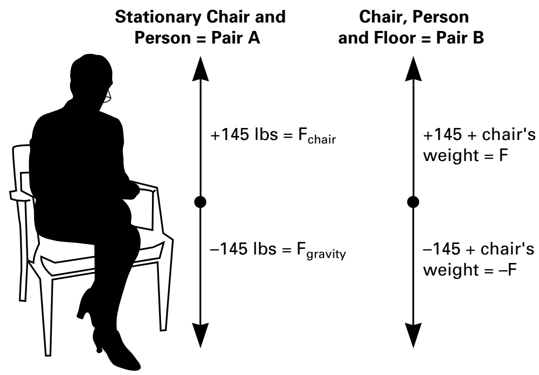
For example a person who weighs 145 pounds sitting in a chair, experiences the force of gravity acting in a downward direction, but this force is balanced by an equal and opposing force exerted upward by the chair. In addition, and **this is important to understand, the earth exerts a pull on the person and chair that is balanced by the pull of the chair and person on the earth.**[17] There are two **action-reaction pairs** in this example.

15 This assumes a local frame of reference. If we look at any object on the earth's surface from a point in outer space, it is moving along with everything else on the surface as the earth rotates and revolves around the sun. The idea of a stationary object requires a local frame of reference.

16 A change is location is also called a displacement and is often represented by s in formulas.

17 A more detailed discussion of action-reaction pairs and Newton's third law is given in Science – Module 3 – Special Topics.

Topic 5 – Force and Motion: Solid Objects



In any stationary situation on the earth's surface there will be two pairs of forces to consider. The person and the chair form one pair of objects that exert force on each other, and the earth and the person and the chair are a second pair to consider in the same situation.

If one of the forces in either pair were unequal, an unbalanced force would cause the person to move – either falling to the ground if the force of gravity was greater than the supporting force of the chair, or moving upward if the force supplied by the chair was greater. The person is stationary, and he is only able to get up by supplying the additional upward force needed to overcome the downward pull of gravity.

The arrows in the diagram represent the amount of force in a specific direction.[18] Here, the forces balance out to a net force on the person of zero pounds in the vertical, or y, direction.[19] There is no motion in the vertical direction.

For Greater Clarity:

An important idea, is that solid objects in contact can exert forces on each other even when they are not moving. When you press your hand on the edge of a table, for example, the table pushes back with an equal amount of force.[20] The table and your hand form an 'action-reaction pair'.

Notice that people of different weights would also be stationary in the same chair. In each case, the chair will supply the upward force equal to the person's weight – for example: 60 lbs., 120 lbs. or 210 lbs – unless it breaks and the person falls to the ground. The point of breaking is the breaking point of the chair when it can no longer provide an equal and opposite upward force to the weight placed on it.

A force that compresses an object is called a **longitudinal stress.** In the trades it is useful to know the breaking points of materials so that design requirements are met safely. When the breaking point is exceeded, there will be motion (fracture and collapse) because the forces applied to an object become unbalanced. The direction of motion will be in the direction of the larger, or net, force. Different materials will have different abilities to withstand stress.

18 The arrows are called vectors. A vector has two components: size (called magnitude) and direction. You can learn more about them in Science – Module 2 – Science Development and Module 3 – Special Topics, as well as in Math – Module 5, Unit 2 – Trigonometry.

19 Review the x,y coordinate system used in graphs in Math – Module 2 – Patterns and Relations.

20 Don't confuse the application of a force with the concept of agency, or intentional action. In physics, forces are only seen by their effects. An inanimate object can apply a force to other objects.

Topic 5 – Force and Motion: Solid Objects

What You Need to Know About Action and Reaction

For every acting force there is an equal and opposite reacting force

1. When two bodies exert forces on each other, the force exerted by one will be equal to a force of the same size exerted by the other body back on it – but in the opposite direction. These are called "action reaction pairs".
2. Either force can be viewed as the action or the reaction.
3. Action and reaction does not require motion – stationary objects in contact form action-reaction pairs also.
4. More than one action reaction pair can be involved in a situation. Look at all of the interactions between objects to discover the forces acting on each object.

Examples:

a) A man throws a pack to shore from a canoe and the canoe moves away from shore.

The man's force on the pack equals the force of the pack on the man – causing the canoe to move in the opposite direction of the throw.

b) A club hits a golf ball. The club's force on the ball is equal to the ball's force on the club. The club exerts a force on the ball, and the ball exerts a force on the club that is felt by the golfer.

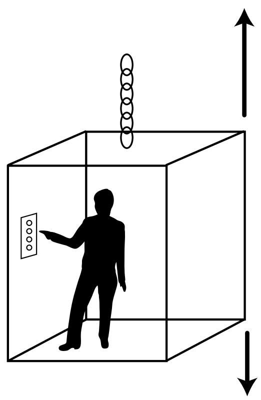
c) A rocket pushes gases out towards a launching pad and the gases push back with equal force on the rocket causing it to lift off. The rocket exerts a force on the gases, ie, it's weight, and the exploding gases exert a greater force on the rocket causing it to lift off.

d) A person sits on a chair and the chair "pushes" back with a force equal to the person's weight. Also, the floor "pushes" back on the chair with a force equal to the weight of the person plus the weight of the chair.

Notice that either force in these situations can be called the action or the reaction, and also that each force acts on a different object. In every case, $F = -F$, the force of action is equal and opposite to the force of reaction.

A Second Example:

Only when there is a net force on an object, will it move (or change shape). Consider a 145 lb person in an elevator that weighs 1000 pounds. The net (combined) force of gravity on the person and the elevator will be 1145 lbs in the downward direction. The elevator will only carry the person upward if the cables pull up on the elevator with a force that is greater than 1145 lbs as shown in this diagram:



Here you can see how the arrows are drawn to scale to show how the forces combine to give a net upward force of 855 lbs. We can conclude that the elevator will go up, because the forces acting on the elevator do not balance out to zero.[21] If the cables pulled upward with 1145 pounds, then the elevator would be stationary, if they pull with a force less than 1145 pounds the elevator will move downward, i.e. fall.

Inertia

When you push an object it can start to move, resist being pushed and stay where it is, or, if it is already moving – change either its direction or how fast it is going or both. **Solid objects have matter, and their resistance to motion aside from any force due to friction is called their inertia.** The more mass an object has, the greater the force that will be required to start it moving, stop it moving, or change its direction if it is in motion. It is also true that an object in motion will tend to remain in motion, with no change in its velocity (speed and direction) unless an outside force acts on it.[21]

Predicting Motion

The path taken by a moving object will be a result of the forces that act on it. The direction and speed of a moving object can be predicted by measuring all of the forces that act on the object. In this section we consider moving objects traveling in two dimensions (vertical and horizontal).[22]

21 See Science – Module 3, Unit 1, Topic 2 – Velocity and Acceleration for more on inertia, force and motion.

22 We can conclude the elevator will go up without knowing how fast it will move. See Sections two and three for more on how to calculate the velocity and acceleration of an object in motion.

Topic 5 – Force and Motion: Solid Objects

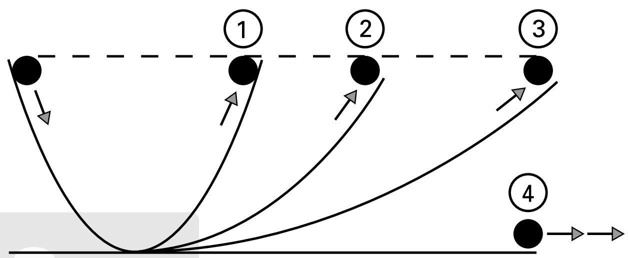
A Supporting Observation

It is harder to push or pull a car than to push or pull a child's toy wagon. It is also harder to stop a car that is moving or to change its direction. Notice that there is not much friction in either case because the four wheels run smoothly on a hard surface. **The greater mass of the car is responsible for its greater resistance to changes in its motion. It** may take only 2 lbs of force to get the child's wagon to start moving at 1 foot per second, but it may take 500 pounds of force to get a car to start rolling at 1 foot per second.

You can also see that a force of 2 lbs will cause a child's wagon to accelerate, but will be too small to start a car rolling on a flat surface. You can also see that it will take 500 pounds of force to stop the car, but only 2 lbs to stop the wagon once they are moving at 1 foot per second.

A Supporting Experiment

A classic experiment by Galileo (1564-1642) shows that an object in motion will tend to remain in motion, in a straight line, unless acted on by an outside force:



When a steel ball on a very smooth inclined plane is released, it will roll up to a height almost equal to its starting height. In the absence of friction, we can see that as the opposite side of the incline approaches a straight line, the ball will continue moving in the horizontal direction indefinitely until and unless an outside force acts on it. The diagram shows the paths the ball will take as the angle of the opposite side approaches a straight line in path #4.

Topic 5 – Force and Motion: Solid Objects

What You Need to Know:

1. When a force is applied to a moving object it will move faster (be pushed) and continue in a straight line, unless the force is applied in a direction other than the direction the object is already moving in. The applied force will cause it to change direction and possibly speed as well. When a moving object collides with another object a force opposing the direction of motion is applied. The moving object will slow down, stop, or change direction. It may also be fractured, collapsed, or crushed if the force is great enough.

Examples:

a) A child starts down a hill on a toboggan at 2 feet per second and his friend gives him a push that increases his speed to 4 feet per second.

b) The friend runs alongside the toboggan and pushes with 10 lbs of force to the right. The toboggan changes direction 30 degrees to the right, but maintains the same speed.

c) The friend runs alongside the toboggan and pushes with 20 lbs of force to the right. The toboggan changes direction 30 degrees to the right and goes faster.

d) A friend runs in front of the toboggan and applies a force of 50 lbs. The toboggan collides with the friend and stops moving.

Motion in Outer Space

In outer space objects have mass but no weight unless they are in a gravitational field. Objects will appear to float, and will continue moving in a straight line if given a push until they meet another force that can act on them. In outer space a hand held propulsion jet can cause a person to move by burning gases that push against the jet. Unless the person is tethered, or can reverse direction, he will travel indefinitely in the line of propulsion. An ice skater pushing off from a wall also travels in the opposite direction of the push until friction or another force stops the skater.

Topic 5 – Practice Questions

Question 1
A ball is given a push in outer space. How far will the ball travel before it stops moving?

a) 100 miles unless it hits something.
b) Until it meets an opposing force of the same size and opposite direction.
c) Until the force of friction stops it.
d) Until its weight brings it to earth.

Answer: b

Question 2
A body's resistance to motion is called its:

a) weight.
b) friction.
c) inertia.
d) density.

Answer: c

Question 3
A magnet pulls on a nail. What are the action and reaction forces?

a) Magnet's pull on nail and nail's pull on magnet.
b) Magnetic force and nail force.
c) Causing force and responding force.
d) Strength of magnet and strength of nail.

Answer: a

Question 4
A 40 lb force is applied horizontally to a 30lb weight on a table. Ignoring friction, will the 30 lb weight move?

a) No.
b) Yes.
c) Depends on the shape of the weight.
d) Depends on how long the force is applied.

Answer: b

Topic 5 – Practice Questions

Question 5
Which motion will require the largest amount of force?

a) Pushing a shopping cart.
b) Pushing a car.
c) Lifting a bag of groceries.
d) Fixing a computer.

Answer: b

Question 6
A car is given a 50lb push and starts to move on a horizontal surface. What will happen to the car if a 50 lb push is given in the opposite direction?

a) It will stop.
b) It will move faster.
c) It will slow down.
d) It will change direction.

Answer: a

Question 7
If a man holds a 40 lb suitcase 2 feet above the ground, what is the size of the force exerted by the suitcase on the earth?

a) 80 lbs
b) 40 lbs
c) 9.8 Newtons
d) zero lbs.

Answer: b

Unit 1 – Matter

Topic 6 – Structure and Design

Well designed structures can be studied in nature. For example, living things have to support their weight, get food by getting around or by catching passing prey, and withstand changes in the environment (temperature, humidity, pressure). Man-made structures also must support weight, exchange energy with an environment, and withstand changes. A bridge, a crane, a warehouse, and a factory, all combine design goals with structural solutions that work.

As these examples show, the same design function can be satisfied in more than one way. For example the function of a bridge can be satisfied by using different materials: wood, steel, stone, or plastics. The components of a bridge can include arches, spans, suspensions from above, supports from below. Each design task will require a solution that makes the best selection from possible materials and components.

Structure refers to how something is put together to achieve the goals of stability and functionality. A stable structure will maintain its shape under a variety of stresses. Functionality is the ability of a structure to do what it was designed for. Well designed structures have built in protection in the form of backups, redundancy, and fail-safes. In nature, one organ can sometimes take over the functions of another when damage occurs. In a building, emergency power can be designed to kick in when there is a power failure. Springs can be included in buildings subject to earthquakes. If one component fails, another is ready to take over the function that is threatened.

Examples

1) The stem in a leaf can support the weight of fluids traveling through vessels in the leaf, and also withstand winds and temperature changes. If a windstorm destroys many leaves, a tree will rely more on its root system for water.

2) Skeletons in man and animals are **rigid** structural components that support the weight and organization of muscle, tissue, circulation, and respiration. Non rigid structures are ones that can alter their characteristics within limits to perform a function. A jelly fish has a non-rigid body, the heart muscle of an animal is a pump with a non-rigid structure, as opposed to a vacuum pump in a shop.

3) A building combines structural components that do what skeletons and stems do. Girders, bricks, ductwork, and sheathing are structural components that provide stability and functionality to a building.

4) Containers are designed to give the greatest amount of support, volume, or area, using the least amount of energy and material. Form and function are related by these considerations. An egg is remarkably strong when force is applied equally to all points on its surface. The egg of a chicken and the corrugated containers for eggs designed by man are well designed structures for their purposes.

5) Hinges are joints that permit motion around an axis. Your elbow is a hinge, as well as the one way valve in your heart or the hinge on a car door. Many functions require joints that connect parts of a structure for specific purposes.

Example of Multiplying the Effect of a Stability Factor:

A cylinder with equal bases is not as stable as a modified cylinder with the lower circular base larger than the top one. An ordinary wax paper cup is an example. It is more stable when its larger end is used to support the smaller end. A single cup will not support the weight of a person. However, if a large number of paper cups are placed upside down on a cafeteria tray covered with another tray and this process is repeated, a person can stand on the resulting platform.

Components and Materials

Every design will have to allow for a structure that performs a function, possible moving parts, possible "skin" (sheathing, covering), and possible skeleton (supports for components).

The same design function can be achieved by several choices of components and materials. For example, the function of insulating a northern home can be achieved by any or all of the following:

1) Airtight joints around windows and doors.
2) Use of insulating material in walls, ceilings and floors.
3) Increasing thickness of walls and decreasing ceiling heights.
4) Using solar energy and wind energy to supply heat.
5) Using a membrane to "wrap" the structure that repels water but allows water vapor to exit.

The choice of materials and methods will depend on many factors including:

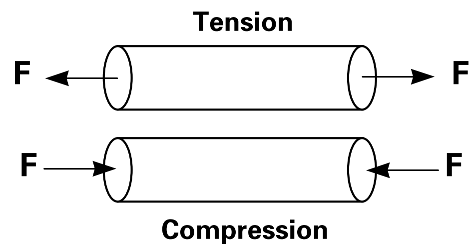
1) Cost.
2) Availability of materials.
3) Maintenance after installation.
4) Skills required.
5) Time required.
6) Life span of components.
7) Negative impacts on the environment.
8) How pleasing the result looks (aesthetics).

Trade offs, and a combination of solutions are usually involved in any design process. Trade offs involve estimating the relative value of options. For example, a siding job may look great but only last half as long depending on the materials used. Chipboard may cost less than plywood, but each sheet weighs much more. Windows with a vacuum seal are better insulators, but cost more than conventional windows.

Topic 6 – Structure and Design

Stress and Strain

We can measure the strength of materials and compare materials based on their strength. **Tension and compression** are forces that can act on materials and structures. Tension is a stretching force, compression is a squeezing force.

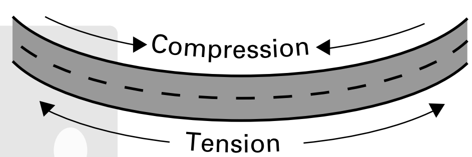


All solid materials are elastic to some extent. Even steel will deform and return to its original shape if the force that is applied is not too great. When a material becomes permanently deformed it has reached its elastic limit. For example, a spring can be stretched too far and fail to return to its original shape. We are interested in how much deforming force, or stress, a material or structural component can withstand. **Stress is measured as a ratio of applied force to an area.**

$$\text{Stress} = \frac{F}{A}$$

The maximum stress that a material can take before it fractures (breaks) is called its tensile, or ultimate strength.

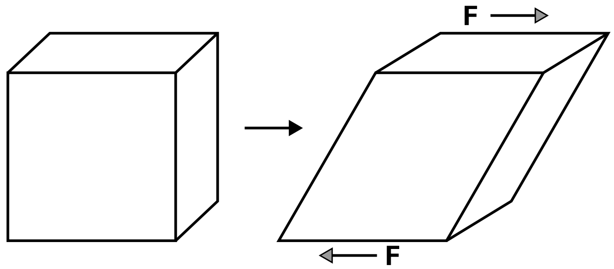
Tensile stress is the amount of pulling or stretching force over a unit of area in a material. **Compressional stress** is the amount of squeezing force over a unit of area in a material. Both of these stresses are called normal stresses, or longitudinal stresses, because they result from force that is applied at a right angle to the material. Both stresses can be measured in a beam that bends under its own weight across a span.



The lower half of the beam is being stretched, while the upper half is being compressed.

An arch is an example of tensile and compressive forces that are in equilibrium.

Sheer stress involves a twisting or turning force, for example the force that will sheer off a pin in an outboard motor in order to protect more important components of the drive system. A sheering force will change the shape of an object because equal but opposing forces operate on different places on the object.



Strain is defined as the change in length divided by the original length of a material. This ratio will measure relative changes in the dimensions of the shape of a body.[23]

Together, stress and strain make up the components of elastic deformation for a material.

Materials are tested for strength by applying forces to see how much materials stretch, bend, compress, twist, and break. This leads to calculating the elastic limit and ultimate strength of each material. For example, steel has an elastic limit of 2.5×10^8 Newtons per square meter, while aluminum has a limit only about half as great. Steel is therefore preferred over aluminum where deforming forces are a concern in a building.

23 The formula is Strain (tensile) = $\frac{DL}{L_0} = \frac{L - L_0}{L_0}$, the ratio of change in length divided by the original length.

Topic 6 – Practice Questions

Question 1
Which is an example of a compressional stress?

a) Pulling on each end of a wire.
b) Standing on a garbage can.
c) Drinking through a straw.
d) Heating a metal pipe.

Answer: b

Question 2

The elastic limit of a material is reached when:

a) it breaks.
b) it stretches.
c) it can’t return to its original shape and size.
d) it can’t be stretched any further.

Answer: c

Question 3

The components of a well designed structure should:

a) all serve one function.
b) contribute to the purpose of the structure.
c) be as simple as possible.
d) be made of one material.

Answer: b

Question 4
Which part of a beam across a span is under tension?

a) The top side.
b) The bottom side.
c) The midpoint.
d) The endpoints.

Answer: b

Topic 6 – Practice Questions

Question 5

Which is an example of a sheer stress?

a) Twisting the head off a screw.
b) Cutting a metal rod in two.
c) Compressing a spring.
c) Stretching a string to the breaking point.

Answer: a

Topic 7 – Centre of Gravity

When you balance a pencil on your finger you have found its centre of gravity. The balance point is the central point at which all the weight is concentrated. A body suspended from its centre of gravity will not rotate. There will be no clockwise or counter-clockwise motion. The forces of gravity operating on all sides of the centre of gravity balance out. Stable structures will have this property.

> **Optional Topic**
>
> **Torque**
>
> **Centre of gravity can also be understood as the fulcrum point of a lever in equilibrium.** Torque measures the force that can cause a body to rotate. As you will learn in the discussion of levers and basic machines, the sum of the products of each force applied to the lever times the distance to the fulcrum will be equal on both sides of the fulcrum when the body is at rest in a gravitational field. If they aren't, the lever will rotate until they are in equilibrium and their sum equals zero. Each force times distance calculation gives a product that is called a torque. The lever arm (or moment arm) is the distance from a point of force application to the fulcrum.

The centre of gravity for a sphere is its exact centre, and in general, the centre of gravity of solid objects such as cylinders, pyramids, and cubes that are made of a single material is found at their geometric centre. When suspended from this point, all moments of torque are in equilibrium.

Centre of Gravity and Stability

The lower the centre of gravity in an object and the wider the base the more stable the object will be. A beam lying on its surface will be more stable than when it stands on an end. It will be less likely to tip over when disturbed by an outside force when it is lying on its length (side).

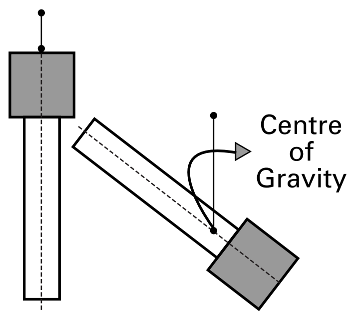
Finding the Centre of Gravity

Every object has a centre of gravity, and when bodies are suspended from a point, the centre of gravity is at or below the point of suspension. This is true for bodies with any kind of shape or density.

You can find the centre of gravity for an object by suspending it from different points. Each time you suspend it wait until it stops moving and draw a vertical (ie. Perpendicular) line down through the point of suspension. After doing this two or more times, choosing different points of suspension each time, you will find that the centre of gravity is the point where all of the vertical lines intersect. Each line will go through the centre of gravity.

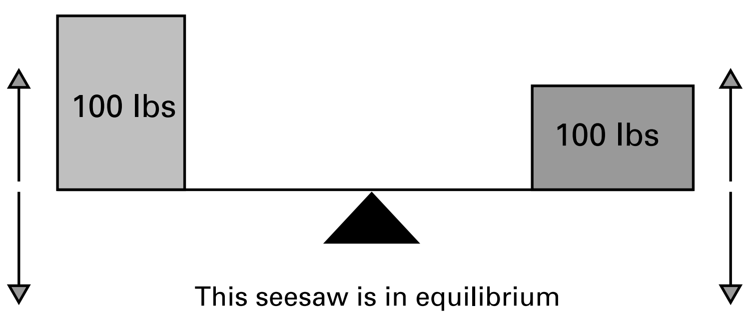
Topic 7 – Centre of Gravity

Sometimes this point is outside the object. For example, a pole vaulter will arch his body so that more of his mass is concentrated below the high bar, this allowing him to vault over a higher bar. This method will work even when the density of an object is not uniform- in other words when one part of an object is heavier than another part- for example a two by four stud with an iron cap over one end.



Rotation and the Centre of Gravity

When forces act unequally on parts of a suspended object it will rotate. For an object not to rotate, the sum of all the forces acting on it must equal zero and the sum of all the torques (twisting forces) acting on it must also be zero. This situation is called one of equilibrium.



This seesaw is in equilibrium

All of the forces acting on an object balance out when it is in equilibrium. When two people tug with equal force on each end of a rope, there is no movement and the rope and people are in equilibrium. When two people of equal weight sit on opposite ends of a seesaw, the seesaw balances and there is no movement up or down. Imagine a meter stick with a movable fulcrum (pivot point). The stick will balance when the pivot point is at the 50cm mark. Other locations will cause the stick to rotate clockwise if there is more weight to the right of the pivot point and counter clockwise if there more weight to the left of the pivot point. **When a body is suspended, it will rotate until the centre of gravity is directly below the point of suspension.**

Unit 1 – Matter

Topic 7 – Practice Questions

Question 1
The centre of gravity is always at the centre of an object:

a) true.
b) depends on mass.
c) depends on shape and composition.
d) depends on density.

Answer: c

Question 2
The forces that act in a counter clockwise direction must equal the clockwise forces acting on a suspended object for it to:

a) rotate freely.
b) spin.
c) change location.
d) not rotate.

Answer: d

Question 3
Objects with a lower centre of gravity tend to be more:

a) restless.
b) unstable.
c) stable.
d) dense.

Answer: c

Question 4
The centre of gravity of an object is where:

a) the density is greatest.
b) the weight is evenly distributed.
c) the weight appears to be concentrated.
d) the rotational forces are working.

Answer: c

Topic 7 – Practice Questions

Question 5

A meter stick is held at one end and a fulcrum is placed 20 cm away under the stick. What will happen when the stick is let go of?

a) It will balance.
b) It will rotate.
c) It will seek the centre of gravity.
d) It will change its pivot point.

Answer: b

Question 6

Which situation describes a body in equilibrium?

a) A person skipping rope.
b) A train moving slowly.
c) A book on a desk.
d) A flag flapping in the wind.

Answer: c

Question 7

When the centre of gravity of an object is not vertically above and inside its base of support what will happen?

a) It will rotate.
b) It will be stabilized.
c) It will be unstable and tip over.
d) It will have torques that sum to zero.

Answer: c

Unit 2

Pressure, Fluids and Gases

Topic 1 – Atmospheric Pressure

The earth's atmosphere is a mixture of gases, about 78% nitrogen and 21% oxygen with small amounts of carbon dioxide, water vapor, and other gases. The weight of the air above the earth is measured as atmospheric pressure. Atmospheric pressure at the earth's surface is 14.7 lbs./in^2, or 760 mm of mercury (also known as 760 Torr) in the S.I. system.[24] The atmosphere is a mixture of gases that press downward with this much force. We do not feel this pressure because we are designed to withstand it and compensate for it by an equal and opposing pressure.[25]

[24] Torr is a shortened form of Evangelista Torricelli (1608-1647), inventor of the mercury barometer

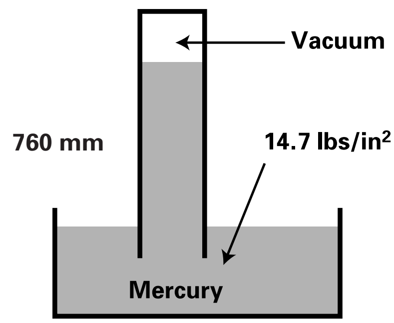
[25] See Science – Module Two – Science Development for a discussion of forces in equilibrium in the discussion of flotation.

Unit 2 – Pressure, Fluids and Gases

Topic 1 – Atmospheric Pressure

A Suction Cup Reveals Atmospheric Pressure
You can experience atmospheric pressure by pressing a rubber suction cup onto a smooth surface. A bathroom plunger will make a seal when collapsed because all the air has been driven out. The force needed to pull it off the wall is equal to the pressure of the surrounding atmosphere on it.

The pressure of the atmosphere can be measured scientifically by a mercury barometer. Mercury (Hg) is a liquid at room temperature that is 13.6 times more dense than water and provides a convenient material for the measurement of atmospheric pressure. There is so much air pressure, that if we chose a less dense substance like water to measure with, the column of water would have to be 10 metres high. In its simplest form, the mercury barometer is a device that looks like this:



The space above the column of mercury in the tube is a vacuum created by filling the tube with mercury first, and then turning it upside down (i.e. inverting it). As the mercury is pushed up by the surrounding air pressure it meets no resistance in the tube and responds only to atmospheric pressure. At sea level the column of mercury will be pushed up 760 mm (aka 760 Torr). This is called **standard pressure**. As altitude changes, the amount of air pressing down on the mercury in the exposed dish will decrease and the column will fall to a level equal to the pressure of the atmosphere that is acting on it.

Standard pressure of the atmosphere at sea level is expressed in several units, but all are equal to each other

Pounds per square inch (psi), 14.7 psi

Centimetres of mercury, 76.0 cm of mercury

Millimetres of mercury, 760 mm of mercury (Hg) (1mm Hg = 1Torr)

Inches of mercury, 29.9 inches of mercury

Atmosphere (atm), 1.00 atm

Pascal (Pa), 1.013×10^5 Pa (1 Pa = $1 N/m^2$)

Unit 2 – Pressure, Fluids and Gases

Topic 1 – Atmospheric Pressure

STP = Standard Temperature and Pressure

Standard Temperature is 0° Celsius = 273 Kelvin

Standard Pressure is

1. **S.I. = 760 mm = 100 Kpa (kilo pascals)**
   1 Pascal (Pa) = 1N/m^2

The Newton (N) is the S.I. unit of force. It takes about 9.8 Newtons to lift one kilogram.

2. **Imperial = 14.7 psi (pounds per square inch)**

Atmospheric pressure varies not only with height above sea level, but also with weather conditions. Weather conditions can change the density of air, which is the ratio of the mass of the air to a unit of its volume.

Moist Air is Less Dense than Dry Air

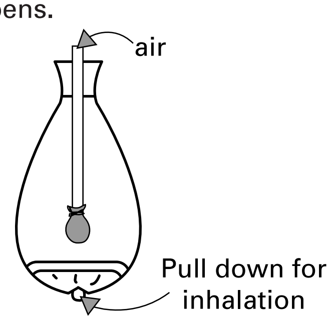
This is because moist air contains more lighter-weight water molecules (amu = 18) in place of heavier molecules of oxygen (amu = 32) and nitrogen (amu = 28).[26] A volume of moist air will weigh less than an equal volume of dry air. Moist air will exert less pressure on a column of mercury than drier air. Dry air is found in high pressure weather systems and moist air in low pressure systems. The barometer falls when a moist air mass moves in and creates a low pressure area.

Warm Air is Less Dense than Cold Air

The molecules in warm air move more rapidly and occupy more volume. Less mass per unit of volume means less density. Cold air molecules move more slowly and more are contained in a unit of volume. Cold air is more dense than warm air.

Optional Topic: How the Lung Works

The atmospheric pressure on our lungs is changed by our breathing which moves our diaphragm up and down. When we breathe in, the diaphragm moves down and we expand the volume around our lungs in our rib cage, thus decreasing the pressure around the lungs. Air rushes in through our nostrils now that the lungs are free to expand in their lower pressure environment during inhalation. When we exhale, the reverse happens.



[26] Atomic mass units (amu) are explained in Supplementary Topic 1 – Atoms and Elements and Supplementary Topic 2 – Molecules.

Topic 1 – Atmospheric Pressure

Gauge Pressure

A gauge that measures air pressure, for example in a tire, does not include the standard atmospheric pressure at sea level. When this is added to the gauge pressure we get absolute pressure.

The absolute pressure of a tire with a gauge pressure of 32 psi would be 32 psi + 14.7 psi = 46.7 psi absolute pressure.

Unit 2 – Pressure, Fluids and Gases

Topic 1 – Practice Questions

Question 1

Atmospheric pressure will change when:

a) the mercury barometer is heated.
b) the altitude above sea level changes.
c) the buoyancy of air is measured.
d) the suction of air changes.

Answer: b

Question 2

Two atmospheres will lift a column of mercury in a barometer:

a) 760 mm
b) 34 feet
c) 1520 mm
d) 9.6 Newtons

Answer: c

Question 3

We don't feel the pressure of the atmosphere because:

a) we are unaware.
b) we wear clothes.
c) we oppose it with equal and opposing pressure.
d) it is too little to notice.

Answer: c

Question 4

Moist air has lower atmospheric pressure than dry air because:

a) it is less dense than dry air.
b) it is more dense than dry air.
c) it creates a wind.
d) it is wetter than dry air.

Answer: a

Topic 1 – Practice Questions

Question 5
Standard pressure is measured as:

a) 32 psi
b) 14.7 psi
c) 9.6 N
d) 86 mm

Answer: b

Question 6
Suction is not a force because:

a) it requires atmospheric pressure.
b) it isn't strong enough to overcome atmospheric pressure.
c) it resists gravity.
d) it depends on work.

Answer: a

Question 7
Will warm air exert less atmospheric pressure than cold air?

a) Yes.
b) No.
c) Depends on temperature.
d) Depends on moisture.

Answer: a

Question 8
Absolute pressure in a tire is 50psi. What will the gauge pressure of the tire be?

a) 32 psi
b) 42 psi
c) Can't tell from this information
d) 35.3 psi

Answer: d

Unit 2 – Pressure, Fluids and Gases

Topic 1 – Practice Questions

Question 9

A mercury barometer is carried from sea level to an altitude of 10,000 feet. What will happen to the height of the column of mercury?

a) It will go higher.
b) It will go lower.
c) It will freeze up.
d) It will boil.

Answer: b

Question 10

The pressure of the atmosphere can be expressed in S.I. units as:

a) 14.7 psi
b) 100 Kpa
c) 10 N/m^2
d) 700 mm Hg

Answer: b

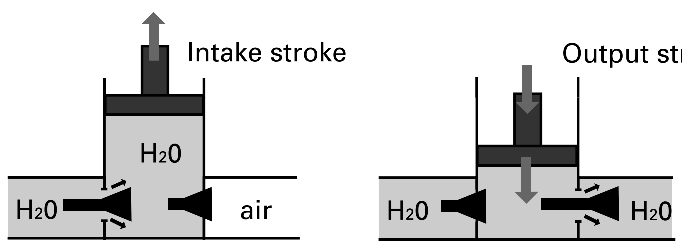
Unit 2 – Pressure, Fluids and Gases

Topic 2 – Pumps

Pumps are machines that use, or combine, the principles of suction and/ or of circulation by applying force to a fluid. Pumps do work by either causing a change in the outside pressure on a fluid, or by exerting pressure (a force) on a fluid to make it flow.

Vacuum Pumps

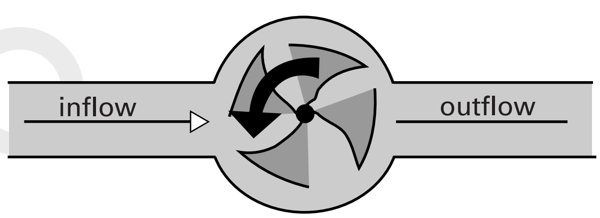
When you suck on a liquid through a straw, you are pumping the liquid upward by removing the column of air in the tube that provides the pressure normally keeping the liquid from rising. You decrease the pressure acting on the liquid under the straw's opening. This creates a difference between the air pressure acting on the liquid outside the straw and inside. The greater external pressure (14.7 lbs/in^2) forces the liquid up into your mouth. **It is important to realize that the liquid is pushed up the tube, not drawn up.** Suction is not a force in its own right. In practice, water can only be raised 28 feet by creating a vacuum that then allows outside air pressure to push water upwards.



This pump operates by decreasing the air pressure in the piston chamber on the intake stroke so that the external pressure on the fluid becomes greater and forces the intake valve open and brings fluid up and into the cylinder. On the downward piston stroke, the water is pressed downward closing the inlet valve and opening the outlet valve.

Force Pumps, Circulating Pumps

Pressure can be exerted on a liquid to make it flow. When there is a difference in pressure on a fluid from one area to another, a fluid will follow in the direction of least pressure. A circulating pump is used in automobile cooling systems and in vacuum cleaners to provide pressure in one direction that causes the coolant and air to flow and circulate. The human heart is a pump.



Unit 2 – Pressure, Fluids and Gases

Topic 2 – Practice Exam Questions

Question 1
A circulating pump in a car engine is used to:

a) decrease coolant pressure.
b) move coolant continuously from high to lower pressure areas.
c) drive the coolant against heat pressure.
d) circulate the heat stress on the engine.

Answers: b

Question 2
A piston pump is able to lift water by:

a) sucking up the water.
b) pushing the water around.
c) creating a low pressure area in the pump for the atmosphere's pressure to push the water into.
d) closing the escape route for the water.

Answers: c

Question 3
A pump can only lift water 28 feet without adding pressure because:

a) this is the limit of the downward force one atmosphere will exert.
b) this is greatest amount of suction that is possible.
c) a column of air cannot be lifted any higher.
d) a column of water cannot be lifted any higher even with extra pressure.

Answers: a

Question 4
A pump moves a fluid by:

a) applying a force to the fluid.
b) creating a partial vacuum for the fluid to be pushed into by atmospheric pressure.
c) both a and b.
d) by opposing the force of gravity on the fluid.

Answers: c

Topic 2 – Practice Exam Questions

Question 5

A device that removes air from a pipe and enables water to flow up the pipe is called a:

a) barometer.
b) circulator.
c) vacuum.
d) pump.

Answers: d

Unit 2 – Pressure, Fluids and Gases

Topic 3 – Expansion and Contraction

Matter expands when it is heated and contracts when it is cooled. This means the same amount of matter can take up different amounts of space depending on its temperature. **Volume changes as temperature changes**. The volume of a gas can also change with a change in pressure as well as with a change in temperature. Liquids and solids, unlike gases, however do not expand and contract noticeably from changes in pressure.

Expansion of a solid, liquid or gas occurs when molecules move faster and this causes an increase in volume. Contraction causes a decrease in volume as the molecules slow down and move closer together. These changes are also described as changes in **kinetic energy**, or the energy of particles in motion.[27] The average motion of the molecules in a substance equals its kinetic energy at that time. Changes in kinetic energy cause expansion and contraction that is the same in every direction, i.e. uniform. Expansion and contraction happens in all directions when the kinetic energy of something changes.[28]

27 See Science – Module 2 – Science Development for the laws governing the expansion and contraction of gases.

28 Science – Module 2 – Science Development and Module 3 – Special Topics have more on the topic of energy and energy conversion.

Unit 2 – Pressure, Fluids and Gases

Topic 3 – Practice Questions

Question 1
When a gas expands it's volume:

a) decreases.
b) increases.
c) stays the same.
d) changes randomly.

Answer: b

Question 2
A change in temperature will cause a substance to:

a) change its mass.
b) change its weight.
c) change its volume.
d) change its coefficient of expansion.

Answer: c

Question 3
The kinetic energy of a liquid increases when:

a) its mass changes.
b) its temperature increases.
c) it contracts.
d) it freezes.

Answer: b

Question 4
Contraction and expansion are uniform for a substance. This means that:

a) heating and cooling affect all dimensions.
b) heating and cooling affect length and width differently.
c) heating and cooling don't affect gases.
d) heating and cooling are the same.

Answer: a

Unit 2 – Pressure, Fluids and Gases

Topic 3 – Practice Questions

Question 5

An increase in pressure will have the greatest effect on the volume of:

a) a gas.
b) a solid.
c) a liquid.
d) water.

Answer: a

Unit 2 – Pressure, Fluids and Gases

Topic 4 – Gas, Pressure and Temperature

Recall that gases are a state (or phase) of matter with no fixed volume and no fixed shape. There are relationships described by "ideal gas laws" that tell how changes in the temperature, pressure or volume of a gas affect each other.[29] A change in one of these variables will cause a change in the others. A change in temperature will cause a change in volume (if there is room for expansion) and in pressure. A change in pressure will cause a change in temperature and volume, and a change in volume will cause a change in temperature and pressure.

What you need to know about gas:

If the temperature goes up, the pressure will increase and the volume will increase (unless a container prevents this)

If the pressure goes up the temperature will increase.

If the volume is decreased, the pressure and the temperature will increase.

[29] See Science – Module 2 – Science Development for a discussion of the ideal gas laws with formulas and examples.

Unit 2 – Pressure, Fluids and Gases

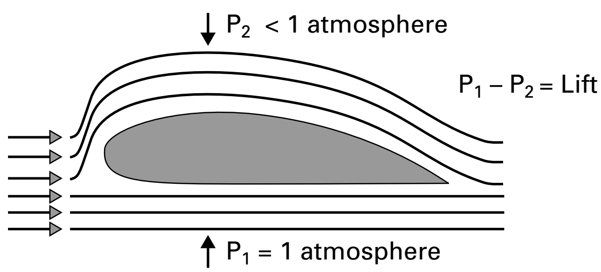
Topic 5 – Bernoulli's Principle: Lift

Flight is only possible when there is enough lift to overcome the force of gravity. You have seen that motion is only possible when there is a net unbalanced force. Flight is a form of motion, and it requires the application of a force to an object that is greater than the force of gravity. An unbalanced upward force produces lift. In order for an object to stay in the air, this force must continue to be applied to the object.

Flight

When air flows over a surface it can produce lift. Changing the speed of fluid flow changes the pressure exerted by the fluid. Try this experiment: hold a piece of paper with one edge just below your mouth so you can blow out and across the top. You will find that the paper is lifted up. The air movement across the paper has produced lift. The air you blow across the top creates a lower pressure area there, and the surrounding greater air pressure is able to lift the paper as long as you keep blowing.

The same principle is involved when you hold two pieces of paper vertically parallel about 3 inches apart and blow between them. You will find that the pieces move towards each other. You have created a lower pressure between the papers as a result of causing a streamline fluid flow. The surrounding greater air pressure exerts a force on the papers and pushes them together – as long as you continue to blow.

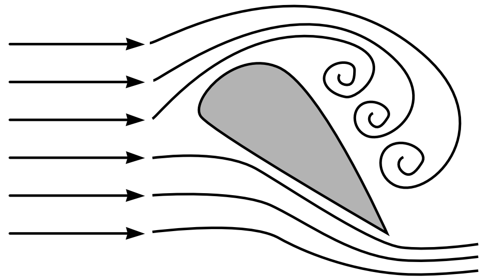


This cross section of a wing (an airfoil) shows how a region of lower pressure is created on top of the wing as the streamlines move more quickly to cover the greater distance of the wing's top surface. A net upward force, called lift, is the result. The lift is the net upward force after the downward pressure above the wing is subtracted from the upward pressure supplied by the atmosphere below the wing. In order for there to be lift, P_1 must be greater than P_2.

When a flowing fluid meets an obstacle, or moves very fast, eddies and turbulence result. This can happen with a wing if it is tilted too much. When the particles in a fluid have the option of two paths, their flow will be turbulent. If you look at a lit cigarette in an ashtray, you can see the streamlines from the rising smoke turn into turbulent eddies.

Unit 2 – Pressure, Fluids and Gases

Topic 5 – Bernoulli's Principle: Lift



When you blow you are creating **streamlines** of air. A stream line is a smooth path followed by a fluid. Fluids flow, and parallel Streamlines are created, when there is a difference in pressure from one place in the fluid to another.

A law explaining lift described by Bernoulli (1700-1782)
Where the velocity of a fluid is high- the pressure is low, and where the velocity is low, the pressure is high.

An aircraft uses this principle by combining an airfoil with a means of propulsion that creates streamlined air flow across an airfoil to produce lift and forward motion. This principle is also used by bicycle racers when a competitor rides in the area of lower pressure immediately behind a leader.

Well designed aircraft are streamlined to allow air to flow in parallel lines while producing areas of low pressure where they are needed for lift. Drag, or resistance to flight, comes from the friction (viscosity) of the air and turbulence. Streamlining reduces drag by guiding fluid flow in repeatable parallel paths over a surface.

Another Example
A vacuum cleaner set to blow out a steady stream of air will hold a ping pong ball in the centre of the column of moving air because the ball is pushed back into the lower pressure environment of the moving air column by the surround higher pressure air. The pressure of the moving air is less than the pressure of the surrounding air.

Unit 2 – Pressure, Fluids and Gases

Topic 5 – Practice Questions

Question 1
When a fluid increases its speed what happens to the pressure it exerts on its surroundings?

a) The pressure increases.
b) The pressure decreases.
c) The pressure doesn't change.
d) The pressure becomes turbulent.

Answer: b

Question 2
Why is streamlining important for aircraft design?

a) It costs less.
b) It reduces drag.
c) It causes turbulence.
d) It makes air flow faster.

Answer: b

Question 3
What is responsible for lift on an aircraft?

a) The difference in pressure between the upper and lower surfaces of the airfoil.
b) The thrust of the engines.
c) The propellers.
d) The streamlining.

Answer: a

Question 4
What is necessary for flight in both animals and aircraft?

a) Streamlining.
b) The ability to overcome the force of gravity.
c) Very high speeds.
d) Height.

Answer: b

Topic 5 – Practice Questions

Question 5

If the pressure on the bottom of an aircraft wing is less than the pressure on the top of the wing, what will happen?

a) There will be a large amount of lift.
b) The wing will produce turbulence.
c) The streamlines will meet.
d) There will be no lift.

Answer: d

Unit 3

Heat and Temperature

Topic 1 – Temperature

Background

When we say something is hot, we are describing its temperature. We can feel that the substance is hotter, i.e. has a higher temperature, in comparison to cooler objects. When we touch a person's hand after they have been outside without a mitten, we feel a cold hand, and this means that the temperature of the hand is below normal. When you judge temperature by touching something, you are using your hand as a thermometer. Temperature is relative, it is based on comparisons.

Temperature measures the average kinetic energy of a substance. The average speed of molecules affects the rate at which heat is transferred from one substance to another. Temperature is a measure of how average molecular speeds compare. Temperature can be measured for gases, liquids and solids. Substances expand and take up more space (i.e. have more volume) when they are heated. **Thermometers** measure temperature by responding to the expansion and contraction of substances.

Unit 3 – Heat and Temperature

Topic 1 – Temperature

What You Need to Know

Consider how an alcohol thermometer works. A red dye is added to the alcohol liquid to make it visible. The tube is sealed with no air inside so that the alcohol is free to rise without meeting any resistance from air pressure. The bulb of the thermometer will absorb heat energy from a hot liquid that it is immersed in. The kinetic energy in the alcohol will increase as the heat is transferred and alcohol molecules will move faster so that some are pushed up the tube. How far will depend on how hot the material surrounding the bulb is. The hotter the surrounding liquid, the higher the alcohol will go. When the surrounding liquid cools, the alcohol will contract and move down the tube to take up less space.

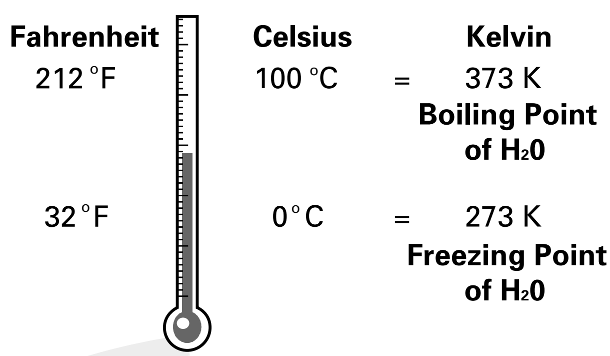
When a liquid cools sufficiently, its molecules will slow down and it will become a solid. All gases will liquefy at some temperature, and all liquids will solidify at some still cooler temperature. The molecules in the liquid will form a solid structure when the solid phase temperature is reached.

Temperatures in Mixtures
When the same amount of two liquids with different temperatures are mixed together the temperature of the mixture will be the average of the two temperatures of the ingredients.

Example:
1 liter of water measuring 20 degrees Celsius is mixed with 1 liter of water measuring 40 degrees Celsius. The new temperature will be 40 + 20 divided by 2, which is 30 degrees Celsius. If the liquids are different substances, and/or of unequal amounts, this rule will not work because other factors discussed in Module Two – Science Development are involved.

Three Scales are Used for Temperature

The Fahrenheit, Celsius, and Kelvin scales are used to measure temperature. The standard interval between freezing and boiling is the benchmark for these scales.



The temperature at which molecules would stop moving altogether is –273°C (-460° F). This temperature is absolute zero. The Kelvin scale measures absolute zero as 0K (zero Kelvin).

Unit 3 – Heat and Temperature

UNIT 3

Topic 1 – Temperature

Optional Topic

Absolute Zero
Absolute zero is the temperature at which there is a minimum of kinetic energy. This is a theoretical limit set at –273° Celsius. –273° Celsius = 0 on the Kelvin scale. The Kelvin temperature scale uses the same size for a degree as the Celsius scale. Kelvin scale is used in science and can be converted from Celsius by adding 273 to the Celsius temperature. Example: 100° Celsius, the boiling point of water, equals 373 Kelvin (no degree symbol is used for the Kelvin scale).
In symbols: **K = °C + 273**

Temperature can be measured by non liquid thermometers because any substance that expands and contracts in response to changes in temperature will provide an a way to compare materials. Colour can be related to temperature in a **pyrometer**. This is how the temperature of molten steel is measured. A **bimetal strip thermometer** is used in thermostats and in ovens. The metal that will expand more is placed on the outer surface of the coiled strip. Expansion will cause the coil to wind up in proportion to the change in temperature.[30]

[30] See Unit 3, Topic 3 – Expansion and Contraction.

Unit 3 – Heat and Temperature

Topic 1 – Practice Questions

Question 1
What does a thermometer measure?

a) The potential energy of molecules.
b) The average kinetic energy of molecules.
c) The difference in heat.
d) The change in energy.

Answer: b

Question 2
What is zero degrees Celsius equivalent to on the Kelvin scale?

a) 100 K
b) –273 K
c) 273 K
d) 32 K

Answer: c

Question 3
A non liquid thermometer can measure temperature because it uses a substance that:

a) knows the heat of a sample.
b) measures the change in kinetic energy.
c) expands and contracts in response to changes in temperature.
d) boils at 100°C.

Answer: c

Question 4
The column rises in an alcohol thermometer because:

a) the surrounding temperature is different than the alcohol temperature.
b) the molecules in the alcohol are pushed higher.
c) the alcohol molecules start to move and take up more volume.
d) the alcohol is heat sensitive.

Answer: c

Topic 1 – Practice Questions

Question 5

A pyrometer measures high temperatures by comparing the:

a) heat of a substance with a standard.
b) comparing the temperature of a substance with a standard.
c) comparing the change in colour with a standard.
d) comparing the change in density with a standard.

Answer: c

Question 6

What happens to water at zero degrees Celsius?

a) It boils.
b) It freezes.
c) It melts.
d) It vaporizes.

Answer: b

Question 7

What will be the temperature after 1 liter of alcohol measuring 16 degrees Celsius is mixed with 1 liter of alcohol measuring 32 degrees Celsius?

a) Depends on the heat characteristics of alcohol.
b) 24 degrees Celsius.
c) 48 degrees Celsius.
d) 16 degrees Celsius.

Answer: b

Topic 2 – Heat and Temperature Are Different

Background

When you hold a hot ceramic (i.e. uninsulated) cup of coffee your hand gets warmer. A transfer of heat energy from the faster moving molecules of the coffee causes the molecules in your hand to move faster. A thermometer shows an increase of temperature. Heat and temperature are NOT the same thing. Heat is a transfer of the energy of molecules in motion from one body to another, and temperature is the measurement of the average kinetic energy of molecules in a substance.

When heat is transferred a temperature change will occur. Heat can also be measured as a form of work. Heat always flows in one direction: from a hotter object to a cooler one.

What you need to know:

Temperature depends on how fast molecules are moving, i.e. their average kinetic energy.

Heat depends on both temperature (the average kinetic energy of molecules) and on mass (the number of molecules whose average kinetic energy is being measured).

For Greater Clarity:

Heat and temperature are different
The difference between heat and temperature can be illustrated by the difference between the heat energy (the fire) needed to boil a pot of water and the temperature of the boiling water.

The temperature doesn't change once the boiling point of 100°C is reached at sea level. Yet heat energy must continue to be added to the liquid to keep it boiling. If the fire is removed the boiling will stop. The average kinetic energy (temperature) of the boiling water doesn't change, but the total amount of energy needed to completely change the water to gas (water vapour) by boiling all of it, is the amount of heat energy that must be contributed (transferred) by the fire after the boiling point is reached.

Topic 2 – Practice Questions

Question 1
When a hot liquid is poured into a cold liquid what will happen to the temperature of the mixture?

a) It will be the average of the two temperatures.
b) It will be less than the temperature of the hotter liquid.
c) It will be less than the temperature of the colder liquid.
d) It will boil.

Answer: b

Question 2
Heat is a form of:

a) temperature.
b) energy.
c) force.
d) mass.

Answer: b

Question 3
Heat always flows from a hotter area to a cooler area:

a) true.
b) false.
c) depends on the relative temperatures.
d) depends on the masses involved.

Answer: a

Question 4
When water reaches 100 degrees Celsius, what can be said about its average kinetic energy compared to water at 50 degrees Celsius?

a) It is unchanged.
b) It has more.
c) It has less.
d) It depends on the quantities involved.

Answer: b

Topic 2 – Practice Questions

Question 5

Which has more heat energy, a liter of boiling water or a cup of boiling water?

a) They have the same.
b) The liter has less than the cup.
c) The liter has more than the cup.
d) It depends on how long they boil.

Answer: c

Unit 3 – Heat and Temperature

Topic 3 – Expansion and Contraction

Expansion occurs because heating increases the kinetic energy of atoms and molecules. Kinetic energy involves motion and the increased movement of atoms and molecules. Increased motion will increase the space between molecules as they collide more often with each other and with their surroundings. Cooling has the opposite effect, and decreases the distance between atoms and molecules as they slow down.

Expansion and Contraction are Uniform

A solid will expand or contract in all three dimensions: length, width, and thickness when its temperature changes

Fluids (liquids and gases) will expand or contract their volume in all directions when their temperature changes.

Expansion is the result of an increase in the average space between the atoms of a substance, and contraction is a decrease of the average space between atoms. **Notice that there is no change in mass (weight) due to expansion or contraction.** There is no change in the number of molecules and atoms. The same mass will take up different amounts of space and hence have different volumes when expansion or contraction occurs.

In the unusual case of water, expansion occurs between the liquid and solid states. Ice has a volume that is 1.1 times larger than the water it was formed from. This apparent exception is due to the crystal structure that water molecules form when they are cooled.

A **coefficient** is a number that is multiplied times a variable in an equation.

In 3y, 3 is a coefficient of y.

Unit 3 – Heat and Temperature

Topic 3 – Practice Questions

Question 1
What happens when a substance expands?

a) It dissolves.
b) Its kinetic energy increases.
c) It loses heat.
d) It flows.

Answer: b

Question 2
A fluid will expand the same amount in each dimension when heated.

a) True.
b) False.
c) Depends on pressure.
d) Depends on timing.

Answer: a

Question 3
Absolute zero is reached when:

a) kinetic energy equals potential energy.
b) kinetic energy is decreased.
c) kinetic energy is at a minimum.
d) kinetic energy is conserved.

Answer: c

Question 4
A liquid thermometer works because:

a) expansion and contraction are equal.
b) the height of the liquid is determined by the kinetic energy of the liquid's molecules.
c) the liquid knows the temperature.
d) the thermometer has the right coefficient of expansion.

Answer: b

Topic 3 – Practice Questions

Question 5

Water is an exception to the normal process of contraction because

a) water expands when it freezes
b) water has little kinetic energy
c) water contracts when it freezes
d) water is unable to contract

Answer: a

Question 6

When a substance expands, it will expand:

a) equally in all directions.
b) downward or upward depending on gravity.
c) until it freezes.
d) towards the centre.

Answer: a

Unit 3 – Heat and Temperature

Topic 4 – Sources of Heat Energy

Primary sources of heat energy include the sun and combustion. Radiation controlled in a nuclear reactor is a third source. Combustion for heating is the burning (rapid oxidation) of fuels. Common fuels include oil, wood, coal, and gas (propane). Fuels have different heating values that reflect the amount of heat they produce, and the costs involved. A complete assessment of fuel costs includes the cost of obtaining the fuel, costs of using the fuel in a heating system, and costs for dealing with cleanup and pollution outcomes associated with each type of fuel. Different fuels will have different energy content. For example a liter of oil will produce more heat than a piece of wood with the same weight as the liter of oil.

What you need to know:

1) Radiant Energy

Radiant energy from the sun causes the molecules in an absorbent material to increase their speed and the temperature goes up. Heat can be generated from solar energy by concentrating the sun's energy and by storing it. A heat sink made of absorbent material, for example concrete or water, will absorb the sun's energy and release it to cooler surroundings. For example: A black hose looped on a roof with water in it will absorb heat energy from the sun's rays in summer and provide hot water for an outdoor shower.

2) Combustion

Burning fuel can be used to transfer heat energy to a storage and distribution system. A stone chimney in a cabin will absorb some of the heat of the hot gases going up it and radiate the heat into the room after the fire is out. This energy is part of the system that adds to the heat given to the cabin by the hot metal stove.

An oil furnace will use the oil fire to heat air in a closed chamber (a plenum). When the air reaches a desired temperature a fan will drive it through a network of ducts with outlets to rooms at floor level. Alternatively, the oil fire will heat a liquid in a reservoir and the liquid will be pumped through pipes under a floor. The hot pipes will transfer heat to the floor and the floor will transfer heat to the air in the room.

3) Steam Heating

Steam forms when water is heated in a closed container, for example in a pressure cooker or a boiler. The gas state of water is called steam. The temperature of steam can increase once a given amount of water has been vaporized. Steam will absorb heat and increase its temperature and pressure in a closed space. The pressure of steam will increase in a closed space as it is heated.

When heated steam cools, it will condense at 100°C and a cycle of vaporization and condensation can be engineered that is the basis for steam heating systems. A steam heating system relies on a source of heat energy to produce the steam. Any fuel can be used to fire a steam heating system, coal, oil, wood etc., however, each will have advantages and disadvantages to consider.

Steam Heating Systems

1. Steam is put under pressure by being heated in a closed boiler. The heated steam carries latent heat in addition to what is required to vaporize water.
2. The heated steam is sent throughout a building in pipes that lead to radiators. The radiators give off radiant energy and the steam is cooled as a result.
3. The cooled steam condenses (liquifies) and returns to the boiler.

Advantages and Disadvantages

Each source of heat will have advantages and disadvantages.

Examples:

1) Wood

Advantages: can be plentiful in some areas and easy to cut, is renewable if well managed, includes hardwood species that have high heat values.

Disadvantages: cutting wood can cause environmental problems including erosion, damage to wildlife habitat and pollution from machinery. Smoke can pollute the air, particularly in northern cities where inversions trap smoke at ground level in subdivisions. Creosote can form in chimneys and increase fire hazards.

2) Oil:

Advantages: has a higher heating value than wood by weight and volume. Is affordable when global supplies are stable. Can be easily stored and transported.

Disadvantages: costs and availability can change on short notice, combustion produces air pollution, supply is not renewable.

Food is a Fuel

Our bodies "burn" food to produce heat energy. Just as fuels for heating buildings have different characteristics and advantages and disadvantages, so do foods. For example: sugar produces more energy more quickly than protein. The heat produced by a food source is measured in calories.

Unit 3 – Heat and Temperature

Topic 4 – Sources of Heat Energy

The calorie is a metric measurement of heat. The amount of heat needed to raise one gram (or 1 ml) of water one degree Celsius is defined as one calorie.

1 Calorie (C) = 1000 calories (c) = 1 kilocalorie (kcal)

Use the capital C to mean 1000 calories.

1. **The British Thermal Unit (B.T.U.) is an Imperial unit of heat.**

   1 B.T.U. = the amount of heat needed to increase the temperature of 1 pound of water 1 degree Fahrenheit.

Topic 4 – Practice Questions

Question 1
Which of the following is not a possible disadvantage of solar heating?

a) The source is not renewable.
b) solar heat varies with the seasons.
c) solar heat depends on clear weather.
d) the source is too far away.

Answer: a

Question 2
A candy bar has 1000 calories of energy and a potato has 500 calories. Which food will produce more heat?

a) The potato.
b) The candy bar.
c) They are equal.
d) Neither can produce heat energy.

Answer: b

Question 3
What is needed in addition to burning a fuel for a heating system?

a) Creosote protection.
b) Oil filters.
c) A safe and clean distribution system.
d) A renewable fuel source.

Answer: c

Question 4
What does a heat sink do?

a) It washes the fuel.
b) It holds heat energy.
c) It settles ashes.
d) It pumps the exhaust.

Answer: b

Unit 4

Basic Machines

Topic 1 – Background

In this unit we study mechanical systems. The work, power, and energy of a mechanical system can be calculated. **A machine is a device that can multiply force, and that may also change the direction of an input force to a different direction for the output force of the machine.**

A claw hammer is a simple machine based on the principle of the lever

When the claw of a hammer head is used to pull out a nail we have an example of a lever that uses a smaller input force over a larger distance, to exert an output force of greater size over a smaller distance. The hammer also changes the horizontal direction of the input force (pulling) into a vertical output force (lifting). In this example, force multiplication is at the expense of a reduction in distance. All machines involve trade offs of distance, force, and time (speed).

Machines do not eliminate or reduce work, but they can give us an advantage that multiplies our effort. Work becomes easier, but at a cost. This advantage can be calculated in two ways: as a **theoretical (or ideal) mechanical advantage,** or as **an actual mechanical advantage.**

Unit 4 – Basic Machines

UNIT 4

Topic 1 – Background

We can solve problems involving machines by calculating mechanical advantage, calculating work, and remembering that work input minus work done to overcome friction equals useful work output.

Part of the cost of using a machine includes friction. Friction is an "up-front cost" of using a machine, and the work done to overcome friction must be subtracted from the overall work input of a machine. **The useful work output of a machine will always be less than the work input. No machine will be 100% efficient.**[31]

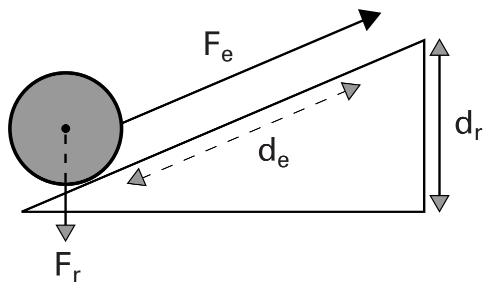
[31] See Science – Module 2 – Science Development for solving problems involving mechanical advantage.

Topic 2 – Simple Machines

There are three principles for all basic machines and combinations of machines: the principles of the lever, the inclined plane, and the hydraulic press. Rollers, wheels, gears, and pulleys apply the principle of the lever. Screws apply the principle of the inclined plane. Braking systems in cars apply the hydraulic press. The output force divided by the input force gives the mechanical advantage of a simple machine.

Inclined Plane

This basic machine allows a force to be applied over a greater distance to reduce the effort required for lifting objects. Simple lifting would achieve the same goal but take more effort (input force). The length of the incline (the run) is the effort (input) distance (d_e), and the height (the rise) (h) is the resistance (output) distance (d_r).



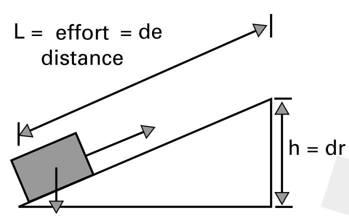
The input force (Fe) is applied to the object over the effort distance, or run. The output force will equal the weight of the load that is being lifted. The output work will equal the weight of the load times the height (rise) of the inclined plane.

Optional Topic:

Finding the Advantage of the Inclined Plane

$$IMA = \frac{d_e}{d_r} = \frac{L}{h} \qquad AMA = \frac{F_r}{F_e}$$

1. The Fe will be less than the Fr because a part of the object's weight is supported by the inclined plane.
2. The work input will equal the work needed to lift the object to the height (h) without using the inclined plane, plus work done to overcome friction with the plane's surface.
3. The less steep the slope, the greater the mechanical advantage and also the greater the effort distance.



$$IMA = \frac{de}{dr} = \frac{L}{h}$$

Unit 4 – Basic Machines

Topic 2 – Simple Machines

An inclined plane wrapped around a cylinder or cone is a **screw**. **A wedge** is a pair of inclined planes joined at their base. A force applied to a wedge by a sledge hammer travels through a large distance and moves the wedge down through a log a small distance but the wedge multiplies the downward force outward to split the log.

Levers

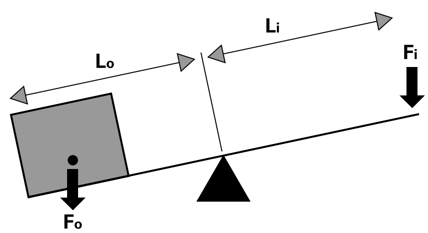
A lever is a rigid bar with a fulcrum that provides a pivot point. The lever will rotate around the pivot point depending on what forces act upon it. A lever in equilibrium will not rotate because the sum of all of the forces acting on it is zero. A lever gives a force multiplier for effort in exchange for distance.

A fixed wheel and axle (includes pulleys) is really a rotating lever with unequal lever arms.

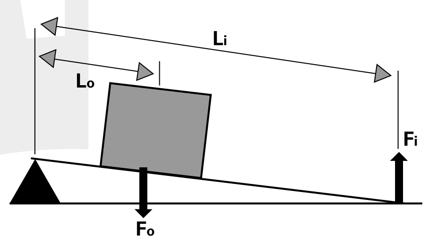
Three Classes of Levers

Depending on where the fulcrum is placed, levers fall into three classes:

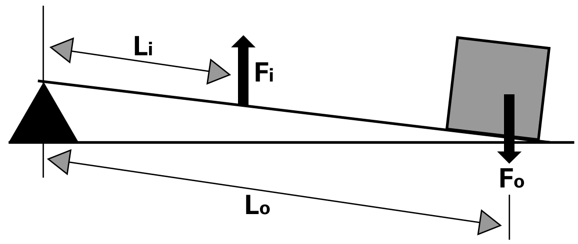
Class One:
The fulcrum is between the load and the effort. Example: a crowbar. First class levers always cause a change in direction. The placing of the fulcrum will determine the mechanical advantage.



Class Two:
The load is between the fulcrum and the effort. Example: a wheelbarrow. Second class levers always have a mechanical advantage greater than one and involve a trade off of loss in distance or speed.



Class Three:
The effort is between the fulcrum and the load. Example: lifting a shovel of dirt by pivoting on one hand and lifting with the hand closest to the load. Third class levers always give a mechanical advantage less than one in exchange for a gain in distance or speed.



Unit 4 – Basic Machines

Topic 1 – Practice Questions

Question 1

A wheelbarrow is an example of:

a) A first class lever.
b) A second class lever.
c) A third class lever.
d) A lever in equilibrium.

Answer: b

Question 2

A screw uses the principle of:

a) The lever.
b) The wheel.
c) The inclined plane.
d) Gravity.

Answer: c

Question 3

When the fulcrum of a first class lever is moved closer to the effort force being applied, what happens to the output distance?

a) It increases.
b) It decreases.
c) It doesn't change.
d) It doubles.

Answer: a

Topic 2 – Simple Machines

Pulleys

Pulleys are wheels with a line over them. Pulleys gain their mechanical advantage from the principle of the lever. Just as with gears, the radius is the arm of the lever that is moving. A pulley can provide a gain in force or a change in direction. The trade off will be in distance. A pulley system can combine both movable and fixed pulleys. Pulleys can be used to move objects in any direction, not only up and down. Pulley systems can combine several fixed and movable pulleys.

The TMA (aka IMA) and the AMA of a pulley is defined as for all other simple machines:

TMA = de/dr = the number of lines attached to the movable pulleys in a system.

You can count the number of support lines to the movable pulley block to find the TMA.

AMA = Fr/Fe

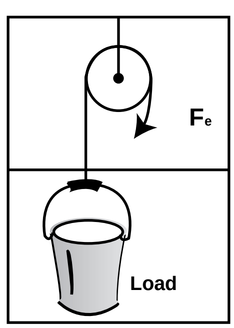
Remember:

1. Fr is also known as the output force, or the load, and that the load equals the weight of the object being moved.
2. Fe is also known as the input force or applied force.
3. The de (effort distance) will equal the length of the line that is pulled through the pulley system.

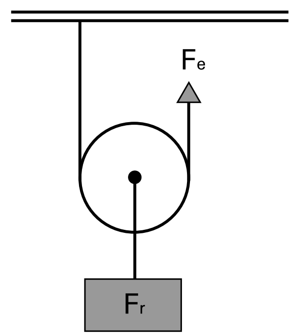
What You Need to Know About Pulleys:

1. **The single fixed pulley (aka a block)** is a wheel with a groove around its circumference (the rim) that allows a rope or other kind of line to travel in. When a load is attached to one end of the line, the application of an effort force to the other end causes the pulley to rotate on its axle.

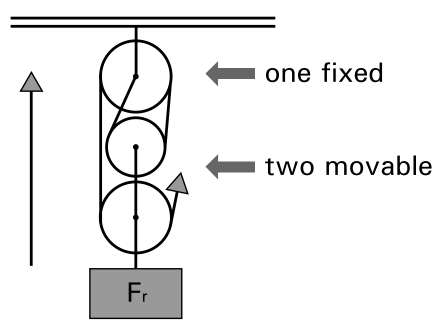
   This simple fixed pulley provides no mechanical advantage because Fe = Fr, and de = dr, but it does reverse the direction of the effort force. Pulling is safer and easier than lifting, and this is what a simple fixed pulley does for us. When the line is pulled down the load moves up. Pulleys can prevent back injuries. Example: a full bucket of water in a well is lifted by a single fixed pulley.



2. A **single movable pulley (aka a tackle)** can provide a TMA (aka IMA) of 2 but it does not change the direction of the input force. Input force is applied in an upward direction, and the load (output force) also moves up. However, the effort distance is two times the distance that the load moves. The force of the effort is a bit more than half of the output force due to friction. This pulley is really a second class lever with unequal lever arms. Li is the diameter of the pulley and Lo is the radius because the fulcrum is on the circumference on the fixed side. Two lines go to and from a single movable pulley to give the ideal mechanical advantage of two.



3. **A block and tackle system** combines both kinds of pulley.



In this example there are four lines in and out of the movable pulley and therefore the IMA = 4. If the resistance (load) is 100 lbs, then the input force Fe will be 100 ÷ 4 = 25 lbs plus the force needed to overcome friction. The distance of the effort will be four times greater than the distance that the resistance moves.

Ideal (aka theoretical) Mechanical Advantage Summary for Pulleys

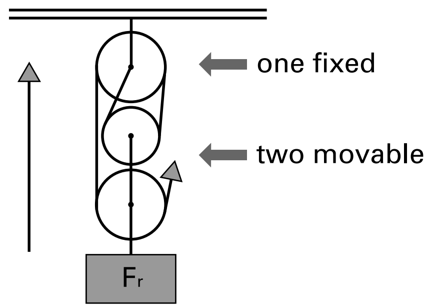
Single fixed pulley: TMA = 1

Single movable pulley: TMA = 2

Block and tackle combinations: TMA = number of support lines to the moveable pulleys.

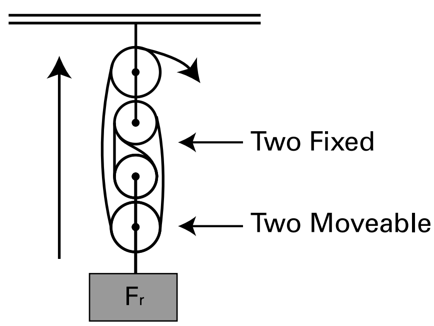
Sample Problems

1. What is the TMA of the following pulley systems



a) This block and tackle system has one fixed and two movable pulleys. There are four lines supporting the movable pulleys, the TMA = 4, and there is no change in direction.

b) This system has two fixed and two movable pulleys. There are four lines supporting the movable pulleys here as well. The TMA = 4, and there is a change in direction.



c) This system has 3 fixed and two movable pulleys. There are 5 lines supporting the movable pulleys. The TMA is 5 and there is a change of direction.

2. In a friction free pulley system, how much effort is applied by a rig worker if he lifts a 500 lb load with a block and tackle system that used 4 ropes to support the movable pulleys in the system?

   The key to this problem is the realization that we are given the TMA and the AMA when we are told the number of supporting ropes in a frictionless system. The AMA for the system is 4, therefore the force output (= the weight of the load) divided by the force input will equal four in a frictionless system. Solving for F_i = 500 lb/4 = 125 lb.

Unit 4 – Basic Machines

Topic 2 – Practice Questions

Question 1
The direction of effort in a pulley system can be reversed. What kind of pulley reverses direction but offers no mechanical advantage?

a) A friction free pulley.
b) Single movable pulley.
c) Block and tackle.
d) Single fixed pulley.

Answer: d

Question 2
A pulley system has a TMA of 4. How far will a person have to pull the rope attached to this system in order to move a 50kg load 10 metres?

a) 5 metres
b) 200 metres
c) 40 metres
d) 500 metres

Answer: c

Question 3
How far will a load move if a pulley system with a TMA of 5 is used and the effort line is pulled 50 metres?

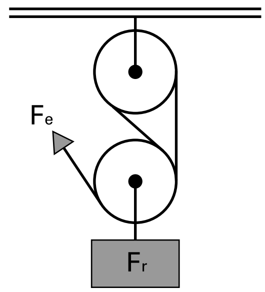
a) 25 metres
b) 250 metres
c) 55 metres
d) 10 metres

Answer: d

Topic 2 – Practice Questions

Question 4

What is the TMA of this pulley system?



a) 1
b) 2
c) 3
d) 4

Answer: c

Question 5

In a frictionless pulley system with one fixed and one movable pulley, will a man who weighs 180 lbs be able to use his weight to lift a 225 lb load?

a) Yes.
b) No.
c) Can't tell without more information.
d) Depends on his strength.

Answer: a

Topic 2 – Simple Machines

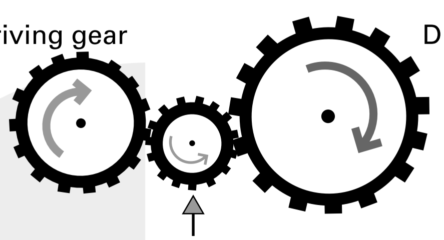
Gears

Gears are notched wheels that can be used to change the direction of motion, change the speed of motion, or change the magnitude (size) of the applied force. Like the pulley and the wheel and axle, **Gears apply the principle of the lever to give us mechanical advantages.** The radius of a gear is its lever arm.

You need to know:

1. When two gears are of unequal size, the smaller is called the pinion.
2. When the direction of motion needs to be changed from one gear to another, an **idler gear** is inserted between them.
3. The gear that the input force is applied to, often by a motor, is called **the driving gear**, or the master gear.
4. The gear being turned by the driving gear is called the **driven gear**. The driven gear usually transmits the output force to an object to do work. The output gear can be parallel or at an angle to the driving gear.
5. In a system of several gears, only the first gear receiving the input force is called the driving gear, and only the final gear that transmits the output force is called the driven gear.
6. An even number of gears will produce motion opposite to the motion of the driving gear. For example, if the driving gear rotates clockwise, the final driven gear will rotate anti-clockwise in an even number of gears that mesh. The reverse is also true. In an odd number of gears, the direction of the motion of output will be the same as the motion of input. Clockwise driving gear motion will produce clockwise driven gear motion in an odd number of gears.
7. The radius of a gear determines how fast it will turn. A small gear will go through more revolutions per unit of time than a larger gear that it meshes with. When the driving gear is smaller than the driven gear, there is a loss in speed but a gain in force. When the driving gear is larger than the driven gear, there is a gain in speed but a loss in force.

To summarize:
A Small gear driving a larger gear transfers a larger force in exchange for more revolutions, and a large gear driving a small gear transfers less force in exchange for fewer revolutions per unit of time.



Topic 2 – Simple Machines

Mechanical Systems

A bicycle is an example of a mechanical system that combines several simple machines. Levers, gears, wheels and inclined planes are often combined in machinery. In a mechanical system force is applied to an input component. The force applied to the pedals is transferred to the driving wheel by a gear system. Notice that the pedal is itself a mechanical subsystem. The pedal rotates on an axle so the foot can continue to press down on it as force is transferred to the driving gear.

Unit 4 – Basic Machines

Topic 2 – Practice Questions

Question 1

A gear system can be used to:

a) transfer motion.
b) increase the speed of a rotating shaft.
c) decrease the speed of a rotating shaft.
d) all of the above.

Answer: d

Question 2

An idler gear is used to:

a) change the direction of motion.
b) increase speed.
c) increase mechanical advantage.
d) connect two machines.

Answer: a

Question 3

When a large gear drives a smaller one, which gear will turn faster, (i.e. complete more rotations in the same time period)?

a) The large gear.
b) The small gear.
c) They will turn the same number of times.
d) It depends on the force applied to the large gear.

Answer: b

Question 4

If the same force is applied to two gears, what will determine how fast each gear turns?

a) The number of teeth on the gear.
b) The radius of the gear.
c) The output force of the gear.
d) The direction of turning.

Answer: b

Unit 5

Electricity, Circuits and Motors

Electricity is a moving electric charge. Electrical energy can be changed into other forms of useful energy. For example, electrical energy is changed into magnetic energy in a solenoid or speaker, into heat energy in an electric baseboard heater, and into mechanical energy in a fan, vacuum cleaner, or other device with an electric motor.

Safety

Household electrical currents should not be used for experiments because they are strong enough to cause injury and even death if the current flows through your body. Small batteries are useful for experiments because they produce small amounts of direct current that can be used to test circuits. Do not short circuit a battery by connecting the leads from each terminal: the wire will heat up and the battery will stop producing current.

Unit 5 – Electricity, Circuits and Motors

Topic 1 – Electricity and Magnetism

The structure of matter includes the basic property of positive and negative electric charge. Like charges repel and unlike charges attract. Electric force is the movement of electric charge, electricity can do work and is trillions of times stronger than gravitational force when compared on the same scale.[32]

Electric current is possible because electric charges can flow in matter. Materials that allow an electric charge to flow easily are called **conductors**. Conductors have many free electrons. A conductor will remain electrically neutral (have no net charge) when electrons flow freely through it. When an electron enters a wire at one end, another one leaves from the other end.

> **More Precisely…**
> It is really the electric force field that travels through a wire and drives conducting electrons. Energy is what is flowing in a circuit, and at the speed of light (186,000 miles per second). The actual net movement of electrons is much slower. The energy of the electrical field does the work.

Insulators are non-conductors. Electrical **insulators** are materials with very few electrons free to move. Every material will conduct electricity if enough electrical pressure (voltage) is applied. Materials can be listed in the order of their conductivity. Good **conductors** include silver, copper and iron. Poor conductors include dry wood, pure water, and oils. Insulators are poor conductors that are convenient to use to prevent conduction. Materials that conduct electricity only to some degree are used as **resistors** in circuits.

Magnetism

Magnetism is an attractive force like gravity, but unlike gravity, and like electricity: magnetic force has a north and a south pole or direction. As with electric charge, like poles repel and unlike poles attract each other. The strength of the attraction or repulsion decreases with distance. the earth has a magnetic field, and a compass needle will turn until it is parallel to the earth's lines of magnetic force. The north pole of the compass points to the north magnetic pole of the earth.[33]

Iron and the magnetic properties of iron are important for electric motors and electric generators. Magnets are either natural or artificial. Lodestone, i.e. magnetite, is a naturally occurring magnet. Magnets attract magnetic materials. A piece of lodestone will attract iron filings. Magnetism can be induced in a piece of iron by stroking it with a strong magnet.

32 On a relative scale, electromotive force = 10^{40} times the gravitational force.

33 The north magnetic pole of the earth attracts the north pole of a magnetic compass, therefore it is really a south magnetic pole- and it is located about 1500 km from the earth's geographic north pole.

Unit 5 – Electricity, Circuits and Motors

Topic 1 – Electricity and Magnetism

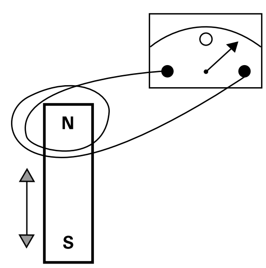
An artificial magnet is made by passing electric current through a wire. All wires carrying current are create a magnetic field that will attract magnetic material.

Electricity from Magnetism

When a wire is moved through a magnetic field, a small amount of current is produced. Electric generators use this principle by moving large amounts of wire (in coils) through powerful magnetic fields.

Evidence of Magnetic Fields

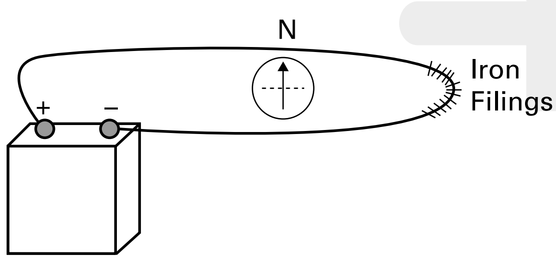
A magnetic field can be demonstrated by sprinkling iron filings on a piece of cardboard on top of a bar magnet. The filings will be pulled into patterns that show the lines of force that attract them. Or, a number of small compasses can be put on the cardboard. The needles will line up with the magnetic lines of force in the field produced by the magnet.



When the bar magnet is moved up through the wire coil, a small amount of current can be detected by a galvanometer.

Magnetism from Electricity

When current flows through a wire, magnetic force can be measured. If a compass is placed near a wire, and the wire is connected to a source of electricity, the compass needle will move in a direction parallel to the lines of magnetic force that are generated. Iron filings will also be attracted to the wire while current flows through it. Electromagnets are made by increasing the windings of the wire and increasing the current.



Unit 5 – Electricity, Circuits and Motors

Topic 1 – Electricity and Magnetism

Current and Amperes

It is helpful to compare an electric current to a river current. Although no matter is travelling in an electric current, other points of comparison are instructive. For example, the more water, and the faster it flows, the greater the current in a river. The same thing is true of Electric current. Electric current can be compared to moving water and is sometimes referred to as "juice".

In the case of moving electric charge, the more charge and the faster it flows the greater will be the electric current. The amount of current is given the symbol "I", and measures the amount of charge flowing per second.

I = Electric Current = Charge/Time

Example:

Current flow in a wire.

One ampere means that one coulomb of charge is flowing by any point in the wire every second.

I is given in units called **amperes** in recognition for the work of Andre Ampere (1775-1836) (also abbreviated as A, or amp). Electrical current is measured by an **ammeter.**

Conventional Current: from + to -

For all practical purposes, positive charge flowing in one direction is equivalent to negative charge flowing in the opposite direction.

Historically, current flow was thought to be from positive to negative and this convention is stilled used today to describe current flow. **The actual direction of electron flow is always from negative to positive** because unlike charges attract and electrons do the moving.

Electrical potential is measured in volts (V). Comparing electricity once again to a flowing river, voltage measures the "electrical pressure" of electric current. Voltage is a measure of the electromotive force (EMF) in a circuit.

A moving charge will take "the path of least resistance". This is what happens when a lightning bolt strikes the earth, or when a short circuit provides a route for current that avoids resistance. When current flows there is a difference in potential involved.

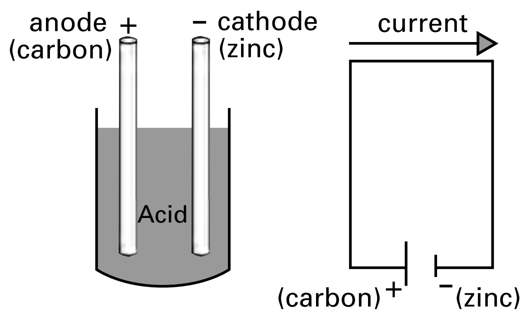
Unit 5 – Electricity, Circuits and Motors

Topic 1 – Electricity and Magnetism

Electric Cells

Electric cells produce electric current and are commonly called **batteries.** The simplest electric cell has two electrodes in an **electrolyte.** The electrolyte is a conductor, usually an acid in paste or liquid form. For example, a simple cell could have a carbon electrode and a zinc electrode in a dilute (weak) sulphuric acid solution. This would be called a **wet cell.** A **dry cell** would have the electrolyte in a paste or other non-liquid form. Car batteries combine wet cells in series. Each electrode has a portion above the electrolyte called the terminal. Wires are attached to the terminals.

One electrode is positive and is called the **anode.** The other electrode is negative and is called the **cathode.** The electrolyte is a conductor, and electrons are transferred form the anode to the cathode to produce current. This flow of **direct current** is driven by a difference in electrical potential between the material chosen for the anode and the material chosen for the cathode.[34]



The voltage between the terminals will depend on what the electrodes are made of and how well they give up electrons in an electrolyte. The voltage of a typical cell will be between 1.0 and 2.0 volts. **Cells connected in series will have their voltages add up.** For example the total voltage of two 1.5 volt flashlight batteries in a flashlight will be 3.0 volts. In a car battery, the total of six 2.0 volt cells will be 12 volts.

34 See Supplementary Topics for a description of the electrochemical series and corrosion as a result of electron transfer between materials with different electric potentials in the series.

Unit 5 – Electricity, Circuits and Motors

Topic 1 – Practice Questions

Question 1
An electric cell produces:

a) alternating current.
b) direct current.
c) voltage current.
d) electrical potential.

Answer: b

Question 2
The voltage of a typical electric cell will be:

a) between 6 volts and 12 volts.
b) between 5 volts and 12 volts.
c) between 1 volt and 2 volts.
d) depends on the size of the cell.

Answer: c

Question 3
How many cells are in a battery?

a) 2
b) 6
c) 12
d) Any number is possible.

Answer: d

Question 4
A battery has 15 cells. Each cell has a voltage of 2.0 volts. What voltage will be measured between the two terminals of the battery?

a) 7.5 volts
b) 12 volts
c) 30 volts
d) 17 volts

Answer: c

Topic 1 – Practice Questions

Question 5

In order for current to flow in an electric cell, what must be true about the electric potential of the electrodes?

a) It must be identical.
b) It must be different.
c) It must be increasing.
d) It must be free of resistance.

Answer: b

Question 6

Every battery has a positive terminal and a negative terminal. The negative terminal is also called the:

a) cathode.
b) anode.
c) diode.
d) electrolyte.

Answer: a

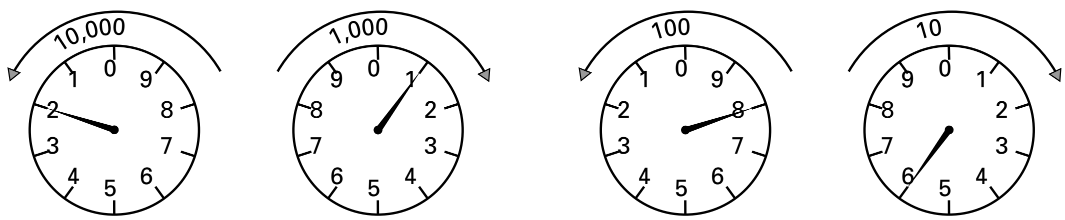
Unit 5 – Electricity, Circuits and Motors

Topic 1 – Electricity and Magnetism

Electrical Meters

A familiar meter is the kilowatt hour meter. This meter measures electrical energy consumed and is usually found on an outside wall. Kilowatt hours are measured by meters that measure current being drawn over periods of time.

A kilowatt equals 1000 watts. The watt is a unit of power and power and energy is measured in watt hours. Appliances are rated according to how much power they use per hour. power x time equals watt hours. A reading at the beginning and end of a period will tell how many kilowatt hours of power were used. Electric bills are based on the kilowatt hours consumed.



Read this meter from left to right. Notice the arrows that show which way the arrows rotate. The dial showing ten thousand hours has passed two and is headed for 3. The number passed is always used to record the kilowatt hour total. This meter reads 21860 kW hours.

Electrical meters are also used to measure volts. **Amperes and ohms**. These meters rely on electromagnetic forces to get readings by allowing a needle mounted on a spring to move in response to changes in the electromagnetic field that governs its position.

What You Need to Know:

1. An **ohmmeter** measures electrical resistance, for example the resistance of a light bulb. A short circuit will show infinite resistance on an ohmmeter.
2. A **voltmeter** measures electrical potential, for example the potential across the terminals of a battery. A dead battery will show zero on a voltmeter connected to the terminals of the battery. Electricity flows from a higher potential to a lower potential. Electric potential can be compared to pressure in a water circuit.
3. An **ammeter** measures current, for example the current flowing between two bulbs in series.

Unit 5 – Electricity, Circuits and Motors

Topic 1 – Practice Questions

Question 1

Which meter would you use to measure the current produced by a battery?

a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Test lamp.

Answer: a

Question 2

A battery has no markings on it. Which meter will tell you what the electrical potential of the battery is?

a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Test lamp.

Answer: c

Question 3

Electrical meters make use of:

a) changes in electro magnetic fields.
b) conductors that flow.
c) differences in potential.
d) temperature differences.

Answer: a

Question 4

Which meter should be used to measure the resistance in a circuit?

a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Test lamp.

Answer: b

Topic 1 – Practice Questions

Question 5

What do the dials on a kilowatt hour meter measure?

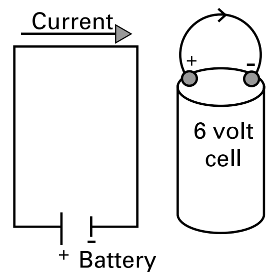
a) Volts.
b) Amps.
c) Electric power consumption.
d) Appliance time.

Answer: c

Unit 5 – Electricity, Circuits and Motors

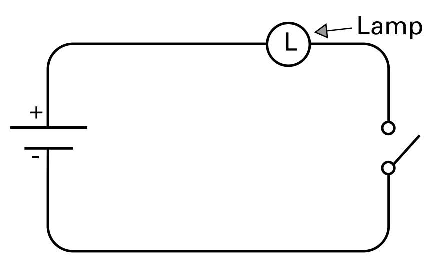
Topic 2 – Circuits

Circuits are continuous (i.e. unbroken) conducting paths. For example, a wire connecting the two terminals of a battery creates a simple electric circuit. If a light bulb is added to the circuit the current will flow from one terminal of the battery through the **resistance** of the bulb and back to the other terminal of the battery. Some of the electrical energy will be given off by the bulb as heat (90%) and some as light (10%). If the wire is cut, not connected, or if a switch is open, the current will not flow and the bulb will not light. The circuit must be closed for current to flow. A circuit will also require a **voltage source,** like a battery, to provide the energy needed to keep the flow of electrons going.

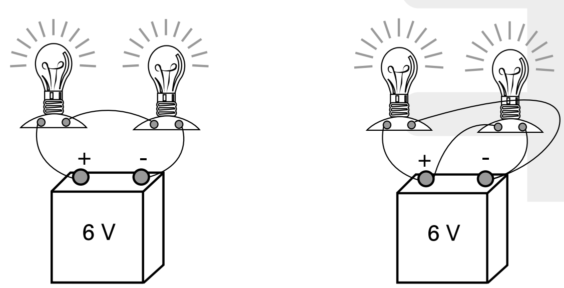


If resistance in a circuit is zero, for example if a live wire touches ground or if two live wires touch each other, a large amount of current will flow to the ground and not through the circuit. This is called a short circuit.

You can see in the next diagram that the light will not glow when the current flow is stopped. Switches are used to control the flow of current. When the switch is open, the circuit is interrupted and there is no flow of current.



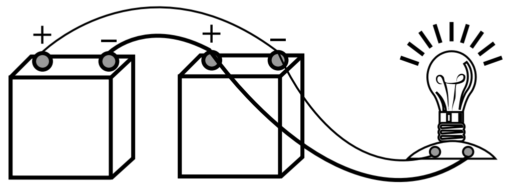
There are two ways to connect two lights to a single power source.



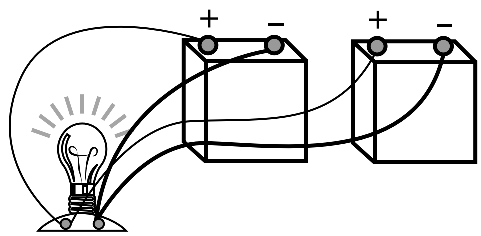
The circuit on the left will deliver less pressure to the second or "downstream" bulb. The circuit on the right delivers the same pressure to both lamps. As a result, the two lamps on the right will glow more brightly than the pair on the left.

When two batteries are used to light a single bulb, a similar difference can be seen in the brightness.

When the batteries are connected to each other in series before going to the lamp, the voltage of each battery is combined and the bulb burns more brightly than it would from a single battery.



When each battery is separately connected to the lamp it will glow less brightly because the voltage is not being doubled.



Switches

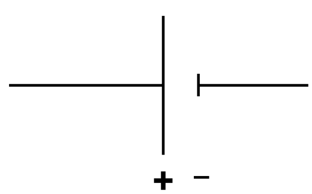
A switch controls the flow of current in a circuit. A switch can be a mechanical device that opens and closes a circuit, or a variable resistor that controls how much resistance is introduced into a circuit to change the voltage or current. A dimmer switch on a light does this. It is called a **rheostat.** A thermostat is a switch that uses a heat sensitive metal to open and close a circuit. A burglar alarm uses a broken circuit to detect intrusions. Plate glass windows can have conducting tapes put around the perimeter that are connected to an alarm sender. If the glass is broken, the tape will break, and the alarm will be triggered.

Circuit Diagrams

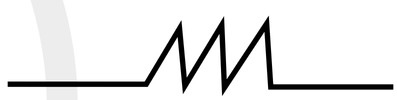
Circuits are Diagrammed

Circuit diagrams are useful ways to show what is happening in an electrical circuit. You need to know the following basics about circuit diagrams

1. A battery is represented by

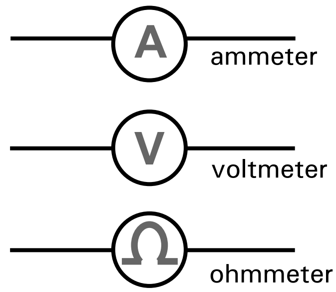


2. A resistance is represented by

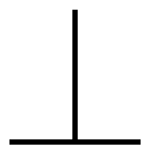


Topic 2 – Circuits

3. An electrical meter is represented by

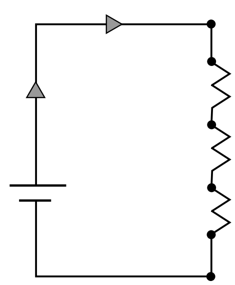


4. Ground is represented by

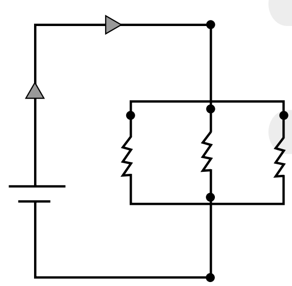


5. A switch is represented by

6. A series circuit looks like this



7. A parallel circuit looks like this



Topic 2 – Practice Exam Questions

Question 1
What does a switch do in a circuit?

a) It regulates the amount of current flowing
b) It opens and closes the circuit
c) It measures voltage
d) It converts kilowatt hours

Answer: b

Question 2
What does a resistor do in a circuit?

a) Uses electrical energy
b) Opposes current flow
c) Produces light or heat
d) All of the above

Answer: d

Question 3
When the leads of two batteries are connected to each other in series before delivering current to a lamp, will the lamp glow more brightly than if two batteries have their positive leads each separately connected to the lamp?

a) No
b) Yes
c) Can’t tell
d) The lamp will glow the same amount in both cases

Answer: b

Question 4
What causes a burglar alarm to go off?

a) A broken circuit
b) A lamp
c) A resistor
d) A thermostat

Answer: a

Topic 2 – Practice Exam Questions

Question 5

When a live wire touches ground what will happen?

a) A large amount of current will flow to the ground
b) An open circuit will result
c) An infinite resistance will result
d) The voltage will increase

Answer: a

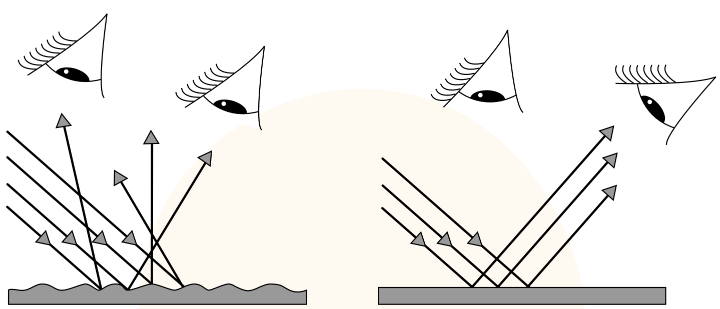
Unit 6

Light and Energy

Topic 1 – Properties of Light

Light can be understood as a form of energy and as a stream of particles. Unlike sound waves, light travels in waves without a medium.[35] The light from the sun travels in a vacuum. Bright lights can damage our eyes, and welding torches, the sun, and other intense light sources should never be looked at directly or with ordinary telescopes or binoculars.

Light follows straight line paths and travels out in all directions from a light source. Our eye receives bundles of rays that are reflected by objects. Light sources include flames, electric lights, stars and materials that glow. The light that we can see comes either from a body that radiates light, or that reflects light. Bodies that reflect light require an source of light to hit them before they can be seen. Surfaces that reflect light can be rough or shiny. The smoother a surface is, the more light it reflects. A mirror reflects 95% of the light that hits it.



When a point source of light, for example a flashlight, is used to illuminate a surface you can see that light is reflected in straight lines. On a rough reflective surface, (on the left) you can move your eye and some reflected rays will enter your eye. You can change the position of your eye and still see something. On a smooth surface, for example a mirror, (the right) your eye must be in the right place to see the reflected rays of light. If you move your eye where there are no reflected rays, you won't see the light.

[35] See Science – Module 3 – Special Topics for more on the nature of light as a transverse wave.

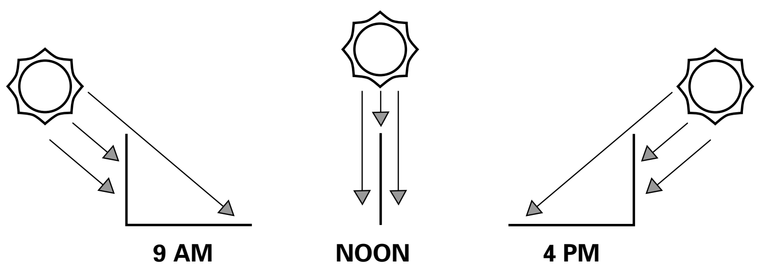
Unit 6 – Light and Energy

UNIT 6

Topic 1 – Properties of Light

What you need to know about light:

1. Materials can be **transparent, translucent or opaque**. Transparent materials let light through. Glass, clear water, cellophane and air are transparent. Translucent materials let some light through, and opaque materials let no light through.
2. A **shadow** will only be cast by an opaque or translucent body when a light source is directed at it. The size of a shadow depends on the angle of the light rays that hit it.

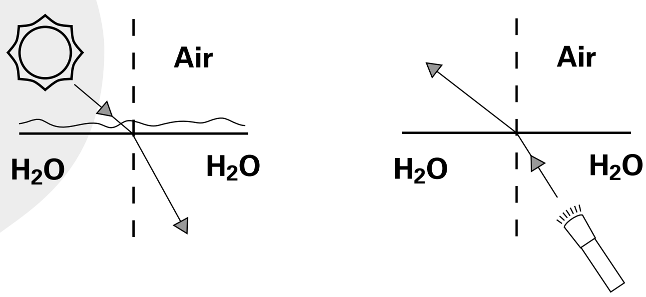


This diagram shows how the Shadows made by the sun on a pole change as the earth rotates. Parallel rays strike the pole, but because the pole is opaque, some of the rays are blocked. A shadow results in the area that light can't reach. Light will travel outward from a source and continue unless blocked by an opaque object.

3. **Refraction and colors**

Light can be broken into colours and different colours of light can be combined to form a new colour. This can be seen by using color filters over a light source.

Also Light rays can be bent when light changes the medium it travels through. This is because the speed of light is different in different substances. An index of refraction has been calculated for different substances that light can travel through. For examples diamonds have a very high index of refraction that causes light to bend when it leaves air and enters the diamond. We see the component colors of light in the diamond which gives it brilliance.



Unit 6 – Light and Energy

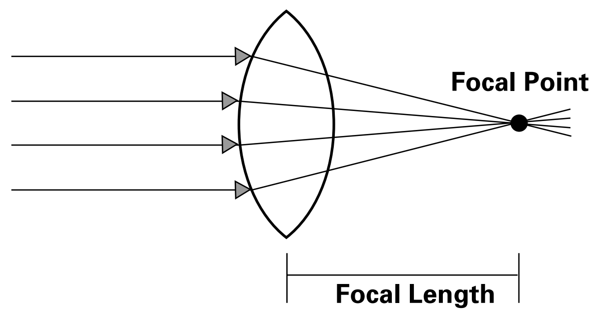
Topic 1 – Properties of Light

As a beam of light leaves air and enters water, it bends towards a vertical line (the perpendicular). The reverse happens when a beam of light is sent from the water to the air. When light is refracted we can also see that it is made of colors.[37] A rainbow is the result of light being refracted by water droplets in the air. White light is broken down into all of the colors of the spectrum from red to violet. Experiments with glass prisms show that light that is separated into colors can also be re-combined by using a second prism and reversing the refraction process.

37 The wave theory of light uses wavelengths to explain colors.
This is discussed in Science – Module 3 – Special Topics, Unit 3 – Electricity.

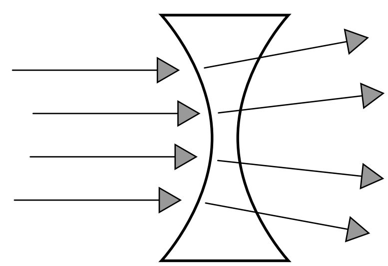
Topic 2 – Optical Devices

Eyeglasses, microscopes, and telescopes use lenses to bend light rays. A lens is a curved transparent piece of glass. A convex lens will cause rays from a distant object to come together (i.e. converge) at a focal point. The focal length determines how strong the lens is.



The parallel rays entering the lens are bent to a focal point. A distant object will converge at the focal point.

A concave lens does the opposite



Unit 6 – Light and Energy

Topic 2 – Practice Exam Question

Question 1
Which material is translucent?

a) Colored glass.
b) Clear water.
c) A window pane.
d) A barrel.

Answer: a

Question 2
When light enters a lake what will happen?

a) The rays will bend.
b) The rays will continue in straight lines.
c) The rays will reflect.
d) The rays will stop.

Answer: a

Question 3

What happens to sunlight when it is passed through a prism?

a) It speeds up.
b) It stops.
c) It produces colors.
d) It gets darker.

Answer: c

Question 4

Which optical device is used to study bacteria?

a) Telescope.
b) Binocular.
c) Microscope.
d) Prism.

Answer: c

Topic 2 – Practice Exam Question

Question 5

What explains the fact that the sun casts a shadow from a pole that is longer at 4:00 pm than at 1:00 pm?

a) The pole has moved.
b) The sun has moved.
c) The earth has rotated.
d) The light hitting the pole has decreased.

Answer: c

Unit 7

Practice Exam Questions for Science – Module 1 – Science Foundations

This is the first of three modules in the science curriculum for trades entrance science exams. Science foundations covers material required for all levels of the trades entrance science exam. Each module has a set of practice exam questions with an answer key. Each topic in the table of contents has sample questions to test your preparation for the trades entrance exam.

You should aim for 100%, and study the modules in the curriculum for any topics that you do not get right. After each answer the topics you should review are identified. Turn to the appropriate topic in the curriculum whenever you need help.

Science Foundations is based on "need to know" competencies that are important in all trades. You may want to use the following sample exam questions both as a way of assessing what you need to learn before you work on the curriculum, and as a test of what you know after you have completed your preparation for the exam.

Answer Key

The following questions are grouped in clusters of related items. You may want to randomly pick questions from different parts of the test for pre-test purposes, or you may want to home in on a particular area by using the answer key. If you want to take a pre-test, select every fourth question, score yourself, and you will get an idea of what to study. After studying, try every third question and see how well you do and repeat the study cycle based on your results.

Unit 7 – Practice Exam Questions

Question 1
A gas is heated in a closed container. What will happen?

a) The gas will escape.
b) The gas will change to a liquid.
c) The pressure will increase.
d) The gas will settle.

Question 2
What happens to the mass of a gas in a closed container when it changes into a liquid?

a) It increases.
b) It decreases.
c) It stays the same.
d) It gets heavier.

Question 3
A solid has a fixed volume and shape. What does a liquid have?

a) Fixed volume but variable shape.
b) Variable volume but fixed shape.
c) Variable volume and variable shape.
d) No volume and fixed shape.

Question 4
Gases are considered fluids because:

a) They pour like a liquid.
b) They freeze like a liquid.
c) They are not solids.
d) They react to pressure.

Question 5
When molecules in a solid vibrate more they:

a) Get hotter.
b) Produce sound.
c) Dissolve.
d) Change into a gas.

Unit 7 – Practice Exam Questions

Question 6
The molecules in water change into water vapour when the water is boiled.
What causes this change in state?

a) The molecules move more slowly.
b) The molecules gain kinetic energy.
c) The molecules break into atoms.
d) The pressure changes.

Question 7
Which meter would you use to measure the current produced by a battery?

a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Test lamp.

Question 8
A battery has no markings on it. Which meter will tell you what the electrical potential of the battery is?

a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Test lamp.

Question 9
Electrical meters make use of:

a) changes in electro magnetic fields.
b) conductors that flow.
c) differences in potential.
d) temperature differences.

Question 10
Which meter should be used to measure the resistance in a circuit?

a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Test lamp.

Unit 7 – Practice Exam Questions

Question 11
An electric cell produces:

a) alternating current.
b) direct current.
c) voltage current.
d) electrical potential.

Question 12
The voltage of a typical electric cell will be

a) between 6 volts and 12 volts.
b) between.5 volts and 12 volts.
c) between 1 volt and two volts.
d) depends on the size of the cell.

Question 13
How many cells are in a battery?
a) 2
b) 6
c) 12
d) Any number is possible

Question 14
A battery has 10 cells. Each cell has a voltage of 1 volts. What voltage will be measured between the two terminals of the battery?

a) 11 volts
b) 12 volts
c) 10 volts
d) .1 volts

Question 15
The electric potential of the electrodes in a battery is the same. What will be the output of the cell?

a) The sum of the potentials
b) Zero volts
c) 1.5 volts
d) 2.0 volts

Unit 7 – Practice Exam Questions

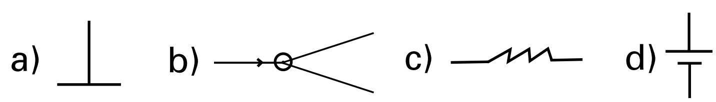
Question 16
Every battery has a positive terminal and a negative terminal. The positive terminal is also called the:

a) cathode.
b) anode.
c) diode.
d) electrolyte.

Question 17
A switch is used in a circuit to:

a) increase current.
b) decrease voltage.
c) open and close the circuit.
d) prevent shorts.

Question 18
What is the symbol for a battery in a circuit diagram?



Question 19
When a bar magnet moves through a coil of wire attached to a galvanometer what will happen?

a) The meter will show an electric current.
b) The meter will reverse direction.
c) The magnetic field will increase.
d) The magnet will lose strength.

Question 20
A circuit will conduct current if:

a) the breaker is closed.
b) the resistances are shorting out.
c) the battery is dead.
d) the wire is broken.

Unit 7 – Practice Exam Questions

Question 21
An wire carrying an electric current is placed near a compass. What will happen?

a) The compass will freeze.
b) The compass will point north.
c) The compass will point in the direction of the magnetic field generated by the wire.
d) The compass will lose its magnetic ability.

Question 22
Household current is not a safe source for experimenting with electricity because:

a) it is too expensive.
b) it can injure or kill a person.
c) it is too easy to connect incorrectly in an experiment.
d) it is hard to detect.

Question 23
Suction is the result of:

a) atmospheric pressure on a vacuum.
b) the suction force.
c) the removal of air from a container.
d) the seal between two substances.

Question 24
A pump is able to lift water by:

a) sucking up the water.
b) pushing the water around.
c) creating a low pressure area in the pump for the atmosphere to push the water into.
d) closing the escape route for the water.

Question 25
A pump moves a fluid by:

a) applying a force to the fluid.
b) creating a partial vacuum for the fluid to be pushed into by atmospheric pressure.
c) both a and b.
d) by opposing the force of gravity on the fluid.

Question 26
Atmospheric pressure is less:

a) at high altitudes.
b) below ground.
c) under the sea.
d) inside your body.

Unit 7 – Practice Exam Questions

Question 27
Two atmospheres will lift a column of mercury in a barometer:

a) 760 mm
b) 34 feet
c) 1520 mm
d) 9.6 Newtons

Question 28
We don’t feel the pressure of the atmosphere because:

a) we are unaware.
b) we wear clothes.
c) we oppose it with equal and opposing pressure.
d) it is too little to notice.

Question 29
How high must the temperature go to completely boil off a pot of water?

a) 1000 degrees Celsius.
b) 100 degrees Celsius.
c) as high as the source of heat allows.
d) 10 degrees Celsius.

Question 30
When a piece of metal expands which direction does it prefer?

a) North.
b) It will expand equally in all directions.
c) The side gravity acts on.
d) The front.

Question 31
Weight is defined as:

a) the amount of mass in an object.
b) the force of an object on the ground.
c) the amount of gravitational force acting on an object.
d) the density of an object.

Question 32
What happens to a gas when it is heated in a closed container?

a) It expands and its temperature goes up.
b) It exerts more pressure and its temperature goes up.
c) Its temperature goes down.
d) It contracts and its temperature goes up.

Unit 7 – Practice Exam Questions

Question 33
The most stable structure will have a centre of gravity that is:

a) anywhere.
b) near the top of the structure.
c) near the base of the structure.
d) in the middle of the structure.

Question 34
When an object is given a push in outer space what will happen?

a) It will move in a straight line until friction stops it.
b) It will gradually slow down and fall.
c) It will move indefinitely in the direction of the push.
d) It will circle and return to its starting place.

Question 35
When light goes from air into water what happens?

a) It changes direction.
b) It changes speed.
c) It changes both speed and direction.
d) It continues in a straight line.

Question 36
A heat source has costs that can include:

a) environmental impact.
b) costs of fuel.
c) costs of a heating system.
d) all of the above.

Question 37
Friction can be reduced by:

a) lubrication.
b) using more force.
c) using gravity better.
d) changing direction.

Unit 7 – Practice Exam Questions

Question 38
Lift is possible when:

a) the propellers are strong enough.
b) the air pressure below an airplane wing is greater than the pressure above the wing.
c) the air is moving quickly enough.
d) the air pressure below an airplane wing is less than the pressure above the wing.

Question 39
A single fixed pulley is used to:

a) increase mechanical advantage.
b) multiply effort.
c) change direction.
d) reduce work.

Question 40
A wheelbarrow is an example of:

a) an inclined plane.
b) a lever.
c) a gear.
d) a screw.

Question 41
Light can travel through materials that are:

a) translucent.
b) transparent.
c) opaque.
d) a and b.

Question 42
When a man throws a pack from a canoe onto shore, and the canoe moves away from shore we have an example of:

a) a force in motion.
b) a frictionless system.
c) an action reaction pair.
d) an inertia.

Unit 7 – Practice Exam Questions

Question 43

An object will only move when

a) a force is applied to it that is balanced.
b) an unbalanced force is applied to it.
c) it has no friction.
d) it has lift.

Question 44

An insulator is

a) a conductor that is protected.
b) a semi-conductor that is inexpensive.
c) a partial conductor that is convenient to use to resist the flow of electricity.
d) a non-conducting material that is easy to use to prevent the flow of electricity.

Question 45

Which simple machine is the claw on a hammer an example of?

a) A wheel.
b) An inclined plane.
c) A lever.
d) A bar.

Question 46

When light passes through a prism what will you see?

a) A straight light beam.
b) A light ray at an angle.
c) The colors of the spectrum.
d) The index of refraction.

Question 47

When a movable pulley and a fixed pulley are combined it is called a:

a) simple machine.
b) block and tackle.
c) combination pulley.
d) rigging pulley.

Unit 7 – Practice Exam Questions

Question 48

What does temperature measure?

a) Heat.
b) Kinetic energy.
c) Average kinetic energy.
d) Degrees.

Question 49

It takes more effort to start a truck rolling than a small car on earth and in outer space because:

a) the truck has more mass.
b) the car is smaller.
c) the truck has more friction.
d) the truck has to change direction more.

Question 50

Which machine uses several mechanical subsystems:

a) a shovel.
b) a roller.
c) a bicycle.
d) a nail.

Unit 7 – Practice Exam Questions

Answers	Study Topics
1) c	Unit 1, Topic 1
2) c	Unit 1, Topic 1
3) a	Unit 1, Topic 1
4) a	Unit 1, Topic 1
5) a	Unit 1, Topic 1
6) b	Unit 1, Topic 1
7) a	Unit 5, Topic 1
8) c	Unit 5, Topic 1
9) a	Unit 5, Topic 1
10) b	Unit 5, Topic 1
11) b	Unit 5, Topics 1 and 2
12) c	Unit 5, Topics 1 and 2
13) d	Unit 5, Topics 1 and 2
14) c	Unit 5, Topics 1 and 2
15) b	Unit 5, Topics 1 and 2
16) b	Unit 5, Topics 1 and 2
17) c	Unit 5, Topics 1 and 2
18) d	Unit 5, Topics 1 and 2
19) a	Unit 5, Topics 1 and 2
20) a	Unit 5, Topics 1 and 2
21) c	Unit 5, Topics 1 and 2
22) b	Unit 5, Topics 1 and 2
23) a	Unit 2, Topic 2
24) c	Unit 2, Topic 2
25) c	Unit 2, Topic 2
26) a	Unit 2, Topic 1
27) c	Unit 2, Topic 1
28) c	Unit 2, Topic 1
29) b	Unit 3, Topic 2

Answers	Study Topics
30) b	Unit 2, Topic 3
31) c	Unit 1, Topic 3
32) b	Unit 2, Topic 3
33) c	Unit 1, Topic 7
34) c	Unit 1, Topic 5
35) c	Unit 6, Topic 1
36) d	Unit 3, Topic 4
37) a	Unit 1, Topic 3
38) b	Unit 2, Topic 5
39) c	Unit 4, Topic 2
40) b	Unit 4, Topic 2
41) d	Unit 6, Topic 1
42) c	Unit 1, Topic 5
43) b	Unit 1, Topics 4 and 5
44) d	Unit 5, Topic 1
45) c	Unit 4, Topic 2
46) c	Unit 6, Topic 1
47) b	Unit 4, Topic 2
48) c	Unit 3, Topic 1
49) a	Unit 1, Topics 3, 4 and 5
50) c	Unit 4, Topic 2

Unit 8

Supplementary Topics

Topic 1 – Atoms and Elements

All matter is made out of tiny particles called atoms. The study of how these atoms interact is called Chemistry. Elements are pure substances that cannot be broken down into simpler substances by ordinary chemical methods. Each element is made of only one kind of atom. Iron, copper, chlorine, and carbon are elements. Every atom of an element has the same components as every other atom of that element.

The three particles that make up atoms are **protons, neutrons, and electrons.** Protons and neutrons are heavier than electrons and are found in the "nucleus," which is the center of the atom. Protons have a positive electrical charge, and neutrons have no electrical charge. Electrons are extremely lightweight and are negatively charged. They exist in a cloud that surrounds the atom. The electron cloud has a radius 10,000 times greater than the nucleus. In stable atoms, the charge on the electron(s) balances out the charge on the proton(s) to produce a neutral charge for the atom as a whole.

The Nucleus

99.9% of all the mass of the atom is found in the nucleus. The nucleus is held together by the tight pull of what chemists and physicists call the "strong force." This force between the protons and neutrons overcomes the electrical force between the positively charged protons that would, according to the rules of electricity, push the protons apart.

Basic electrical law:

Opposite charges attract, like charges repel.

Unit 8 – Supplementary Topics

Topic 1 – Atoms and Elements

Electrons

The electron is the lightweight particle that "orbits" outside of the atomic nucleus. Chemical bonding is what happens when the electrons from one atom interact with the electrons of another atom. Electrons surround the atom in pathways called **orbitals**. The inner orbitals surrounding the atom are spherical but the outer orbitals are much more complicated.

Isotopes

An isotope is an atom with the same number of protons as other atoms of the same element, but with a different number of neutrons. The number of neutrons will affect the atomic weight of the atom but not change its atomic number. Atoms of the same element can have different atomic weights. In the periodic table of the elements the average atomic weight is given for each element based on a survey of its isotopes. Isotopes of the same element have the same chemical properties, but slightly different physical properties.

The Periodic Table of Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zh	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	07 Rb	08 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Fa	89 +Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 ?								

*Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Unit 8 – Supplementary Topics

Topic 1 – Atoms and Elements

Each element is in a square that contains the following information:

In this example, the element Boron has 5 protons (atomic number), the symbol B to represent Boron, and an atomic mass of 10.81 expressed in atomic mass units (amu's).

5	Atomic Number
B	Atomic Symbol
10.81	Atomic Mass

Atomic Number

The number of protons in an atom tells what element it is. For example Boron has 5 protons and carbon atoms have six protons. An atom with 5 protons will be boron. The number of protons in an atom is the atomic number of that element. The number of protons in an atom also determines the chemical behavior of the element. When the atom carries a neutral electrical charge, the number of its protons is equal to the number of its electrons. The atomic number also tells us the number of electrons in an atom of an element.

Atomic Symbol

The atomic symbol is one or two letters chosen to represent an element (H for hydrogen, B for boron, Zn for zinc etc.). These symbols are used internationally.

Atomic Mass

The atomic mass is the average mass of an element in atomic mass units (amu). The atomic mass is the sum of the mass of the protons, (atomic number) and the mass of the neutrons. Individual atoms always have a whole number of amus, but the atomic mass on the periodic table is stated as a decimal number because it is an average of the various isotopes of an element. Isotopes can have a weight either more or less than the average. **The average number of neutrons for an element can be found by subtracting the number of protons (atomic number) from the atomic mass.**

> Atomic mass units (AMU) are based on the atomic mass of Carbon 12 (^{12}C) which has been set at 12. One amu equals 1/12 the mass of a carbon 12 atom. An atom three times as heavy as carbon would have amu = 36. An atom with amu = 1 would have 1/12 the mass of a carbon atom.

The rows of elements are called periods. The period number of an element indicates the highest energy level an electron in that element occupies (in the unexcited state). Elements that are in the same column on the periodic table (called a "group") have identical electrical, or valence, properties, and behave in a similar fashion chemically. For example, all the group 18 elements are inert gases.

Unit 8 – Supplementary Topics

Topic 1 – Atoms and Elements

The simplest atom is the hydrogen atom. It has one proton with a + charge, and one electron with a - charge. In contrast to hydrogen, uranium appears near the end of the periodic table and is a heavier and more complex element. Atoms of uranium have 92 protons and atomic mass = 238 atomic mass units. Uranium has more mass than hydrogen and will weigh more.

Summary

Every atom has protons and neutrons in a nucleus that is surrounded by orbiting electrons. The number of electrons is equal to the number of protons in the nucleus of an atom. The electrons are much smaller than the protons and neutrons in the nucleus. Practice Exam Questions: The Atom and elements and matter

Unit 8 – Supplementary Topics

Topic 1 – Practice Exam Questions[37]

Question 1

Which statement is true for an element?

a) Elements are the simplest parts of matter.
b) Elements can combine to form compounds.
c) Elements weigh more in space.
d) Elements are bigger than molecules.

Answer: b

Question 2

How many times heavier than carbon 12 is an atom of uranium? (Uranium atomic mass of 238 and atomic number of 92. Carbon 12 has atomic mass of 12 and atomic number of 6).

a) 19.83
b) 2
c) 7.6
d) 91.96

Answer: a

Question 3

The periodic table gives information about:

a) the energy of elements.
b) the atomic weight of elements.
c) the molecules of heavy elements.
d) the mass of electrons.

Answer: b

Question 4

Copper has an atomic number of 29 and an atomic mass of 63.546. What is the average number of neutrons in copper atoms?

a) Can't tell from this information
b) 34.546
c) 92.54
d) 1842.83

Answer: b

[37] The 2001 list of competencies does not include this topic. Check with your apprenticeship branch for the latest requirements.

Topic 1 – Practice Exam Questions

Question 5
An element is:

a) a compound.
b) a molecule.
c) a collection of protons.
d) a pure substance.

Answer: d

Question 6
One atomic mass unit is:

a) 12 grams.
b) 12 carbon atoms.
c) the mass of one carbon atom.
d) 1/12 the mass of one carbon atom.

Answer: d

Question 7
Where is most of the mass of an atom found?

a) In the environment.
b) Near the electrons.
c) In the nucleus.
d) Between the neutrons.

Answer: c

Question 8
The weight of an object increases when:

a) it comes closer to the earth's surface.
b) it leaves the earth's surface.
c) it changes its shape.
d) it gets colder.

Answer: a

Unit 8 – Supplementary Topics

Topic 1 – Practice Exam Questions

Question 9

One Newton measures:

a) the force of the earth's gravity on 100 grams.
b) the force of one pound of water.
c) the weight of a cubic centimetre.
d) the force of gravity.

Answer: a

Question 10

Atoms of the same element will have the same:

a) atomic weight.
b) atomic number.
c) number of neutrons.
d) frequency.

Answer: b

Question 11

Calcium (Ca) has an atomic number of 20. How many electrons with an atom of calcium have?

a) 10
b) can't tell without knowing the AMU
c) 20
d) 40

Answer: c

Unit 8 – Supplementary Topics

Topic 2 – Molecules

Molecules and Compounds

Different combinations of neutrons, protons, and electrons, produce the atoms of the elements that we can isolate and work with. Every atom is one of the elements. **There are 118 elements.** Elements can combine with each other to form molecules, and molecules combine to form compounds. For example, water is made of molecules that combine one oxygen atom with two hydrogen atoms. The chemical symbol for water is H_2O. Elements can also form molecules that join several identical atoms. For example oxygen occurs in a molecule of two oxygen atoms as O_2.

Table salt is a compound made of molecules that combine the elements sodium (Na) and chlorine (Cl). The chemical name for table salt is sodium chloride (NaCl). The compound has different physical properties than the elements it is made of. For example, the element chlorine by itself is a poisonous gas, and the element sodium by itself is positively charged and will attract oxygen atoms from its surroundings so quickly that rapid oxidation, i.e. burning occurs. Many elements are not found in nature, but in compounds that can be separated by chemical and physical means into their component atoms.

A molecule is also the smallest unit of a substance that keeps the physical properties of that substance. One molecule of salt has all of the properties of salt. A molecule of salt can stand alone and still be salt. Molecules can contain many atoms. Some molecules have over 10,000 atoms. All atoms can form molecules.

The weight of a molecule is calculated by adding the atomic mass units of its atoms. For example the weight of one molecule of carbon dioxide (CO_2) is one carbon atom, C = 12, + two Oxygen atoms = 2 x 16 = 44 amus.

Unit 8 – Supplementary Topics

Topic 2 – Practice Exam Questions

Question 1
A molecule is made of:

a) compounds.
b) protons.
c) gas.
d) elements.

Answer: d

Question 2
The weight of a molecule is equal to:

a) the sum of the protons.
b) the mass of the protons.
c) the sum of the masses of each atom in the molecule.
d) the neutrons in the molecule.

Answer: c

Question 3
A molecule has the same chemical properties as the atoms it is made of.

a) True.
b) False.
c) Only at sea level.
d) Impossible to tell.

Answer: b

Question 4
A compound is a pure substance with molecules that:

a) contain the same elements.
b) that contain different elements.
c) that contain no elements.
d) that contain mixed combinations of elements.

Answer: a

Topic 2 – Practice Exam Questions

Question 5

The molecules in a compound have physical properties that are:

a) different.
b) identical.
c) uncertain.
d) mixed.

Answer: b

Unit 8 – Supplementary Topics

Topic 3 – Chemical Reactions

A chemical bond is formed when a chemical reaction takes place. When a chemical bond occurs, the atoms that bond form a compound. Substances change into new and different substances. For example, when sodium combines with chlorine, sodium chloride, table salt, is formed. The ingredients for the reaction are called the reactants, and the substances that are formed are called the products of the chemical reaction.

Chemical Reactions

Reactants ➔ Products

Examples:

H + H+ O ➔ H_2O

Two hydrogen atoms combine with one oxygen atom to produce one molecule of water.

Na + Cl ➔ NaCl

One sodium atom combines with one Chlorine atom to produce one molecule of sodium chloride (table salt).

Chemical reactions occur when two particles can exchange or combine their outer electrons in such a way that is energetically favorable for them. An energetically favorable state is electrically neutral, and therefore stable. In the case of table salt, Na^+ combines with Cl^- to form the electrically neutral NaCl.

Chemical reactions happen when there is an unstable situation such that when two atoms are close to each other and their electrons are of the correct type, it is more energetically favorable for them to come together and share electrons (become “bonded”) than it is for them to exist as individual, separate atoms.

In a chemical reaction three things can happen:
Atoms can change places with each other, molecules can be split into atoms, and atoms can be joined to form molecules.

Topic 3 – Chemical Reactions

Many chemical reactions require a contribution of energy before they can start. The **activation energy** is the energy that must be supplied in these cases. A match supplies the activation energy needed to start the chemical reactions that take place during combustion (rapid oxidation).[38]

Heat of Reaction

Heat (thermal energy) is always absorbed or released in a chemical reaction. **The heat of reaction** is the number of calories (or joules or B.T.U s) released or absorbed during a reaction. Every reaction will have a positive or negative heat of reaction.

Endothermic reaction: heat is absorbed

Example: a chemical cold pack that combines ammonium nitrate with water. The pack becomes cold and is used as an "ice" pack.

Exothermic reaction: Heat energy stored in the reactants is released

Example: sulphuric acid and sodium hydroxide, this acid + base reaction causes a flask to become warm.

Here is what you need to know about chemical reactions:

Solutions are mixtures with one substance (the **solute**) dissolved in another (the **solvent**). Solutions can involve solids, liquids and gases. Examples: sugar (solid solute) in coffee (liquid solvent), carbon dioxide (gas solute) and water (liquid solvent).

Solubility is the maximum amount of a solute that will dissolve in a solvent at a given temperature. Usually solubility increases with temperature, but not in the case of gases dissolved in a liquid. When gases are dissolved in a liquid, for example carbonated soft drinks, the solubility increases as the temperature is lowered. When the solubility is exceeded, the excess solute will **precipitate**, and fail to dissolve. Instead, the excess solid solute will fall to the bottom of a liquid solvent.

How fast something dissolves also depends on temperature. The kinetic theory helps explain that as a liquid is heated the molecules move around more quickly and spread apart creating more room for the molecules of a solute.

38 See Science – Module 2 – Science Development for a discussion of heat energy and how it is calculated and measured.

Unit 8 – Supplementary Topics

Topic 3 – Chemical Reactions

Ions

Ions are electrically charged atoms. Ions are unstable, and will be attracted to particles with an opposing charge. Ions are also parts of molecules that move as electrically charged groups. In a solution of an acid and water, the OH- and H+ ions separate from their parent molecules in the acid or base and go into solution.

Acid

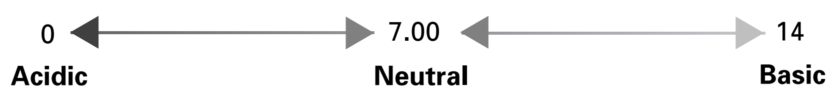
A substance that contributes hydrogen ions (H+) in a solution containing water. Acids dissolve in water and release these positively charged ions. Acids can be strong or weak. A strong acid will have more H+ ions to release, the greater concentration of H+ ions causes the solution to strongly attract any negatively charged ions it comes in contact with. A weak acid is citric acid, a strong acid is concentrated sulphuric acid. The story is the same for hydroxide ions in the case of a base with the difference that OH- ions are negatively charged.

Base

A substance that releases hydroxide ions (OH-) in a water solution

PH Scale

The pH scale measures the concentration of H+ and OH- ions. The scale ranges from 0 to 14, with the strongest acids near 0, the strongest bases near 14 and a neutral solution (equal numbers of H+ and OH-) having a value of 7 on the scale.



Salt

A compound that forms when a chemical reaction takes place between an acid and a base. Example: NaOH + HCL yields NaCl and H_2O. Sodium hydroxide (a base) combines with hydrochloric acid to produce sodium chloride (table salt) and water.

Organic Compounds

Organic compounds are compounds that have carbon atoms. Organic compounds occur in biological organisms (living systems) and usually involve bonds between carbon and hydrogen, nitrogen, or oxygen.

Hydrocarbon

A compound that is made exclusively of carbon and hydrogen. Coal and fuel oil are hydrocarbons.

Unit 8 – Supplementary Topics

Topic 3 – Chemical Reactions

Catalysts

A catalyst is a substance that must be present to make some chemical reactions possible. A catalyst is not one of the reactants, and is not changed or used up in the process of the reaction. However, without the presence of the catalyst, the reactants will not interact. The chemical reactions in living systems are often able to take place at body temperature due to the presence of catalysts called **enzymes**.

Unit 8 – Supplementary Topics

Topic 3 – Practice Exam Questions

Question 1

An exothermic reaction will:

a) give off heat.
b) absorb heat.
c) require a catalyst.
d) need activation energy.

Answer: a

Question 2

The activation energy needed to start a reaction is:

a) always greater than the energy provided by the reactants.
b) less than the energy provided by the reactants.
c) a catalyst.
d) sometimes required to start chemical reactions.

Answer: d

Question 3

An acid is dissolved in water. What happens to the pH value of the solution?

a) It will increase.
b) It will decrease.
c) It will remain the same.
d) It will hesitate.

Answer: b

Question 4

When the solubility of a solution is exceeded by a solute, what may happen?

a) The solute will need a higher temperature.
b) The reactants will need a catalyst.
c) The solute will precipitate.
d) The solution will freeze.

Answer: c

Topic 3 – Practice Exam Questions

Question 5
An acid and a base combine to produce:

a) OH- ions.
b) H+ ions.
c) a salt.
d) a mixture.

Answer: c

Question 6
If heat energy is absorbed during a chemical reaction we describe the reaction as:

a) exothermic.
b) catalytic.
c) endothermic.
d) favourable.

Answer: c

Question 7
In this reaction: Na + Cl ✇ NaCl, which reactant is negatively charged?

a) NaCl
b) Cl
c) Na
d) none are

Answer: b

Question 8
Which compound is organic?

a) CH_4OH
b) NH_4OH
c) $CaCO_3$
d) H_2O

Answer: a

Topic 3 – Practice Exam Questions

Question 9

Which chemical reactions either absorb or give off heat?

a) None do.
b) Some do.
c) All do.
d) Organic reactions do.

Answer: c

Question 10

Which best describes what happens in a chemical reaction?

a) The substances form a mixture.
b) The substances change their state.
c) Atoms combine to form molecules or molecules break apart.
d) Heat is given off.

Answer: c

Unit 8 – Supplementary Topics

Topic 4 – Alloys and Mixtures

Mixtures do not involve chemical changes, but merely combine substances by putting them physically close together. **A composite material is a mixture that combines the properties of more than one material in a new substance.** A mixture does not require a chemical change for its formation. In a mixture that produces a composite substance, one substance will be embedded in the other in order to combine the properties of each. For example, a steel belted tire, steel reinforcing steel bars in concrete, and human bones which combine calcium phosphate with living cells.

An alloy is a mixture of metals that are heated together to form a new "hybrid" metal. Many kinds of steel can be made by using heat to **fuse** metals together. Brass is an alloy of copper and zinc. The alloy is a new metal with properties that differ from its ingredients. An alloy is a mixture of metals arranged in a new pattern at the molecular level.

Many of the metal products we use everyday are formed when a mixture of molten metals are combined and then allowed to solidify. Gravity can complicate the mixing process, just as it complicates the mixing of oil and vinegar in making salad dressing. Heavier metals may sink or form clumps in a molten mixture. The creation of alloys requires attention to the mixing process.

Alloys are **mixtures of metals** with other elements – usually other metals. These mixtures are made to create properties which pure metals do not have, e.g. to make them harder or to make them more resistant to corrosion or to make it easier to work with them.

Some Examples of Alloys:

Steel this is a mixture of iron and carbon. It is stronger than iron and easier to shape and to weld. It is used in construction eg ships and vehicles.

Stainless steel is a mixture of iron, chromium, nickel, manganese and carbon. It is very strong and highly resistant to rust. It is used in places where ordinary steel would otherwise corrode, e.g. the drums of washing machines. It is also used for cookware and cutlery.

Brass is a mixture of copper and zinc. It is harder and cheaper than copper. It is also resistant to corrosion. It is used for ornamental purposes, plumbing, screws, etc.

Bronze is a mixture of copper and tin. It is hard and resistant to corrosion. It is strong and it can be cast into almost any shape. It is used for ornamental work.

Titanium alloys are mixtures of titanium, aluminium and vanadium. They are hard and highly resistant to corrosion, but most important of all, they are very light. They are used in aircraft manufacture and as components for spacecraft.

Unit 8 – Supplementary Topics

Topic 4 – Practice Exam Questions

Question 1
An alloy is different than a composite material because:

a) Its chemical properties are not composite.
b) An alloy is the result of fusion.
c) A composite material has no metal.
d) An alloy does not have chemical properties.

Answer: b

Question 2
Bone is a composite material because:

a) one substance is embedded in another.
b) bone is not alive.
c) bone is not the product of a chemical reaction.
d) bone is found in nature.

Answer: a

Question 3
An alloy has properties that are:

a) identical to the properties of its ingredients.
b) different that the properties of its ingredients.
c) dependent on the ingredient with the higher electrochemical potential.
d) dependent on the weight of the ingredients.

Answer: b

Question 4
A steel belted tire is an example of:

a) an alloy.
b) a physical change.
c) a composite mixture.
d) a symbiosis.

Answer: c

Topic 4 – Practice Exam Questions

Question 5

When two metals are mixed together in a molten form the mixing process can be complicated by:

a) the specific gravity.
b) the air pressure.
c) gravity.
d) the exothermic reaction.

Answer: c

Unit 8 – Supplementary Topics

Topic 5 – Corrosion and Oxidation

Oxidation describes the combination of an element with oxygen to form a compound. Oxidation also describes the more general process in a chemical change where a substance loses electrons and becomes more positively charged as a result. In chemical reactions, some substances donate electrons and others receive them in order to become more stable.

Oxidation numbers are used to describe the ability of a n element to join with other atoms. When electrons are lost or gained in a chemical reaction, the oxidation number of an element will change. One substance will be oxidized (gain electrons) and one will be reduced (lose electrons). Corrosion is a form of oxidation that involves the movement of electrons from a donor to a receiver with results that weaken the bonds in the donor substance.

When oxidation happens rapidly we call it combustion. A fire is rapid oxidation because oxygen is taken from the air to combine with other substances that are being burned. When oxidation happens more slowly, as in the case of iron exposed to moist air, we call it corrosion. Rust is iron oxide that forms when iron combines chemically with oxygen to form the compound we call rust. For every rust molecule, atoms of iron have been lost from the underlying iron material. This weakens iron structures, and rusts out automobile bodies.

Metal corrosion is really an electric circuit.
In corrosion there is a flow of current between negatively charged and positively charged sites in a substance. The positively charged areas are called **anodes** (they donate electrons) and the negatively charged sites are called **cathodes** (they receive electrons).

Corrosion occurs in nature and involves the oxidation of metal atoms. Corrosion weakens the binding energy between molecules in a metal.

Part of the corrosion circuit is the base metal itself; the rest of the circuit exists in an external solution that can conduct electricity. A solution that conducts electricity is called an **electrolyte.** The electrolyte must be in contact with the metal for corrosion to occur.

For example, rain on metal provides the electrolyte that conducts the electrons from one place to another. In the case of acid rain, sulphuric acid is dissolved in the rainwater making it a better electrolyte. This makes acid rain more corrosive than pure water.

Unit 8 – Supplementary Topics

Topic 5 – Corrosion and Oxidation

The Electrochemical Series

Some metals will replace other metals in a compound. For example, zinc will replace iron in a solution of iron sulphate and produce zinc sulphate ions and iron ions. The ability to do this depends on the position of a metal in the **electrochemical series.**[39] This series ranks metals in order of their ability to transfer electrons.

Corrosion Can Be Prevented

Strategies for breaking the corrosion circuit involve adding a non-conductor into the corrosion circuit or removing the electrolyte. Coatings that do not conduct electricity protect surfaces from corrosion because they prevent the transfer of electrons that would otherwise occur. This is why cars are undercoated. These coatings must be non-conductive.

Some metals have naturally oxidized surfaces that form a non-conductive coating. Stainless steel, aluminum and titanium are examples. The surfaces of these metals combine with oxygen to form a protective layer that is tough and that lasts.

A sacrificial anode can also be provided to do the job of donating electrons so that corrosion is prevented on another substance. If the material chosen as the anode (electron donor) is lower on the electrochemical series it will satisfy the demand for electrons by the surrounding corrosive material (for example sea water) before the original metal loses any electrons, and thus protect the original metal from forming a corrosive circuit. This idea is used to protect ship hulls and water tanks (e.g. by adding a block of zinc to a steel hull).

Using the same principle, a piece of steel can be plated with zinc. If the zinc coating is scratched, the zinc will corrode before the steel, thereby protecting the steel.

Apply Voltage to Reverse Current

A battery can be used to supply electrons in a corrosive circuit and reverse the corrosive flow. The battery pushes electrons back into the anode, thus preventing the donation of electrons to the cathode and causing corrosion. An application that uses this technique to reduce corrosion is in the protection of underground pipelines. The pipeline metal is protected because the corrosion is shifted to one of the terminals of the battery. The advantage is that a battery can be maintained easier than miles of pipeline.

39 Also known as the electromotive series. Metals have different electric potentials.

Topic 5 – Practice Exam Questions

Question 1
Corrosion is a form of:

a) activation energy.
b) acid base reaction.
c) oxidation.
d) electrochemical resistance.

Answer: c

Question 2
Oxidation involves a transfer of electrons that oxidizes one substance while

__________ another substance.

a) catalyzing
b) insulating
c) reducing
d) protecting

Answer: c

Question 3
The electrochemical series can help us identify which metals to use to prevent corrosion because:

a) It identifies what will work as a sacrificial anode.
b) It tells the melting point of electrolytes.
c) It tell what will oxidize first.
d) It tells what metals will corrode.

Answer: a

Question 4
Corrosion can be prevented by means of:

a) heat.
b) protective coatings.
c) good electrolytes.
d) oxidation.

Answer: b

Topic 5 – Practice Exam Questions

Question 5
What do rust and combustion have in common?

a) Both are forms of corrosion.
b) Both require heat.
c) Both are forms of oxidation.
d) Both are electrolytes.

Answer: c

Question 6
Pipelines are protected from corrosion by:

a) oxidized materials.
b) catalytic conversion.
c) applied battery voltage.
d) reverse osmosis.

Answer: c

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Appendix

Science Foundations reviews the following core requirements from the Alberta trades entrance curriculum:

Entrance Level Competencies in Science

(Numbers in parentheses indicate which Entrance Examination(s) test for this competency)

SECTION ONE: PHYSICS

A. Electricity And Magnetism Materials And Safety

Outcome: Demonstrate safe methods for the study of magnetism and electricity, identify methods for measurement and control, and apply techniques for evaluating magnetic and electrical properties of materials. (1, 2)

1. Recognize and appreciate the potential dangers involved in using sources of electrical currents; understand that household electrical currents are potentially dangerous and not a suitable source for experimentation; understand that small batteries are a relatively safe source of electricity, for experimentation and study, but that care should be taken to avoid short circuits; understand that short circuits may cause wires to heat up, as well as waste the limited amount of energy in batteries.
2. Describe and demonstrate example activities that show that electricity and magnetism are related;demonstrate that electricity can be used to create magnetism; demonstrate that a moving magnet can be used to generate electricity.
3. Demonstrate and interpret evidence of magnetic fields around magnets and around current-carrying wires, by use of iron filings or by use of one or more compasses.
4. Demonstrate that a continuous loop of conducting material is needed for an uninterrupted flow of current in a circuit.
5. Distinguish electrical conductors from insulators.
6. Recognize and demonstrate that some materials, including resistors, are partial conductors of electricity.
7. Predict the effect of placing an electrical resistance in a simple circuit.
8. Recognize that the amount of electricity we use is measured in kilowatt-hours.
9. Interpret and explain the reading on a household electrical meter and efficiency labels on electrical appliances.
10. Draw and interpret, with guidance, circuit diagrams that include symbols for switches, power sources, resistors, lights and motors.

B. Simple Circuits And Motorized Devices

Outcome: Construct simple circuits, and apply an understanding of circuits to the construction and control of motorized devices. (1, 2)

1. Identify example applications of electrical devices in the home and work environment, and classify the kinds of uses. Categories of electrical use may include such things as heating, lighting, communicating, moving, and computing.
2. Design and construct circuits that operate lights and other electrical devices.
3. Recognize the importance of switches and other control mechanisms to the design and operation of electrical devices, and identify purposes of switches in particular applications.
4. Construct and use a variety of switches.
5. Design and construct devices that use a battery-powered electric motor to produce motion.
6. Design and construct a burglar alarm.
7. Demonstrate different ways of lighting two lights from a single power source, and compare the results. Learner should recognize that wiring two bulbs in series makes both bulbs glow less brightly than if the bulbs are wired in parallel. Learners may demonstrate this knowledge operationally and do not need to use the terms series and parallel.
8. Demonstrate different ways of using two batteries to light a bulb, and compare the results. Students should recognize that wiring the batteries in series causes the bulb to glow brighter than it would if parallel wiring were used.
9. Given a design task and appropriate materials, invent and construct an electrical device that meets the task requirements.

SECTION TWO – FORCE, WORK, ENERGY AND MOTION

A. Indirect Observation Of Force

Outcome: Describe how the presence of a force can be inferred from its effects. (1, 2, 3, 4)

1. Infer the application of a force based on observed movements.
2. Describe the direction of a force.
3. Identify examples of mechanical, frictional, electrostatic, magnetic and gravitational forces.
4. Describe the effects of these forces.

B. Measurement And Comparison Of Forces

Outcome: Identify the various ways forces can be compared and measured. (1, 2, 3, 4)

1. Identify appropriate means for detection and measurement of different kinds of forces.
2. Identify and describe the principles on which various kinds of force measurement devices are based.
3. Recognize and use units of force.

C. Gravitational Force

Outcome: Describe how the weight of an object (the gravitational force on it) can vary according to the gravitational field in which the weight of the object is measured. (1, 2, 3, 4)

1. Recognize and describe the effects of gravitational force.
2. Describe changes in gravitational force that result from a change of position in space.

D. Mass

Outcome: Explain the concept of mass as a constant characteristic for an object, regardless of its gravitational frame of reference. (1, 2, 3, 4)

1. Identify appropriate means of measuring mass.
2. Distinguish between mass and weight.
3. Recognize and use units of mass.
4. Identify differences in scientific and everyday approaches to identifying the mass of an object.

E. Relative Motion Of Objects

Outcome: Describe how the relative motion of objects is affected by forces that act between those objects. Motion of objects can be interpreted or predicted based on knowledge of forces. (1, 2, 3, 4)

1. Describe and predict the pathways of moving objects.
2. Describe and predict changes in movement that result from the application of force.
3. Identify evidence and effects of friction.
4. Identify factors that affect friction.
5. Describe methods of increasing or decreasing frictional forces.
6. Describe movement of materials in space environments.
7. Identify action–reaction pairs.
8. Identify forces in action–reaction pairs.

SECTION THREE – STATICS (STRUCTURES)

A. Structural Design

Outcome: Identify structural design in both natural and manufactured materials. (1, 2, 3, 4, 5)

1. Recognize stems and skeletons as structural components of living things.
2. Infer the function of plant and animal structures.
3. Identify patterns of organization in manufactured materials.
4. Recognize similarities between natural and manufactured structures.

B. Purpose Of Structures

Outcome: Describe how structures are designed in response to human needs, purposes and aspirations. (1, 2, 3, 4, 5)

1. Infer and describe the function of structures.
2. Recognize examples of ways in which human aspirations have been achieved through the design and construction of structures.

C. Alternative Design Approaches

Outcome: Explain how alternative approaches are considered in the design of structures. (1, 2, 3, 4, 5)

1. Recognize common approaches to the design of bridges and buildings
2. Distinguish between rigid and non-rigid structures.
3. Infer the purpose of components in structures.
4. Recognize examples of various materials being used for the same design function.
5. Recognize the relationship between choice of materials and the design used.

D. Material Properties And Structural Principles

Outcome: Explain the contribution of knowledge of materials and structural principles to the design process. (1, 2, 3, 4, 5)

1. Describe processes for testing the strength of materials.
2. Measure and compare the strength of materials.
3. Distinguish between tensile and compressive forces.
4. Identify points of tension and compression in a structure.
5. Describe the potential effects of tensile and compressive forces on different components of a structure.
6. Recognize the role of ties and linkages in adding to the overall strength and stability of a structure.
7. Describe the effects of the use of different shapes on the strength and stability of materials.
8. Identify the function of hinged components in natural and manufactured materials.
9. Describe the function of different kinds of hinged components.

E. Selection Of Materials And Design

Outcome: Identify the factors affecting the selection of materials and design. (1, 2, 3, 4, 5)

1. Identify environmental implications of design decisions.
2. Recognize costs to be considered in design decisions.
3. Recognize the need to balance functional, esthetic, economic and environmental concerns.

F. Accommodating Design For Specialized Needs And Environmental Conditions

Outcome: Identify design accommodations for specialized needs or environmental conditions. (1, 2, 3, 4, 5)

1. Identify differences in requirements of structures built on earth and in space.
2. Recognize similarities and differences in approaches to construction used on earth and in space.

SECTION FOUR – DYNAMICS (MACHINES)

A. Wheels, Gears And Levers

Outcome: Demonstrate a practical understanding of wheels, gears and levers by constructing devices in which energy is transferred to produce motion. (1, 2)

1. Explain how rollers can be used to move an object, and demonstrate the use of rollers in a practical situation.
2. Compare the wheel and the roller, and identify examples where each is used.
3. Construct devices that use wheels and axles and demonstrate and describe their use in model vehicles, pulley systems, and gear systems.
4. Construct and explain the operation of a drive system that uses one or more of the following: wheel-to-wheel contact, a belt or elastic, a chain, cogs or gears.
5. Construct and explain the operation of a drive system that transfers motion from one shaft to a second shaft, where the second shaft is parallel to the first, at a 90° angle to the first. Demonstrate ways to use a lever that: applies a small force to create a large force, applies a small movement to create a large movement.
6. Predict how changes in the size of a lever or the position of the fulcrum will affect the forces and movements involved.
7. Construct models of levers and explain how levers are involved in such devices as: teeter-totters, scissors, pliers, pry bars, tongs, nutcrackers, fishing rods, and wheelbarrows.

B. Construction Of A Mechanical Device

Outcome: Construct a mechanical device for a designated purpose, using materials and design suggestions provided. (1, 2)

1. Design and construct devices and vehicles that move or have moving parts – linkages, wheels and axles.
2. Use simple forces to power or propel a device.
3. Design and construct devices and vehicles that employ energy-storing or energy-consuming components that will cause motion.
4. Recognize the need for control in mechanical devices, and apply control mechanisms where necessary.
5. Compare two designs, identifying the relative strengths and weaknesses of each.
6. Identify steps to be used in constructing a device or vehicle, and work cooperatively with other students to construct the device or vehicle.
7. Design and construct several different models of a device and evaluate each model, working cooperatively with other students.

C. Understanding Mechanical Devices

Outcome: Explain how mechanical devices are systems made up of subsystems and components. (1, 2, 3, 4, 5)

1. Identify parts or components of some simple mechanical devices.
2. Identify parts of a mechanical device that work together as a subsystem.

D. Mechanical Systems

Outcome: Explain how mechanical systems are designed to perform one or more functions. (1, 2, 3, 4, 5)

1. Identify the functions of some common mechanical devices.
2. Identify the contribution of subsystems to the overall function of a mechanical device. (drill, pump, clock, car)
3. Identify the contribution of individual components to the function of a mechanical device.
4. Identify components that operate as simple machines within a mechanical device.
5. Describe the operation and application of simple machines.
6. Describe the bicycle as an example of a mechanical system.
7. Compare alternative designs of a mechanical device.

SECTION FIVE – HEAT AND TEMPERATURE

A. Temperature

Outcome: Explain how the temperature of a substance provides a measure of its relative hotness or coldness compared with an arbitrary temperature scale. (1, 2)

1. Infer temperatures based on physical properties of materials.
2. Describe temperatures of materials in descriptive, non-quantitative terms.

B. Temperature Measurement

Outcome: Describe how the need for precision in temperature measurement has led to the development of thermometers and temperature scales. (1, 2)

1. Infer the need for precise temperature measurement in given applications.
2. Infer the accuracy of a temperature-measuring device.
3. Describe the Celsius temperature scale and identify significant temperatures on that scale Calibrate a thermometer.
4. Estimate temperatures of materials in degrees Celsius.

C. Expansion and Contraction

Outcome: Describe how thermal expansion and contraction provides the basis for thermometry. (1, 2)

1. Predict changes in materials due to heating and cooling.
2. Compare the amount of thermal expansion for different materials.
3. Describe the components of liquid thermometers and the functions of those components.
4. Describe the operation of liquid and air thermometers in relation to the design of the devices and the principles by which they operate.
5. Describe the operation of various specialized thermometers in relation to their design and the principles by which they operate.

D. Heat

Outcome: Explain the scientific concept of heat as used to describe the thermal energy in a material. (1, 2)

1. Recognize that when the temperature of a substance increases, the substance has absorbed heat; when the temperature of a substance decreases, the substance has lost heat.
2. Estimate final temperature of a mixture of equal quantities of a liquid of different temperatures.
3. Recognize that the final temperature of liquid mixtures is affected by the mass and heat-related characteristics of the original components.
4. Distinguish between the concept of temperature and the concept of heat.
5. Describe temperature and heat in terms of particle motion.

E. Sources Of Heat Energy

Outcome: Identify Sources Of Heat Energy. (1, 2)

1. Identify sources and methods of generating heat.
2. Identify advantages and disadvantages of the use of various heat sources.
3. Recognize that different fuels may have different heat energy content.
4. Compare the energy content of different fuels.
5. Compare energy content of different foods.

SECTION SIX – FLUIDS AND PRESSURE

A. Properties Of Air

Outcome: Describe properties of air and the interactions of air with objects in flight. (1, 2)

1. Provide evidence that air takes up space and exerts pressure, and identify examples of these properties in everyday applications.
2. Provide evidence that air is a fluid and is capable of being compressed, and identify examples of these properties in everyday applications.
3. Describe and demonstrate instances in which air movement across a surface results in lift – Bernoulli's principle.
4. Recognize that in order for devices or living things to fly, they must have sufficient lift to overcome the downward force of gravity.
5. Identify adaptations that enable birds and insects to fly.
6. Describe the means of propulsion for flying animals and for aircraft.
7. Recognize that streamlining reduces drag, and predict the effects of specific design changes on the drag of a model aircraft or aircraft components.
8. Recognize that air is composed of different gases, and identify evidence for different gases.

Appendix

SECTION SEVEN – OPTICS AND LIGHT

A. Light

Outcome: Identify sources of light, describe the interaction of light with different materials, and infer the pathway of a light beam. (1, 2, 3, 4)

1. Recognize that bright lights can damage eyes and that one should not look at the Sun – either directly or with binoculars or telescopes.
2. Identify a wide range of sources of light, including the Sun, various forms of electric lights, flames, and materials that glow.
3. Distinguish objects that emit their own light from those that require an external source of light in order to be seen.
4. Demonstrate that light travels outward from a source and continues unless blocked by an opaque material.
5. Describe changes in the size and location of Sun shadows during the day – early morning, to midday, to late afternoon.
6. Recognize that opaque materials cast shadows, and predict changes in the size and location of shadows resulting from the movement of a light source or from the movement of a shade-casting object.
7. Distinguish transparent materials from opaque materials by determining if light passes through them and by examining their shadows.
8. Classify materials as transparent, translucent or opaque.
9. Recognize that light can be reflected and that shiny surfaces such as polished metals and mirrors, are good reflectors.
10. Recognize that light can be bent (refracted) and that such objects as aquaria, prisms and lenses can be used to show that light beams can be bent.
11. Recognize that light can be broken into colours and that different colours of light can be combined to form a new colour.
12. Demonstrate the ability to use a variety of optical devices, describe how they are used, and describe their general structure.