NWT Apprenticeship Support Materials

Science

Reading Comprehension

Math

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

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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Table of Contents

Module 2 – Science Development

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. Science Development is the second of 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.

Math Foundations Are Required

All trades entrance candidates are expected to understand the competencies covered in the four modules of the math core 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 trade will be assessed.**

Competency:

an ability that can be demonstrated

1 See Appendix A: trades entrance requirements from the Alberta trades entrance curriculum. For a more detailed introduction see "Science Competencies for Trades Entrance" in the introduction for Science – Module 1 – Science Foundations.

Introduction

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. See your apprenticeship advisor to learn which exam level is required for your choice of a trade, then use the chart below to decide which category you are in:

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

This diagram shows how each module of the curriculum relates to an exam level that builds on earlier modules.

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.

Organization of Content

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.

This diagram shows how each module of the curriculum relates to an exam category that builds on earlier modules.

Introduction

Example:

An oil burner mechanic candidate needs to prepare for Exam Levels 3 and 4. He will study Science – Module 1 – Science Foundations, and Science – Module 2 – Science Development. An electronics technician candidate needs to study Science – Module 3 – Science Special Topics, in addition to Science 1 and 2.

The three sections of the curriculum build on each other. For example, the material in Science – Module 2 – Science Development on heat transfer assumes that you already know the foundation material on temperature and heat in Module 1. In Science – 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.

Science – Module 1 – Foundations
Science Foundations (required for all Exam Levels)

Science – Module 2 – Science Development
Science Development (requires Module 1 and adds material required for Exam Levels 3 and 4)

Science – Module 3 – Special Topics
Science 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 modules cover the material that will be on your trades entrance exam.[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 preparing for exam levels 3 and 4, try some questions at the end of Science – Module 2 – Science Development. If you get the score you want, you should get a similar score on the exam for trades that require exam levels 3 and 4.

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.

2 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 4, because a roofer who only needs level 3 competencies according to one grid, may be tested on level 4 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

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.

Organization of Topics in Each Module

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. 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 modules that lead up to it. The competencies are covered in a logical order from simple to more complex concepts and problems. Each module 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, density is introduced before the topic of 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.

When several terms are used for the same thing, the expression "aka," meaning "also known as" is sometimes used to reinforce useful equivalent meanings.

Unit 1

Matter – Density, Specific Gravity and Pressure

Some important properties of matter were reviewed in Science – Module 1 – Science Foundations. Three more properties of matter are useful in the trades:

What you need to know:

1. **Density** = Mass / Volume
2. **Specific Gravity** = Density of Substance / Density of Water
3. **Pressure** = Force / Area

Density is mass divided by volume, specific gravity compares the density of solids and liquids to the density of water, and the density of gases to the density of hydrogen. The ratio given by this comparison is the specific gravity of the substance.

In each case you must remember to use correct units. Density divides mass (or weight) units by volume units. Volume units are always cubic and represent the product of three dimensions. Area units are always squared, and represent the product of two dimensions. Mass units are usually given as weight units (pounds) at sea level in the imperial measurement system.[3]

In the topics that follow you will see how density can change when the mass or the volume of a substance changes. For example, when a submarine changes its density by filling ballast tanks, or when a fixed amount of a gas changes its density when it is heated and occupies a larger volume, for example in a hotter than air balloon.

3 See Science – Module 1, Unit 1 – Matter and Math – Module 4 – Measuring Time, Shapes, and Space.

Unit 1 – Matter

Topic 1 – Density

Mass and Density

The distinction between weight and mass was discussed in Science – Module 1 – Science Foundations. Here we use the idea of mass and review the main points you need to keep in mind for the exam. Several practice exam questions follow that apply the concepts of mass and density.

Density = $\mathbf{\frac{M}{V}}$

Density equals mass divided by volume. Density is the value of the ratio of mass to volume. We can measure the mass and volume of gases, liquids and solids. We can calculate the density of something if we know its mass and volume. Density allows us to compare how much matter is in the same unit of volume for different substances. For example, one cubic foot of wood will be less dense than one cubic foot of iron. Units of density include pounds per cubic foot in the imperial system, and grams per cubic centimetre in the S.I. system.

You Need to Remember:

1. **Weight measures the force exerted by gravity on a mass, and objects with the same mass will have the same weight on the earth's surface.**
2. One **Newton (N)** equals the **force** of the earth's gravity on 100 grams.

   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. It takes .01 Newton to lift one cubic millimetre of water. It takes ten Newtons to lift one kilogram.
3. **Units of weight are units of force** and

   The Newton (N) is an S.I. unit of weight. 4.448 N = 1 pound.

   The pound (lb) is an Imperial unit of weight.

If we know the values of any two of the variables in the density formula, we can find the third.[4] For example, if we know the density of a substance and the volume it occupies, we can calculate the mass (weight).

[4] See Math – Module 3 – Variables and Equations.

Unit 1 – Matter

Topic 1 – Density

Sample Problem

1. The density of a substance is 5.6 kg/m^3. The substance occupies 3m^3. What is the mass?

   We need to find the value of M and express our answer in Kg. D = 5.6kg/m^3, and V = 3m^3

   D = M/V, therefore M = DV

   M = 5.6 kg / m^3 x 3m^3

   M = 16.8 kg (notice that m^3 / m^3 cancel out, i.e. equal one, and leave only the mass unit of kilograms in the answer. Notice also that this mass will weigh 2.2x 16.8 = about 37 pounds)

For Greater Clarity:
Density is a number that measures how much matter is in a unit of volume. Mass units are divided by volume units to arrive at density. The S.I. units for density are kg / m^3, or g / cm^3, and the imperial units for density are lbs. / $ft.^3$ The density of substances can vary greatly. Lead weighs 11,000 kg per cubic meter, while aluminum weighs only 2,700 Kg per cubic meter. Water weighs 1000kg / m^3 at 40 celsius.

Density can also be calculated for liquids and gases. For example, the density of pure water is 1000 kg / m^3, and the density of seawater is 1030kg / m^3. The density of helium is 0.2 kg / m^3 and the density of air is 1.3kg / m^3.

2. What is the density of alcohol (ethanol) if 5,200 kg of alcohol occupy 6.5 cubic metres?

   Recall the formula that defines density:

   Density = mass/volume

   We know that mass can be measured as weight at sea level. We set up the equation using 5200Kg for the mass and solve for density.

   D = 5200 kg / 6.5 m^3 = 800 kg / m^3

   The density of alcohol is 800 kilograms per cubic metre.

Topic 1 – Density

3. A quantity of gold weighs 57 grams. If we know that the density of gold is 19.0 g / cm^3, what will be the volume taken by 57 grams of gold?

   We need to know the volume that 57 grams of gold will occupy. Our answer will be in cubic centimetres. Because we know the density of gold in cubic centimetres, we know that 19 grams of gold takes up a volume of one cubic centimetre. A Proportion can express the relationship between the volume of 19 grams of gold and the volume of 57 grams of gold.

   $$\frac{19}{1} = \frac{57}{V}$$

   $V = 57 / 19 = 3\ cm^3$

   57 grams of gold will occupy 3 cubic centimetres.

In general, densities for different amounts **of the same substance** can be compared with this formula:

$$\frac{Mass_1}{Volume_1} = \frac{Mass_2}{Volume_2}$$

If we know any three of these quantities, we can solve an equation for the fourth. Any amount of mass divided by the volume it occupies will give the number for the density of the substance when the ratio is reduced to lowest terms.[5]

[5] See Math – Module 1, Unit 1, Topic 2 – Fractions and Unit 3, Topic 8 – Ratios.

Topic 1 – Practice Questions

Question 1
What is the density of 4 cubic metres of iron that weighs 31,200Kg?

a) 14,600 kg / m^3
b) 7800 kg / m^3
c) 124,800 kg / m^3
d) 1600 kg / m^3

Answer: b

Question 2
280.8 lb of water takes up 4.5 cubic feet of space. What is the density of water?

a) 1263.6 lb. / cu. ft.
b) 680 lb. /cu. ft.
c) 62.4 lb. /cu. ft.
d) 1030 kg / m^3

Answer: c

Question 3
The density of iron is 7800 kg / m^3. How much volume will be needed to contain 5600 kg of iron?

a) 45 m^3
b) .72 m^3
c) 2 m^3
d) .280 m^3

Answer: b

Question 4
Zinc has a density of 7.1 g / cm^3. how much volume will a 20 Kg piece of zinc occupy?

a) 142 cm^3
b) 2817 cm^3
c) .35 cm^3
d) 14.2 m^3

Answer: b

Topic 1 – Practice Questions

Question 5

If the same mass is made to occupy a larger volume, what will happen to its density?

a) It will increase
b) It will decrease
c) It will remain the same
d) It will depend on temperature

Answer: b

Question 6

The more mass that is contained in a given unit of volume the greater the density will be.

a) true
b) false
c) depends on the weight
d) depends on the temperature

Answer: a

Unit 1 – Matter

Topic 2 – Specific Gravity

The specific gravity of fresh water is one. **Specific gravity is a number that allows us to compare relative densities by using the specific gravity of water as a standard.**[6] The density of fresh water is used as a standard to compare the densities of other substances.

> **Specific gravity is a number** that compares the density of a substance with the density of water at 4° Centigrade at standard pressure (1 atmosphere). When we divide the denominator into the numerator, the resulting decimal number tells how many times more or less dense than water a certain substance is.

By definition the specific gravity of water is simply one – with no units attached.[7] In contrast, density is a number with units, namely unit of mass per unit of volume.

For example, a substance with a specific gravity of 3, is three times more dense

> **Recall that 1 ml = 1 cm^3 = 1 gram. The density of water is 1g / ml by the definition of density.**

> Specific gravity of water = $\frac{1\text{g/ml}}{1\text{g/ml}} = 1$
>
> The units cancel out in a ratio that compares identical kinds of units. **Specific gravity is a dimensionless number.**
>
> Therefore:
>
> **Specific gravity of any substance = its density in gm/cm^3 divided by the density of water.**
>
> Example:
>
> Mercury (Hg)
>
> Density = 13.6 g/cm^3
>
> specific gravity = $\frac{13.6\text{ g/cm}^3}{1\text{ g/cm}^3} = 13.6$

6 See Math – Module 4 – Measuring Time, Shape and Spaces, also Science – Module 1 – Unit 2, Topic 1 – Atmospheric Pressure on standard temperature and pressure.

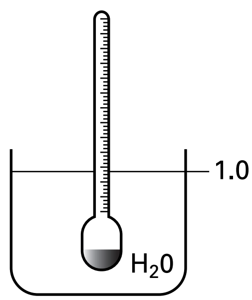
7 Specific gravity is a scalar quantity. See Science – Module 3 – Special Topics for a discussion of scalar vs. vector quantities. Also see Math – Module 5 – Special Topics for more on vectors.

Topic 2 – Specific Gravity

> **Remember**: The higher the specific gravity, the more dense the substance is. A Specific Gravity greater than one means a substance is more dense than water and will sink in water.

than water. This would mean that it would take three units of volume of water to equal the weight of one unit of volume of the more dense substance. For example, it takes 13.6 ounces of water to equal the weight of one ounce of mercury.

Hydrometers measure the density of liquids relative to the density of water, in other words they **measure specific gravity**. A hydrometer is a hollow glass tube weighted at one end that will partly sink in pure water. A scale is marked on the side and the tube is placed in a liquid and allowed to float, rise, or sink. The hydrometer uses the buoyancy of a known weight in water to make the comparisons. In pure water the hydrometer will float at a line marked 1.000. In seawater, which is about 11% more dense than fresh water, the waterline will touch the hydrometer at the 1.11 mark.



Calibrating a Hydrometer

A hydrometer is calibrated by marking the place where the pure water line touches the floating and weighted glass cylinder after it settles and reaches equilibrium. The line is marked 1.000. If this hydrometer is placed in a more dense liquid, it will float higher, and if placed in a less dense fluid it will sink either partly or completely. The line indicated by the liquid's surface will give the specific gravity of the liquid.

For example, a hydrometer that is 30 cm long, with a mass of 50 grams and a volume of 80 cm^3 will have a density of 50/80 = .625 gm/cm^3. The hydrometer will float because it is less dense than water which has a density of 1.00. How high will it float? By multiplying the density times the length of the hydrometer we find that 18.75 cm will be submerged.[8] This is where the 1.00 mark will be. This hydrometer will float and sit still when 62.5% of its volume is submerged. This spot is located 18.75 cm from the bottom of the hydrometer. 11.25 cm will be above the water line. (i.e. 30 cm - 18.75 cm)

8 See the discussion of buoyancy and flotation in Unit 2, Topic 2 – Pressure and Buoyancy. Note the section on density ratios and the conditions that allow an object to float. The hydrometer has a uniform circular cross sectional area. This allows us to calculate depth as a function of density.

Topic 2 – Specific Gravity

The lines showing specific gravity can now be set at a convenient interval. If the density of a liquid is 10% greater than water, the hydrometer will rise 10% of its length or 0.3 cm in this example. The value 1.10 will be marked at 18.75 + 0.3 = 19.03 cm from the bottom of the hydrometer. Other values showing changes of 10% are marked by adding and subtracting 0.3 cm from the line marked 1.00. For example, a liquid that is 30% more dense than water will cause this hydrometer to settle at the 1.30 line which will be 18.75 + 0.9 = 19.65 cm from the bottom of the hydrometer.

Hydrometers Test Antifreeze Concentration

In automobile radiators, ethylene glycol (antifreeze) is added to water to decrease the freezing point of the resulting solution. Antifreeze is more dense than water and therefore has a higher specific gravity. The strength (ratio of antifreeze to water) in the radiator can be measured by the hydrometer scale. The more antifreeze, the higher the hydrometer will float, and vice versa.[9]

Sample Problems

1. The specific gravity of silver is 10.50. How many times more dense is silver than water?

   By the definition of specific gravity for water = 1, we know that we can compare the specific gravity of any substance to that of water. Silver is 10.5 compared to one. Silver is ten and one half times as dense as water.

2. Salt has a specific gravity of 2.16, and cork has a specific gravity of 0.25. Which substance has greater density? How many times denser than water is the denser substance?

   The higher the number, the more dense a substance is. 2.16 is larger than 0.25, therefore salt is more than 8 times as dense as cork, and cork is only one fourth as dense as water. Salt is 2.16 times denser than water.

3. A hydrometer is used to measure the strength of antifreeze in a car battery. The reading is steady at one. What does this tell us about the strength of the mixture?

   This tells us that the mixture is entirely water. If there were any antifreeze present, the hydrometer would rise and give a reading greater than one in the more dense solution created by the antifreeze mixed with the water.

9 Review Unit 2: fluids, for a discussion of buoyancy and flotation principles linked to density.

Topic 2 – Practice Questions

Question 1

A hydrometer sinks in a liquid below the line where it would float in pure water. This indicates that the liquid:

a) is more dense than water.
b) has a higher specific gravity than water.
c) is less dense than water.
d) is antifreeze.

Answer: c

Question 2

The specific gravity of fresh water is:

a) less than one.
b) equal to one.
c) greater than one.
d) never equal to one.

Answer: b

Question 3

The difference between the specific gravity of fresh water and sea water is found by:

a) comparing their weights.
b) comparing their volumes.
c) comparing their densities.
d) adding their specific gravities.

Answer: c

Topic 3 – Friction

Friction is a force that resists motion where there are surfaces in contact. The force of friction has to be overcome for an object to move. Friction is the force that opposes an applied force. When a body is in motion on a surface, or in contact with other substances (fluids), friction is responsible for slowing the object down. We can say that the **energy of motion is dissipated** by the opposing force of friction.

Friction is also found in fluids and gases, but for trades entrance 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.[10] 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.

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 Work

Friction is a force that can be applied to an object over a distance, and the force of friction can be related to the work required to overcome it.

10 Inertia, or resistance to motion, is a property of mass, and will also be involved. Friction combined with the force needed to overcome inertia gives the complete picture. See Science – Module 3 – Special Topics for a discussion of Newton's first law and inertia.

Topic 3 – Friction

Work done to oppose force of friction (W_f)= force of friction (F_f) x friction distance (d_f) (also called the effort distance)

$W_f = F_f \times d_f$ and therefore,

$$F_f = \frac{W_f}{d_f}$$

The friction distance (or effort distance) is the distance over which the force of friction will apply. The force of friction is the force that must be applied to an object until it starts to move. This is called the force of **static friction**.

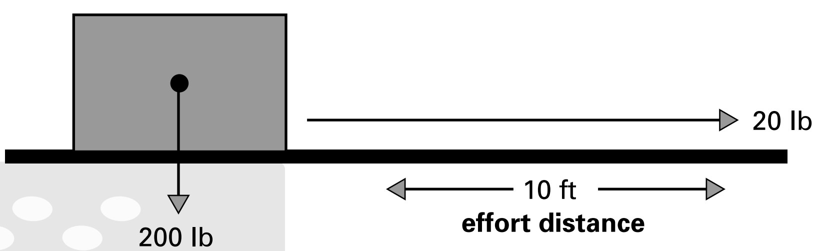
When moving an object horizontally, the weight of the object is not part of the calculation of the work that must be done to move the object. Only the force needed to overcome friction is involved.

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.

Sample problem



What is the work done against friction in this situation?

We know that the work done to move the object 10 feet horizontally by applying a force of 20 lb. equals the work done against friction. If we were to push this object up an inclined plane, additional work beyond what is needed to overcome the force of friction would have to be done because we would be lifting the object (changing its height) as well as pushing it (changing only its horizontal location).

However, in our horizontal situation no work is done to oppose the force of gravity because no lifting is involved. Work must only be done to overcome the force of friction for motion to occur.

Topic 3 – Friction

The weight of the object is not involved in calculating the work done to move it on a horizontal surface. The force of friction = the force of application = 20lb. 20lb is the input force or effort force. The distance over which the force of friction operates is equal to the distance that the object will travel when this force is applied. This distance is the same for both the effort distance (input distance) and the resistance distance (output distance). The effort distance equals the friction distance in this situation.[11]

The work done against friction = Force of friction x distance of friction

Work done against friction = 20lb x 10 ft. = 200 ft.lb

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.

Optional Topic:

Coefficients of static friction and kinetic (sliding) friction are numbers in a proportion that describe how much applied force (or effort force) is needed to overcome the maximum force of friction (Newtons) between specific materials in contact with each other before one will start to slide over the other.

Coefficients of friction (μ) can be found in tables. The symbol μ (greek letter "mu") has a higher value for static friction than sliding (kinetic) friction.
N = the load in Newtons, μ = the coefficient of friction, and f = the maximum force of friction that must be overcome before motion begins.

Static friction	Kinetic friction
$f_s = \mu_s N$	$f_k = \mu_k N$

For example, wood on wood has a static friction coefficient of μ= .58, and glass on glass has μ = 1.94. More than three times as much force is needed to start glass on glass moving than wood on wood.

Generally it takes more force to start an object moving than to keep it moving. **Static friction is generally greater than kinetic friction.** The coefficient of static friction for two materials in contact will be higher than the coefficient for moving friction between the same materials.

Once we know the magnitude (size) of the load we can multiply by the coefficient for static friction to determine how much force will be needed to oppose static friction and start the object moving. This quantity of Newtons will have to be exceeded before the applied force will start to move an object made of one of the materials over the other.

Coefficients of kinetic friction are numbers that describe the force needed to keep an object moving on a surface after it has begun to move.

[11] This is because the load and normal force are the same (N = mg). On an inclined plane the normal force = N = mg cos u.

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. For example, μ_s = .76 for dry steel on steel, and .01 – .23 for lubricated steel on steel. Similarly, for sliding friction, μ_k = .42 for steel moving on steel, and .03 – .11 for lubricated steel on steel.

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.

Topic 3 – Practice Questions

Question 1

What is the force of friction if it takes 200 foot pounds of work to move an object 10 feet on a horizontal surface?

a) 10 lb
b) 20 lb
c) 30 lb
d) 2000 lb

Answer: b

Question 2

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 3

The coefficients 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

Unit 2

Fluids (Liquids and Gases)

Gases and liquids are fluids. Recall from Science Foundations that gas molecules are relatively far apart and free to move.[12] In contrast, liquids have molecules that are about ten times closer together. An important property of a liquid is its incompressibility. A gas will occupy less volume under pressure, while a liquid will not. **A force applied to a liquid in a closed space will be transferred to all points, both within the liquid and to the sides of the container, while a gas will compress into a smaller space.**

Air in a brake line makes the pedal “spongy” because the gas in the line is being compressed by the applied force before the liquid transfers force to the brake cylinders. In a gas cylinder connected to a piston in a shock absorber, the compressibility of the gas is useful because it provides a cushioning effect. Brake systems require a non-compressible fluid, but shock absorbers require a compressible fluid (i.e. a gas). A fluid system combines a source of pressure with valves and pistons to do work. **Hydraulic systems are fluid systems.**

12 See Science – Module 1, Unit 1, Topic 1 – States of Matter. The average space between molecules in a gas is ten times greater than in a liquid or solid.

Valves and Pumps

Fluid movement can be controlled by means of pumps and valves. Review the description of pumps given in Science Foundations.[13] Fluid systems can be found in living things. The circulatory system transports nutrients by means of a pump, the heart. The heart maintains a range of acceptable blood pressures. The heart muscle contracts to apply pressure to a fluid in a chamber that opens a one way valve and transports blood. The heart has four chambers and a series of one way valves that make sure the blood flows in the right direction. A one way valve opens only when pressure is applied to one side of the valve. Two way and three way valves can be designed to open at different pressures and in different directions.

A fluid system will have a reservoir of fluid that is moved by a combination of gravity, and pressure supplied by mechanical force. For example, a fan shaped blade can be propelled by an electric motor to move water up to a higher point in a fluid system. Gravity will then allow the fluid to flow downward and do work, for example by turning a turbine.

[13] Review Science – Module 1, Unit 1, Topic 3 – Friction.

Unit 2 – Fluids (Liquids and Gases)

Topic 1 – Viscosity

Viscosity refers to the thickness of a Fluid (liquid or gas) at a given temperature. **Viscosity is internal friction**. How fast a liquid pours is an indication of its viscosity. Viscosity determines the rate of flow. All liquids have forces of friction between their molecules and between their molecules and the surfaces they contact that resist motion. **This is why pressure is need to keep a liquid flowing in a horizontal pipeline.** If there were no viscosity, a fluid would continue in horizontal motion once it started to move. The same is true for solids.[14]

Higher viscosity means slower flowing. Thicker fluids have more internal friction to overcome before they will flow. Oils are graded according to their viscosity. Viscosity is expressed by the number or "weight" of the oil. The higher the number the thicker it is and the slower it pours. For example, 30 weight oil pours more slowly than 20 weight oil at the same temperature. Viscosity is determined at a given temperature and standard pressure (1 atmosphere).

Viscosity is one of the important factors that determine what a lubricant will do. Viscosity is measured by viscometers. **A Seybolt viscometer** is a standard instrument that measures the time for oil to flow into a receiving flask under standardized conditions.

Temperature Affects Viscosity

The higher the temperature of a liquid the less the viscosity. As syrup heats up it pours more quickly and becomes "thinner". With gases, the reverse is true. **A gas will flow more slower when heated.**

SAE

The Society of Automotive Engineers (SAE) created a numbering system for oils based on Seybolt universal seconds of flow time. Thick oils flow slowly and have high numbers. For example 30 weight oil will flow more slowly than 20 weight oil at the same temperature and pressure. **The weight of the oil is chosen for the flow rate desired at a certain temperature and pressure.** "W" after the SAE number means "winter". These oils are used in colder conditions.

[14] See Science – Module 1, Unit 1, Topic 5 – Force and Motion.

Unit 2 – Fluids (Liquids and Gases)

Topic 1 – Practice Questions

Question 1

Viscosity refers to:

a) the temperature when an oil flows.
b) the time it takes 1 litre of oil to flow.
c) the liquid stage.
d) the thickness of a liquid.

Answer: d

Question 2

Which oil will flow more quickly at 210°F?

a) SAE 10W
b) SAE 30
c) SAE 20-40
d) SAE 20

Answer: a

Question 3

The SAE number is a (an):

a) index of flows.
b) viscosity number.
c) oil brand name.
d) winter rate.

Answer: b

Question 4

Viscosity is due to:

a) the density of a fluid.
b) the age of a liquid.
c) the internal friction of a fluid.
d) the volume of a container.

Answer: c

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Pressure and Buoyancy

Pressure is a measurement of force on an area. Pressure is expressed in pounds per square inch, or metric units of mass per unit of area.

Pressure Equals Force Divided by Area

$$P = \frac{F}{A}$$

If you weigh 60 kilograms, gravity attracts you to the area covered by your shoes with a pressure that can be measured per square centimetre. How much of your weight will "press down" on each square centimetre under your shoes? Find the answer by dividing your weight by the area (500cm2) covered by your shoes.

Pressure = $\frac{\text{weight of object}}{\text{Area}}$ = 60 kg / 500 cm^2 = .12 kg per square centimetre, or 1.179 N/cm^2.

Note:
Here the downward force is equal to the weight of a person.

Weight = mass x g.

g = 9.8m/s^2 , the constant force due to gravity at the earth's surface.
60kg x g = 588 Newtons.

This force divided by 500 cm^2 = 1.179 N/cm^2. Use this example to reinforce your understanding of the relationship between metric units for mass (the kilogram) and the measurement of weight (a force) in the SI system using Newtons. See Newton's second law in Science Special Topics for a more complete discussion of weight and mass.

In the case of an object in a liquid there are forces coming from all directions, but they are not all equal. There are three forces to consider. The force from above, the lateral force from the sides and front and rear, and the force from below.

In a liquid, **Pressure** is force on a unit of area that increases with depth.

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Pressure and Buoyancy

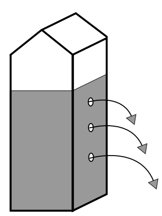
The side (or lateral) forces are equal at the same depth no matter what the shape of the object is. Even if the object is near the edge of a pool, the side pressures at the same depth will not change. **Pressure due to a liquid (i.e. exerted by a liquid) depends only on depth.**

The buoyant force equals the weight of the volume of fluid that is displaced.

Buoyant force acts in a supportive, or upward direction on objects that are submerged or floating.

The pressure at the bottom of a submerged object will always be greater than the pressure from above due to the greater depth at its lower end. Due to this difference, the difference in pressure from above and from below on an object is always in favour of a net upward buoyant force. Whether this force is enough to lift an object to the surface will depend on the density of the object.

To understand this principle keep the idea of force in mind. **Pressure is a force that increases with depth**. An easy way to see this fact demonstrated, is to fill a milk carton with water and put three holes vertically down the side an equal distance apart. You will see the stream from the bottom hole exiting further than the streams from the higher holes. This is due to the greater pressure at the greater depth. An object submerged in the carton would have greater pressure on its lower end. Pressure only depends on depth.



Here you can see that the water comes farthest out of the lowest hole because there is more pressure acting above it. If the pressure were equal at any depth, the water would spurt out of each hole the same distance.

Submerged objects feel lighter

A 500 kilogram outboard motor is at the bottom of Prelude Lake. It has a volume of .1 cubic metres. How much will the motor appear to weigh while it is being lifted and is still submerged?

The buoyant force acting upward on the motor will be equal to the weight of water that would be contained by its volume, i.e. the weight of .1 cubic metre of water. The force needed to lift the motor will equal the weight of the motor minus this buoyant force. One cubic metre of water weighs 1000 kg, so .1 cubic metre will weigh 100 kg. Therefore 500-100 equals the apparent weight of the submerged motor. It will feel like the motor weighs only 400 kg under water.

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Practice Questions

Question 1

Which will compress more when a pressure of 100 pounds is applied to a piston acting on the contents of a cylinder?

a) a gas
b) a liquid
c) a gas/ liquid mixture
d) a solid

Answer: a

Question 2

Hydraulic pressure will be equal in all directions in a closed fluid system because

a) fluids compress easily
b) fluid pressure is balanced by hydraulic pressure
c) fluids transfer pressure
d) fluids are buoyant

Answer: c

Question 3

Hydraulic pressure is measured in

a) unit of force per unit of area
b) Newtons
c) pounds per unit of force
d) area per unit of force

Answer: a

Question 4

A large force applied at one point in a closed hydraulic system will be measured anywhere else in the system as

a) one half the applied force
b) one fourth the applied force
c) equal to the applied force
d) twice the applied force

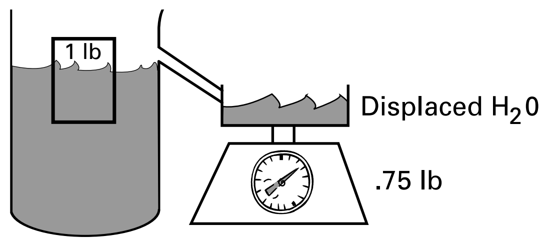
Answer: c

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Pressure and Buoyancy

A More Detailed Discussion of Buoyancy

Why do some objects float while others sink? Even very heavy ocean liners will float if they are shaped so that they obey the principle of flotation described below. Large ships float because they distribute their mass over a large volume. This makes their density less than that of water and they float. Remember: **A floating object will only sink enough to displace fluid equal to its own weight, if it displaces more than this it will be unable to float and sink.**



The weight of the displaced water is equal to the buoyant force. It offsets part of the weight (i.e. the force due to gravity) of the object in air.

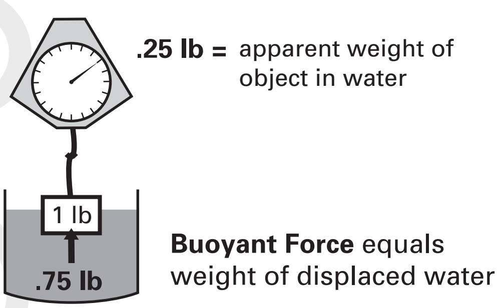
The Principle of Flotation

An object will float if it weighs equal to, or less than, the volume of water(or any other fluid) it displaces. If the object weighs more than the water it displaces it will sink.

To design objects that float, we can decrease mass, increase volume, or do both. A submarine changes its mass by pumping water in and out of ballast tanks. When the tanks are empty, the density of the submarine is lowered because the mass contained by the volume of the ship has decreased, and the submarine will rise to the surface because the buoyant force is now greater than the downward force of gravity.

Four Things You Need to Know for the Exam

1. An object put into water will seem to weigh less by an amount equal to the water it displaces.



2. The amount of displaced water is equal to the buoyant force acting to support the object. If the force of buoyancy is greater than the weight of the object, it will float. If the force of buoyancy is less than the weight of the object it will sink. When the weight of an object and the buoyant force are equal, the object is in equilibrium and won't rise or sink.

3. There are two ways to find the amount of force that causes something to float.

Two ways to find the Buoyant force = F_b

1. The weight of the object in air – the weight of the object in fluid

   $F_b = W_o - W_f$

2. The density of the fluid x the volume of fluid displaced

   $F_b = D \times V$

Example:

A boat weighs 5000 kg. How much water will it displace?

Solution: We know the weight and can use this for the value of the mass in the formula **V = m/D**. We also know the density of water is 1000 kg/m^3.

We get V = 5000 kg / 1000 kg /m^3

V = 5 m^3

The boat will displace five cubic metres of water that will weigh 5000 kg.

4. An object will float if its density is equal to, or less than, that of the liquid it is placed in. For example, objects will float in water if they have a density less than or equal to 1g / cm^3 (the density of water).

A More Detailed Explanation: Weight, Buoyancy and Density

The Greek mathematician Archimedes (287-212 B.P.) is said to have exclaimed "eureka" when he discovered what makes objects float after he took a bath. Eureka means "I have found it", and this principle has been important for boat building, submarines, and many other applications of buoyancy and flotation. The principle applies to gases as well as liquids. Study it first with water as an example of a fluid.

Weigh Displaced Water to Find the Buoyant Force

You can see that the volume of water displaced by an object can be measured by capturing the overflow in a tank or beaker when an object is placed in water. The overflow amount is the displaced amount. Objects that sink weigh more than the water they displace.

Topic 2 – Pressure and Buoyancy

Odd shaped objects can have their volumes measured by this method also. The amount of water displaced by a submerged object can be measured both with respect to it's volume and it's weight.

An Implication:

In general, the ratio of an object's density to the density of the fluid will describe how much of the object is submerged.

the portion of the volume of an object that exceeds the volume of the water it displaces will appear above the water line. Icebergs show only 11% of their volume above the waterline because they are only slightly less dense than seawater. This fact was used to calibrate the hydrometer in Unit 1, Topic 2 – Specific Gravity.

An experiment shows how the concepts of pressure and displacement work:

Notice that you would have to use force to submerge a basketball in a tank of water to measure its volume. This will cause an overflow from the tank that would be equal to its volume.

You would have to use force because normally an inflated basketball floats. It's weight is less than the water it displaces when it is allowed to float. You could measure both the ball and the displaced water to prove that this is true.

However, if you weighed the volume of water displaced by a basketball forcibly held under water, you would get more water overflowing, namely the weight and volume of water that would be needed to fill the ball. A ball filled with water will sink because the buoyant force is not great enough to offset the force of gravity. A filled ball is just as dense as water itself because it has the same mass per unit of volume. The inflated ball, however, is less dense than an equal volume of water.

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Pressure and Buoyancy

Density is a concept that will help you understand flotation better.[15]

Density = $\frac{M}{V}$

Density equals mass divided by volume. Density is the value of the ratio of mass to volume. We can calculate the density of any object if we know its mass and volume. Density allows us to compare how much matter is in a unit of volume for different substances. Units of density include pounds per cubic foot in the imperial system , and grams per cubic centimetre in the S.I. system.

1. If the density of an object is less than the density of a fluid it will float. (examples: a stick floats because it has less mass per unit of volume than the water it displaces, A steel ball will float in mercury because liquid mercury is 13.6 times as dense as water.)
2. If the density of an object is more than the density of a fluid it will sink. (example: a stone has more mass per unit of volume than the water it displaces)

Two other useful relationships are defined by this formula:

1. The Volume of fluid displaced equals the mass of the object divided by the density of the fluid.

   $$V = \frac{M}{D}$$

2. The mass of an object equals the density of the fluid times the volume of fluid it displaces.

   $$M = D \times V$$

15 See Unit 1, Topic 1 – Density.

Optional: Density Ratios

We can compare the density of a solid object with the density of a fluid to see what percent of the object will be above the fluid's surface.

Example:
How much of an iceberg's volume will show above the waterline if the density of the ice is .92g/cm^3 and the density of sea water is 1.03 g/cm^3?

Solution:
We know the object (an iceberg) will float because it has a density less than the density of sea water. Note that sea water is denser by .03 than freshwater (D=1.00) due to the minerals dissolved in it. Seawater has more mass per unit of volume than fresh water.

Form a proportion to compare how much less dense the ice is than the seawater in percentage terms.

.92/1.03=x/100=89%

This tells us that 89% of the iceberg will be submerged and 11% will show above the waterline. The expression, "its only the tip of the iceberg" is true in physical terms.

Important!

The density of water is 1g/cm^3 and its equivalent multiples in the S.I. system. Objects with a greater density will sink in water, and those with a lesser density will float. In general, for any fluid, the density of the object must be less than the density of the fluid for it to float.

Sinking is a Form of Motion

Sinking is a form of motion, and objects only move when forces acting on them don't balance out.[16] A floating object doesn't move up or down, because the forces acting on it are in **equilibrium.** A force can be compared to pushing on something. Objects will move when acted on by a force great enough to overcome inertia and friction unless the forces acting on the object are equal. When opposing forces are equal we say they are in **equilibrium. An object that floats has equal forces acting on it from above and from below.** The pressure from above equals the pressure from below. An object that sinks has more force pulling it towards the earth than buoying it up.

16 See Science – Module 1, Unit 1, Topic 5 – Force and Motion.

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Pressure and Buoyancy

Consider an arm wrestling contest, as long as no one moves from the vertical, a lot of force may be applied but no movement occurs because the opposing forces balance out. In physical terms no work is being done by this opposition of forces because nothing is being moved through a distance. When the density of a fluid equals the density of an object the weight of the object equals the force of buoyancy acting on it. This means the forces are in equilibrium and the object will "float", or hold steady, at any submerged depth it is placed.

No one wins (i.e. moves) until the force of one side exceeds that of the other

An implication: Atmospheric Pressure is in Equilibrium with Our Bodies

Our bodies are in an equilibrium relationship with the atmosphere. The atmosphere applies a downward pressure of 14.7 pounds per square inch, but we don't feel it because our cells in our bodies exert an equal opposing pressure. If a cell is placed in a vacuum, for example outer space, it will explode as the internal pressure no longer meets equal external pressure that balances it.

Buoyancy Applies to Gases Too

Lighter than air balloons rise because the gas inside the balloon has less mass per unit of volume that the surrounding air. Put another way, the density of the hot air in the balloon is less than the **density** of the surrounding air.

The buoyant force is greater than the force of gravity for a balloon filled with hot air, or for a lighter than air gas such as helium. The buoyant force will lift the balloon until equilibrium is reached at a height where the thinner atmosphere equals the density of the air in the balloon. At this height it will "float", or stop rising.

A Submarine Changes its Density to Change its Depth

A submarine works by pumping water in and out of its ballast tanks. When water is let in, the density of the submarine increases because it's mass per unit of its volume increases and it sinks. When the water is pumped out of the tanks, the density decreases because the mass per unit of volume decreases until the buoyant force exceeds the downward forces and the submarine rises.

Unit 2 – Fluids (Liquids and Gases)

Topic 2 – Practice Questions

Question 1
A ship displaces more than its own weight in water. What will happen to this ship?

a) It will float
b) It will sink
c) It will sink until the deck is submerged
d) It will capsize

Answer: b

Question 2
The force of buoyancy is always

a) a product of density
b) a downward force
c) an upward force
d) a sideways pressure

Answer: c

Question 3
Pressure on an object in a liquid is solely determined by

a) the volume of the liquid
b) the temperature of the liquid
c) the depth of the object in the liquid
d) the weight of the object

Answer: c

Question 4
A substance has a density of 0.8. grams per cubic centimetre. Will it float in water?

a) yes
b) no
c) can't tell
d) It will depend on the pressure

Answer: a

Topic 2 – Practice Questions

Question 5

A submarine changes its depth by changing its

a) volume
b) shape
c) density
d) speed

Answer: c

Unit 2 – Fluids (Liquids and Gases)

Topic 3 – Gas Laws

This competency area deals with the behaviour of gases. Recall that gases are a state (or phase) of matter with no fixed volume and no fixed shape. **The gas laws describe how changes in the temperature, pressure or volume of a gas affect each other.** 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.[17] The following discussion combines facts about how pressure, temperature, and volume interact, with formulas that show how to calculate the answers to specific problems based on these interactions.[18]

Gas and Pressure

Gas molecules are not close together unless pressure is applied to the gas in a closed space. Gas molecules move relatively independently of each other.

Pressure was discussed earlier in Unit 2, Topic 2 – Pressure and Buoyancy. You may wish to review this section in preparation for a discussion of the gas laws. The impact of gas molecules on the walls of a container produce the pressure exerted by the gas.

Pressure exerted by a gas is a force per unit of area that can be explained by the kinetic theory of atoms and molecules.[19] As gas molecules increase their movement they collide more often with each other and with the surfaces that surround them. The average kinetic energy of the molecules is proportional to the Kelvin (absolute) temperature. The higher the temperature, the more kinetic energy.

Heating a gas will increase the pressure exerted by a gas in a closed container. If the gas in not contained, its volume will increase when it is heated. Increasing the pressure will decrease the volume and also increase the temperature of a gas in a closed container. The relationship between pressure, temperature, and the volume of a gas is proportional as the formulas known as the gas laws will show.[20]

In this competency area we study the interaction between the volume, temperature, and pressure of a gas. All gases behave the same way, and the gas laws give us formulas that tell us how much one of these three properties of a gas will be when we know the other two. We can also use the formulas to predict what their value will be before and after a change takes place to temperature, pressure and volume for a fixed amount of gas.

17 These relationships are known as ideal gas laws, because they neglect friction and other real world factors that can influence actual outcomes.

18 Ask your instructor or advisor to indicate how much you need to know for the trades entrance exam on this topic.

19 See Science – Module 1, Supplementary Topic 2 – Molecules for a review of the kinetic theory

20 See the trades entrance math curriculum competencies on ratios and proportions

Topic 3 – Gas Laws

The subscript 1 is used to refer to the initial, or earlier, value of temperature T, pressure P, or volume V. The subscript 2 refers to a final, or later, value for T, P, or V. Temperature is always absolute (Kelvin). Students may want to use the following formula for all gas law problems.

Comparing initial (subscript 1) to subsequent conditions (subscript 2) for a gas allows us to use this proportion formula. When a variable doesn't change from the initial to final situation, it is a constant and may be eliminated from the equation.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

You can solve all ideal gas law problems on the exam with this formula. You may want to review the algebra competencies in the trades entrance math curriculum Math – Module 3 – Variables and Equations, to review how to solve for each variable in a formula.

Unit 2 – Fluids (Liquids and Gases)

Topic 3 – Gas Laws

The Gas Laws in Brief:

1. **At constant temperature**, the volume of a fixed amount of gas is **inversely proportional** to the pressure applied to it. The more pressure the less volume and vice versa. $\mathbf{P_1 V_1 = P_2 V_2}$ **or**

   $$\frac{P_1}{V_2} = \frac{P_2}{V_1}$$

2. **At constant pressure**, the volume of a fixed amount of gas is **directly proportional** to the absolute temperature (Kelvin). The more volume the less temperature and vice versa.

   $$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

3. **At constant volume** the pressure in a fixed amount of gas is **directly proportional** to the absolute temperature. The more pressure the more temperature and vice versa.

   $$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

4. Equal volumes of gases at the same pressure and volume contain equal numbers of molecules. Nk is a universal constant for all gases

   All four laws are expressed by this formula:

   PV = NkT

   P = pressure

   V = volume

   N = number of molecules

   K = universal constant

   T = Temperature in Kelvin (absolute)

Topic 3 – Gas Laws

Effect of Temperature on a Gas

When the temperature of a gas increases, the gas expands and its volume increases. When the gas is free to expand its volume, the pressure will not change. As discussed in the overview for this area, the molecules in a gas gain kinetic energy and move more rapidly when they are heated. The amount of the increase is in direct proportion to the change in volume. If the Kelvin temperature doubles, so will the volume.

If the gas is confined, for example in a container, and heated, the gas will be unable to increase its volume but the pressure will increase. To answer questions about the effects of temperature on a gas we also need to know if the volume is being kept constant (i.e. not changing), or if the pressure is being kept constant.

Problems involving temperature have two conditions, often an initial and a final situation, to compare. The gas law allows us to make this comparison. Temperature is always Kelvin. Standard temperature is defined as 00 Celsius or 273 Kelvin.

> **Important:**
> Always change Celsius to degrees Kelvin before solving a problem using the ideal gas laws. This will give the absolute temperature that the gas laws are based on.

Depending on the situation, one of the following formulas will apply:

1. **At constant pressure**, the volume of a fixed amount of gas is directly proportional to the absolute temperature (Kelvin). The more volume the less temperature and vice versa.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or } V_1 T_2 = V_2 T_1$$

And

2. **At constant volume** the pressure in a fixed amount of gas is directly proportional to the **absolute** temperature (Kelvin). The more pressure the more temperature and vice versa.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \text{or } P_1 T_2 = P_2 T_1$$

These proportions can be solved by cross multiplying and isolating the variable we want to find the value for. We need to know the value of any three in order to find the value of the fourth.

Unit 2 – Fluids (Liquids and Gases)

Topic 3 – Gas Laws

Sample Problem

Remember: all degrees are Kelvin for ideal gas law problems.

This summary formula will cover all ideal gas law problems.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Step one:
Determine which variable is not changing and eliminate it from the formula.

Step two:
Solve the resulting formula for the variable you need to know.

1. An amount of nitrogen has a volume of 5.00 L (litres) at a temperature of 27°C. If there is no change in pressure, what will be the volume of this amount of gas at 77°C?

   Discussion:
   We know there is no change in pressure, the pressure is held constant, therefore equation #1 will apply:

   At constant pressure, the volume of a fixed amount of gas is directly proportional to the absolute temperature (Kelvin). The more volume the less temperature and vice versa.

   $$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or } V_1 T_2 = V_2 T_1$$

Topic 3 – Gas Laws

We can also identify which variable is not changing and eliminate it from the summary ideal gas law formula: Pressure is kept constant.

When we eliminate P_1 and P_2 from the summary formula,

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

we get the correct formula, i.e. equation #1 above, for our problem.

Solution:

Step One:
Identify whether we are looking for initial or final T, V, or P and indicate the units of the answer. We are looking for a new volume or V_2, our answer will be in litres.

Step Two:
Convert Celsius to Kelvin: 27°C = 300 Kelvin and 77°C = 350 Kelvin. (Notice that the 50 degree difference between 27° and 77° Celsius represents a greater change in the Celsius scale than does a 50 degree change on the Kelvin scale. The proportionality of the gas laws depends on the Kelvin scale for accuracy.)

Step Three:
Solve

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or } V_1 T_2 = V_2 T_1$$

for

$$V_2 = \frac{V_1 T_2}{T_1}$$

$V_1 = 5.0$ L

$T_2 = 350$ Kelvin

$T_1 = 300$ Kelvin

Step Four:
Put the values in place of the variables and solve the equation:

$$V_2 = \frac{5.00 \times 3.50}{300}$$

$V_2 = 5.83$ L

Unit 2 – Fluids (Liquids and Gases)

Topic 3 – Practice Questions

Question 1

20 L of a gas expands to 40 L under conditions of constant pressure. How much did the temperature of the gas change from the temperature it had at 20 L to its temperature when it expanded to 40 L?

a) Twice the number of degrees.
b) Half the number of degrees.
c) 273 plus the Celsius degrees.
d) Standard temperature.

Answer: a

Question 2

The temperature is raised in a gas with a pressure of 15 mm Hg at 150°C to 350°C. The volume is held constant. What will the new pressure be?

a) 93 mm Hg
b) 22.09 mm Hg
c) 17.57 Torr
d) 101.8 mm Hg

Answer: b

Question 3

A litre of a gas cools from 312 Kelvin to 18 degrees Celcius. What is the new volume if the pressure is held constant?

a) .93 L
b) .75 L
c) .66 L
d) .5 L

Answer: a

Topic 3 – Gas Laws

The Effect of Pressure on a Gas

In a closed container an increase in pressure will increase the temperature in a direct proportion and decrease the volume in inverse proportion. If the pressure doubles, the temperature will double and the volume will be halved. The opposite is also true. If the pressure is halved, the temperature will be halved, and the volume will double.

This double effect will be the result, for example, of pressing down a bicycle tire pump that has its outlet sealed off. When the pressure inside the pump cylinder is two atmospheres, the temperature will be twice what it was before, and the compressed gas will take up half as much volume. Depending on what information you are given, one of the two following formulas will be useful.

1. **At constant volume** the pressure in a fixed amount of gas is **directly proportional** to the **absolute** temperature. The more pressure the more temperature and vice versa. If the pressure doubles, the temperature will double and vice versa.

   Notice that the order of events is important. In order for pressure to double, heat must be applied to the volume of gas first, then the pressure will increase. The reverse is also true, the temperature must drop as heat is lost before the pressure can decrease. The before and after relationship is described by this proportion:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

2. **At constant temperature**, the volume of a fixed amount of gas is inversely proportional to the pressure applied to it. The more pressure the less volume and vice versa. If the volume is doubled the pressure will be halved and vice versa.

$$P_1V_1 = P_2V_2$$

$$\frac{P_1}{V_2} = \frac{P_2}{V_1}$$

Sample Problem

1. A gas takes up (occupies) 625ml at 745mm of pressure. What is the volume of this gas at 815mm pressure if the temperature remains constant?

   Step One
   Identify which variable we are looking for in the summary gas laws formula and identify the units of the answer. We need to know V_2, a new volume after a change in pressure takes place. Our units will be ml.

Step Two
Remove T_1 and T_2 from the formula because temperature is held constant. Solve the remaining formula for V_2.

$P_1V_1 = P_2 V_2$

$$V_2 = \frac{P_1V_1}{P_2}$$

$P_1 = 745$ mm

$P_2 = 815$ mm

$V_1 = 625$ ml

$$V_2 = \frac{745 \times 625}{815} = 571 \text{ ml}$$

The new, and smaller, volume at the higher pressure will be 571 ml.

2. The pressure on 10 L of a gas will be reduced by 20%. The temperature is held constant. What will the new volume be if the reduced pressure is 50 mm?

   We are looking for V_2, but we need to know the pressure of 10 L of gas before it is reduced by 20%. Begin by eliminating T from the formula because it is held constant.

   Next identify the values given for each variable in the remaining formula and solve for V_2. Notice the equation to find P_1 when we know $P_2 = 50$ mm:

   $V_1 = 10$ L

   $V_2 = ?$

   $P_2 = 50$ mm

   $50 = P_1 - (.20) P_1$ (the final pressure is 20% less than the initial pressure)

   $50 = P_1 (1 - .20)$

   $50 = .8P_1$

   $P_1 = 62.5$ mm

   Now solve for $V_2 = \frac{P_1V_1}{P_2} = \frac{62.5 \text{ mm} \times 10 \text{ L}}{50 \text{ mm}} = 12.5 \text{ L}$

   This answer fits our expectation that the volume will increase when the pressure decreases and the temperature is held constant.

Unit 2 – Fluids (Liquids and Gases)

Topic 3 – Practice Questions

Question 1

The pressure on a fixed amount of a gas with a temperature of 14°C is increased from 30 mm Hg to 90 mm Hg. The volume is held constant. What will the new temperature be?

a) 270° C
b) 861 Kelvin
c) 900 Kelvin
d) 28° C

Answer: b

Question 2

The pressure on 5 litres of a gas is increased from 28 psi to 60 psi. If the temperature is held constant what will the volume be at 60 psi?

a) 300 L
b) 10.5 L
c) 2.3 L
d) 33 L

Answer: c

Question 3

A gas is heated from 225 K to 550 K, and the volume is decreased from 10 L to 5 L. The pressure of the gas will:

a) decrease substantially.
b) increase.
c) double.
d) be cut in half.

Answer: b

Unit 3

Heat

Heat is thermal energy. Heat is measured in S.I. and in imperial units. Temperature will change in substances that contact each other because there is a flow of heat from hotter to cooler. The quantity of heat we measure is the amount of heat that a substance has gained or lost. When water increases by one degree it absorbs a certain amount of heat. When it cools by one degree it loses the same amount of heat.

For the exam you need to know three ways to measure the amount of heat in a given amount of water. Any of these ways can be used to calculate the amount of heat in a substance using the formula provided below.[21]

> **Remember that the heat of water is not the same as its temperature.**
> You can focus your understanding of this difference by imagining a match being lit under a pan of 1 litre of water near the boiling point, say 99°C. The flame of the lit match has a higher temperature than the water, but the water has more heat. You can see this by realizing that the match would melt less ice than the pan of hot water. When we measure heat we use temperature as one part of the formula for finding the amount of heat.

[21] See Science – Module 1, Unit 3, Topic 2 – Heat and Temperature are Different.

Unit 3 – Heat

Topic 1 – Measuring Heat

The specific heat capacity of a substance is calculated as the amount of heat needed to raise one weight unit (grams, pounds etc.) of the substance one degree. This quantity is also known as the **heat constant** for the substance. Heat constants have been calculated for many substances. Water is the standard and is set at one. The units chosen will depend on whether imperial or S.I. standards are used.

Substances have different specific heat capacities. This means that a particular substance will be able to hold more or less heat than other substances. For example, you know from experience that a hot stone near a fire will stay warm longer than a piece of wood located next to the stone. Stone has a higher heat capacity than wood. Every substance has a specific value for how much heat is needed to raise one gram of it one degree celsius. This value is the specific heat of the substance. For example, one gram of carbon only needs .12 calories to go up one degree Celsius, but one gram of water needs one calorie – more than 8 times as much heat.

For example, copper has a specific heat capacity of 390 J/kg.°C, and water has a specific heat capacity of 4200 J/kg.°C. Copper will require much less heat to increase its temperature than water. Copper will also gain and lose heat more quickly.

Three ways to measure heat:

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.

   The specific heat capacity of water is defined as 1 B.T.U. per pound per degree Fahrenheit:

   $$\text{Specific heat capacity of water} = \frac{\text{1 B.T.U.}}{\text{1lb. X °F}}$$

   12 B.T.U. will raise the temperature of 1 pound of water 12 degrees, or the temperature of 12 pounds of water one degree.

   Heat can be measured in B.T.U.s
   Heat in B.T.U. s = weight (in lbs.) x (change in temperature in °F) x specific heat capacity of water (i.e. $\frac{\text{1 B.T.U.}}{\text{1lb. x °F}}$)

2. **The Calorie (cal) is a metric unit of heat**

   1 calorie = the amount of heat needed to increase the temperature of 1 gram of water 1 degree Celsius.

   The specific heat capacity of water is defined as 1 calorie per gram per degree Celsius:

   Specific heat capacity of water = $\frac{1 \text{ cal}}{1\text{g.} \times 1°\text{C}}$

   Remember: 1 ml of water = 1 gram of water = 1 cm^3

   12 calories will raise the temperature of 1 gram of water 12 degrees Celsius, or the temperature of 12 grams of water one degree Celsius.

   Heat can be measured in calories

   Heat in calories = weight (in grams.) x (change in temperature in °C) x specific heat capacity of water (i.e. $\frac{1 \text{ cal}}{1\text{g} \times °\text{C}}$)

   Kilocalories are commonly meant when calories are referred to in food energy calculations. The capital C means 1000 calories:

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

   Use the capital C to mean 1000 calories.

3. **The Joule (J) is another metric unit of heat linked to work**

   The joule is a unit of work in the metric S.I. system that links heat energy to the fact that all energy can be understood as the ability to do work. The joule is a unit that describes the mechanical equivalent of heat. Work in turn, is defined as the application of force to an object that moves it through a distance. The joule measures work energy.[22]

   Because the joule is based on the formula for work, it is expressed in Newton metres, where a Newton is the force needed to lift one kg at the earth's surface so as to overcome the force exerted by the earth's gravity on one kg.

   1 joule (j) = 1 Newton (N) x 1 metre (m)

   The link to heat is found by converting a calorie into the equivalent work energy. It can be shown that

   1 calorie = 4.2 joules

[22] Joule used weights on pulleys to turn paddles in a container of water. By measuring the change in temperature he could measure the relationship between work and heat.

Topic 1 – Measuring Heat

Heat Can be Measured in Joules

Recall from #2 above that the specific heat

Capacity of water = $\frac{\text{1 cal}}{\text{1g. x 1°C}}$

By substituting 4.2 joules for 1 cal, we get the specific heat capacity of water as also equal to $\frac{\text{4.2 joules}}{\text{1g x 1°C}}$

Now we can define a third way to measure the heat of water:

The amount of heat of water = Heat in joules = weight (in grams.) x (change in temperature in °C) x specific heat capacity of water

$\frac{\text{(i.e. 4.2 joules)}}{\text{1g X °C}}$

The gigajoule is a larger unit that is often more convenient.

1 gigajoule = one billion (10^9) joules. Notice also that grams can be multiplied by 10 to give kilograms as a choice for weight units with 4200 joules as the work energy needed to raise 1 kg 1°C.

Topic 2 – Calculating Heat

Heat can be calculated using any of the units explained above with the following formula:

Q = Quantity of Heat

M = Mass

Δ = Change in Temperature ($T = T_2 - T_1$)

C = Specific Heat Capacity of the Substance

Q = M x ΔT x C

> **The change in temperature ΔT (‘delta T’) = ($T_2 – T_1$)**
> is the difference between two temperatures. The capital Greek letter delta is used to mean a difference in two quantities, often based on the relationship ‘earlier-later’. Delta T can be read as “change in”.

Sample Problem

1. The specific heat capacity of methanol is 2500 j/kg.°C. How much heat is needed to raise the temperature of 10 kg of methanol from 30°C to 70°C?

   Our solution will be in metric units. We need to know the quantity of heat in joules. We know the values for the following variables in the formula for quantity of heat:

   M = 10kg

   ΔT = 70° – 30° = 40°C

   C = 2500 j/kg.°C

   Q = M x ΔT x c

   Q = 10kg x 40°C x 2500 j/kg.°C = 1,000,000 joules (note the other units cancel out)

   It will take one million joules or .1 of a gigajoule to raise the temperature of 10 kg of methanol 40 degrees Celsius.[23]

[23] Review scientific notation in Math – Module 1, Unit 3, Topic 6.B – Using Scientific Notation and Math – Module 1, Unit 3, Topic 7 – Using a Scientific Calculator.

Topic 2 – Calculating Heat

Remember these definitions for the amount of heat energy needed to raise the temperature of water:

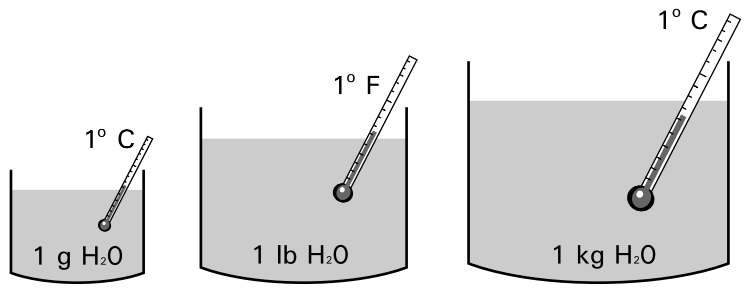
Imperial system

1 BTU increases 1 lb x 1°F

S.I. System

1 calorie and 4.2 j increases 1 g x 1°C and

1 Kcal and 4200 j increases 1 kg x 1°C



1 Calorie **1 BTU** **1 Kilocalorie**

Unit 3 – Heat

Topic 2 – Practice Questions

Question 1

The specific heat capacity of a substance is:

a) the temperature.
b) the ratio of temperature to mass.
c) the absorption factor.
d) the amount of heat needed to raise one weight unit of the substance one degree.

Answer: d

Question 2

How much heat is lost if 300 grams of water are cooled from 95°C to 50°C?

a) 13.5 kilocalories.
b) 1500 Calories.
c) 4200 joules.
d) 3450 kilocalories.

Answer: a

Question 3

How much heat is needed to raise the temperature of 12 pounds of water from 45°F to 180°F?

a) 2520 BTU
b) 1620 BTU
c) 1350 BTU
d) 4350 Kilocalories

Answer: b

Question 4

What is the temperature of 500g of water at 40°C after 20,000 calories of heat are put into it?

a) 70°C
b) 50°C
c) 80°C
d) 90°C

Answer: c

Topic 2 – Practice Exam Questions

Question 5

Lead and gold both have a heat constant of 130 j/kg.0C. What can you conclude about the heat needed to raise an equal quantity of each metal one degree?

a) Lead will need more heat than gold.
b) Gold will need more heat than lead.
c) They will require equal amounts of heat.
d) Gold will heat more quickly than lead.

Answer: c

Unit 3 – Heat

Topic 3 – Boiling and Freezing

As you know from Section One, heat and temperature are NOT the same thing. Heat is the transfer of the energy of molecules in motion from one body to another, and temperature measures 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.

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).

Heat is also called **thermal energy**. The amount of thermal energy depends on the **specific heat capacity** of a substance as well as its mass and temperature. Units that measure heat combine temperature and mass units. For example, a British Thermal Unit (BTU) measures heat. 1 BTU is the heat needed to raise one pound of water (mass unit) one degree Fahrenheit (temperature unit).

Heat and temperature are different

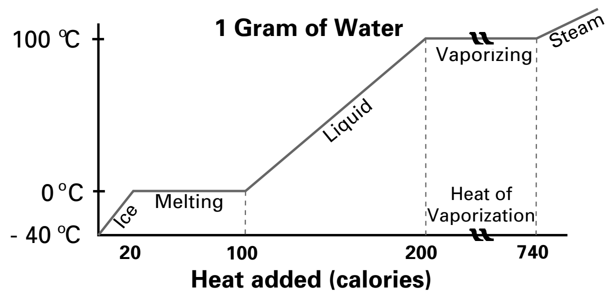
The difference between heat and temperature can be illustrated by the difference between the heat energy (the fire) needed to boil a pot of water and the temperature of the boiling water.

The temperature doesn't change once the boiling point of 100°C is reached at sea level. Yet a great deal of heat is added to the liquid to continue making it boil. 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 sum of all the heat energy contributed (transferred) by the fire.

Boiling, melting, freezing, vaporizing and condensing all refer to changes in the state of a substance. These changes can only happen when heat is either added or removed from a substance. All substances, not just water, have these change points. Changes in kinetic energy, also called the **latent heat** of a substance, cause changes in state between the liquid, gas, and solid phases of a substance.

Unit 3 – Heat

Topic 3 – Boiling and Freezing



Temperature vs. Heat in the Phase Changes of Water

The flat parts of the graph show no change in temperature between phase changes.

Different substances will have different temperatures for boiling/condensing and freezing/melting. The temperature for freezing (changing from a liquid to a solid) is the same temperature as for melting (changing from a solid to a liquid). When the **latent heat of fusion** is added to a solid it will melt and when the **latent heat of fusion** is removed from a liquid it will solidify (freeze). Similarly, when the **latent heat of vaporization** is added to a liquid it will become a gas (boil) and when the latent heat of vaporization is removed from a gas it will condense and become a liquid.

Latent heat

Is the quantity of heat that causes a phase change for a given unit of mass. Remember that the heat added or subtracted to complete a phase change for a given amount of a substance does not cause a change in temperature.

Two important temperatures tell us when the phase change from solid to liquid and liquid to gas occurs for a substance. These temperatures are the boiling/condensation point, and the melting/freezing point. The temperature for boiling (changing from a liquid to a gas) is the same temperature as for condensation (changing from a gas to a liquid). **Boiling is really a rapid form of evaporation.** Evaporation is accelerated by the addition of heat and/or the reduction of pressure.

Vaporization and Boiling

At the boiling point a liquid will change into a gas because the average kinetic energy of its molecules does enough work to drive the molecules apart, increase vapour pressure, and thus successfully oppose the surrounding atmospheric pressure.

Liquids also vaporize through evaporation at temperatures below their boiling points. Liquids are made of molecules that exchange energy and move around at different speeds. This "slow form of boiling" results from the escape of some fast moving particles from a liquid's surface along with their kinetic energy. The liquid is cooled as a result and gradually loses volume. Evaporation is a cooling process.

Unit 3 – Heat

Topic 3 – Boiling and Freezing

Which way things will go at a boiling point or at a freezing point depends on whether heat is being added or removed. Each substance has a specific heat of fusion and of vaporization. The same temperature measures condensation and evaporation. Another temperature is the same for the melting point and freezing point (solidification point) for any substance. Only two temperatures are critical, not four. In this competency area you will learn how to measure heat as well as temperature. Basic facts about heat and temperature are summarized in the following chart.

Phase changes and temperature points

Condensation point	=	Boiling point
Gas Æ Liquid remove heat of vaporization		Liquid Æ Gas add heat of vaporization
Freezing point	**=**	**Melting point**
Liquid Æ Solid remove heat of fusion		Solid Æ Liquid add heat of fusion

The same temperature measures condensation and rapid evaporation (often called boiling). Another temperature is the same for the melting point and freezing point (solidification point) for any substance. Only two temperatures are critical, not four. The quantity of heat added or subtracted from a substance determines which phase change will occur. Each substance has a specific heat of fusion and of vaporization.

Example: Water

1. Gas phase (water vapor) condenses at 100°C and liquid phase boils (vaporizes) at 100°C. The heat needed to vaporize/liquefy water is 540 calories per gram. If heat is removed from the gas (water vapour), it liquifies, as with droplets on a cold glass surface. If heat is added the liquid evaporates.
2. Solid phase (ice) melts at 0°C and liquid phase freezes at 0°C. The heat of fusion for water is 80 calories per gram. If heat is removed from the liquid it solidifies as when water turns to ice. If heat is added the solid liquifies as when ice melts.

Example Alcohol:

1. Gas phase condenses at -78°C when heat is removed and liquid phase evaporates at -78°C when heat is added.
2. Solid phase melts at -114°C when heat is added and liquid phase solidifies at -114°C when heat is removed.

Unit 3 – Heat

Topic 3 – Boiling and Freezing

Vaporization and Boiling

At the boiling point a liquid will change into a gas because the average kinetic energy of its molecules does enough work to drive the molecules apart, increase vapour pressure, and thus successfully oppose the surrounding atmospheric pressure.

Liquids also vaporize through evaporation at temperatures below their boiling points. Liquids are made of molecules that exchange energy and move around at different speeds. This "slow form of boiling" results from the escape of some fast moving particles from a liquid's surface along with their kinetic energy. The liquid is cooled as a result and gradually loses volume.

A further explanation of boiling

Boiling is the process that changes a liquid into a gas. **Boiling is really rapid vaporization** and can be understood by looking at the behaviour of liquids when they change into their gaseous state.

The kinetic theory provides a way to understand this. Recall from area A that the structure of matter is based on molecules in motion. The average molecular movement of a substance is measured as the temperature. Solids have molecules that are tightly bound and that only vibrate. Liquids have molecules with more freedom of motion and movement. Gases have molecules that are relatively independent and that move around freely.

Some molecules in a liquid will leave the surface of the liquid and become part of the surrounding air (or gas). When a particle on the surface of a liquid or solid gains enough energy from collisions or heat to overcome the forces that hold it as part of the substance, the particle escapes and becomes a particle in it's vapor i.e. gas phase. This is a physical change, not a chemical change.

The fastest moving particles leave first, and take their contribution to the average kinetic energy of the liquid with them. As a result, the liquid cools because it is loses part of its kinetic energy through the vaporization process. This is called evaporation for a liquid and sublimation for a solid. A mothball sublimates, a dish of water evaporates. Evaporation removes heat from a liquid. Evaporation is going on all of the time, and so is condensation. Remember, boiling is a physical change, not a chemical change. A molecule of water vapour is still a molecule of water that can be found in the liquid or solid phases of water.

Unit 3 – Heat

Topic 3 – Boiling and Freezing

Evaporation Will Take Place More Rapidly at Higher Temperatures

When more kinetic energy is contributed to increase the movement of the molecules in a liquid they are more able to leave the liquid phase. Boiling can be caused by increasing the rate of evaporation (also called vaporization) through the addition of heat.

Boiling can also be caused by a reduction in the pressure acting on a liquid. If the pressure of air on a dish of water is decreased, the water molecules will have less resistance to overcome when they leave the surface of the liquid. It will take less of an increase in kinetic energy to cause the water molecules to leave the liquid. This is why water boils at a lower temperature at higher altitudes.

In a closed container, if pressure is reduced enough, the liquid will begin to boil, but it will also lose heat and cool. Thus, unless the pressure is further reduced, or heat is supplied, a new equilibrium between the atmospheric pressure and the vapour pressure will be established and the boiling will stop.

The reverse is also true, if the pressure on a liquid is increased, as in a pressure cooker, the temperature needed for boiling will increase. In a pressure cooker the water must reach higher and higher temperatures to boil until the pressure in the atmosphere is great enough to force open a steam release valve.

The pressure that a liquid exerts on the surrounding air (or gas) is called the vapour pressure of the liquid.

Liquid will change to a gas. Evaporation and condensation occur all the time, but when the rate of evaporation and the rate of condensation is equal, there is no net loss or gain to the volume of liquid. Only in perfect equilibrium will the forces on a liquid balance the forces within the liquid.

Every liquid exerts a vapour pressure on its surroundings.

In order for a substance to evaporate, or boil by evaporating rapidly, there must be an unequal relationship between vaporization and condensation in favour of vaporization. This can be achieved by reducing the pressure on the liquid or by increasing the temperature of the liquid, or both.

The boiling point is the temperature for a certain pressure at which a liquid will vaporize quicker than it condenses and thereby change into a gas. The bubbles we see when water boils are a result of this change beneath the surface of the liquid.

Vapour Pressure and Boiling

Liquids boil when the vapour pressure is greater than the atmospheric pressure opposing the movement of liquid molecules.

Boiling is also affected by solutions. **In general solutions boil at higher temperatures than the solvent.** For example, in the case of water the boiling point is increased slightly when salt is dissolved in it.

Unit 3 – Heat

Topic 3 – Boiling and Freezing

To Recap:

In a vacuum water will boil without heat being added, because the vapour pressure is greater than a vacuum which has no pressure to oppose the movement of molecules on the liquid's surface. The liquid will also cool as heat energy is transferred from the liquid to the gas phase.

In a high pressure situation, water will boil at a higher temperature because there is more atmospheric pressure for the molecules of the liquid to overcome and they will require more kinetic energy. This fact is used in car radiators- the engine coolant would boil at engine operating temperatures and create steam if the system were not pressurized. **In general liquids boil at higher temperatures when under higher pressures.**

Topic 3 – Practice Questions

Question 1

A pot of water will begin to boil when the vapor pressure exceeds the atmospheric pressure. When will this happen?

a) when the water is placed in a vacuum
b) when the water is placed on a mountain top
c) when the water is given latent heat
d) when the water is changing into a liquid from a gas

Answer: a

Question 2

What do boiling and evaporation have in common?

a) they both depend on mass
b) they both involve the same vapour pressure
c) they are both heating processes
d) they both involve a phase change

Answer: d

Question 3

What will increase the boiling point of water?

a) an increase in temperature
b) an increase in atmospheric pressure
c) a decrease in vapour pressure
d) adding the heat of fusion

Answer: b

Question 4

A salt is dissolved in water. What will this do to the boiling point of the liquid?

a) it will increase
b) it will decrease
c) it will depend on mass
d) it will stay the same

Answer: a

Unit 3 – Heat

Topic 3 – Freezing

When any substance changes from a liquid to a solid we can say that it freezes. A substance loses kinetic (heat) energy when it freezes. When a substance freezes, it is transferring its latent heat of fusion to its surroundings. This happens when water changes to ice. When the surroundings are colder than 0°C, water will freeze, and will freeze more quickly depending how much colder the surroundings are.

Freezing and solidifying refer to the same phase change from liquid to solid. The **latent heat of fusion** describes the amount of heat that will have to be removed for a given mass to change from a liquid to a solid.

The reverse direction of this phase change is **when a solid changes to a liquid, and then we say that it melts.** The kinetic energy of the solid has to increase in order for it to melt. The **latent heat of fusion** describes the amount of heat that will have to be added for a given mass to change from a solid to a liquid.[24] This amount will be equal to the amount that was removed to go from the liquid to solid phase.

Recall the fact given earlier: The melting point and the freezing point are the same temperature for crystalline substances. A phase change from liquid to solid and from solid to liquid will happen at the freezing/melting point. In most substances the particles are closer together in the solid phase than in the liquid phase.

Freezing and Pressure

With water as an important exception, most liquids will take up less volume (contract) when they solidify (freeze). Increasing the pressure will accelerate this process and the freezing point will go up. **Most liquids under pressure will freeze at a higher temperature than in lower pressure environments**.

Freezing and Solutions

In solutions with water, dissolved salts will lower the freezing point. This is because more heat energy must be removed before the attractive forces between water molecules can offset the repelling forces of the salt ions. Rock salt is used on roads to lower the freezing point of water. In general adding anything to water will have this effect.

Freezing and Water

Water is an unusual substance in that it expands, rather than contracts when it freezes. Water expands its volume about 10% between 4°C and 0°C.

[24] A non crystalline substance, like paraffin will soften gradually when heated. It will soften before flowing, the phase change is gradual.

Topic 3 – Practice Questions

Question 1

Salt is dissolved in water. What will happen to the freezing point of the solution compared to pure water?

a) It will increase.
b) It will decrease.
c) It will remain the same.
d) It will depend on the amount of solute.

Answer: b

Question 2

In a low pressure environment, what will happen to the freezing point of most liquids?

a) It will increase.
b) It will decrease.
c) It will remain the same.
d) It will depend on the amount of pressure.

Answer: a

Question 3

The melting point of Nitrogen is –210°C. If a sample of Nitrogen has a temperature of –60°C, how much will the temperature have to change before the sample freezes?

a) It will have to increase 150°C.
b) It will have to decrease 150°C.
c) It will have to increase 60°C.
d) It will have to decrease 60°C.

Answer: b

Topic 4 – Heat Transfer

Conduction, Radiation and Convection

Thermal energy can be transferred in three ways, by conduction, convection and radiation. Heat transfer is always from areas of greater kinetic energy (hotter) to areas of lower kinetic energy (cooler). How fast a transfer occurs will depend on the method of transfer and the ability of substances to transfer heat.

When heat is transferred, more than one transfer method may be operating. For example, when sitting before a campfire, you will feel heat coming sideways due to radiation, upwards due to convection and radiation, and also in the handle of the iron poker you are using through conduction.

Temperature in Mixtures

When unequal amounts of a liquid at different temperatures are mixed the mixture will have a temperature that is the weighted average of the ingredients.

Example:
1 litre of water at 10 degrees Celsius is mixed with 3 litres of water at 20 degrees Celsius. What will the temperature of the 4 litre mixture be?

Because both ingredients are water they will have the same heat capacity and we can use the weighted average method. Find the answer by multiplying the volume times the temperature for each ingredient and then divide by the number of litres in the mixture. Here 1 x 10 = 10, and 3 x 20 = 60. The total of 70 divided by 4 = 17.5 degrees.[25]

Conduction

When there is a difference in temperature in a solid body, or between two solids that touch each other, a flow of heat will start from the hotter body to the cooler body. This heat transfer is basically mechanical: one atom hits another to transfer its energy. If you hold a iron rod with its end in a fire, heat energy will be conducted towards your hand until the rod is too hot to hold. Metals are good conductors of heat because their molecules are tightly packed. The more dense the metal the better it will conduct heat.

Gases are poor conductors because the reverse is true. Gases are non-conductors. Liquids are in a middle position between gases and solids. The more dense a liquid is, the better it will conduct heat, but still not as well as metals.

Insulators are non-conductors (or very poor conductors) of heat. Insulation stops or slows down heat transfer. Fiberglass is used in the walls of building for this purpose. A rag wrapped around the end of an iron rod held in a fire will protect your hand, up to a point, because it is an insulator.

[25] See Math – Module 5 – Special Topics for more on weighting averages and central tendency.

Unit 3 – Heat

Topic 4 – Heat Transfer

Convection

Convection is a transfer of heat when molecules move from one location to another. Convection can't happen in solids, but does happen in Fluids (meaning both gases and liquids).

Convection is mass transfer
The flow of hotter fluid molecules is always upward. Hot air rises.

A warm breeze is an example of convection, and gases transfer heat by convection. The mechanism for convection is the creation of a buoyant force when the molecules of a gas are given more kinetic energy than their surroundings. A heated gas will expand and become less dense. The cooler gas surrounding it will exert a buoyant force on the less dense molecules and push them upwards.[26]

Radiation

Heat energy can also be transferred through a vacuum where there are no molecules to conduct heat, or to move by convection. The sun's energy reaches us by radiation. Radiation energy has many wavelengths, and this can be studied further in other courses in physics. Heat energy, is infrared, or long wavelength energy. We cannot see heat waves, but infrared radiation is on the same range (spectrum) of wavelengths that includes visible light. Infrared heat radiation is a form of **electromagnetic energy**.

We can observe a transfer of infrared heat energy into convection and conduction in the earth's atmosphere, and at our campfire example. The heat felt to the side of the fire can be absorbed by a cast iron frying pan.

Heat is absorbed by dark coloured rough surfaces, and is reflected by shiny white surfaces. A common example is the way a dark leaf will melt more snow under it in spring that a light coloured leaf.

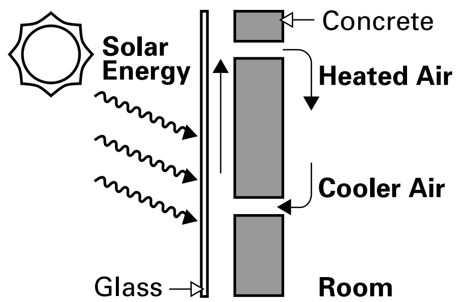
Good absorbers of radiant energy are good emitters and vice versa.

[26] Force, like velocity is a vector quantity. It has both magnitude(its size or strength) and direction (the direction in which the force is exerted) . In diagrams, force vectors are drawn as arrows with the tail of the vector on the object receiving the force.

Topic 4 – Heat Transfer

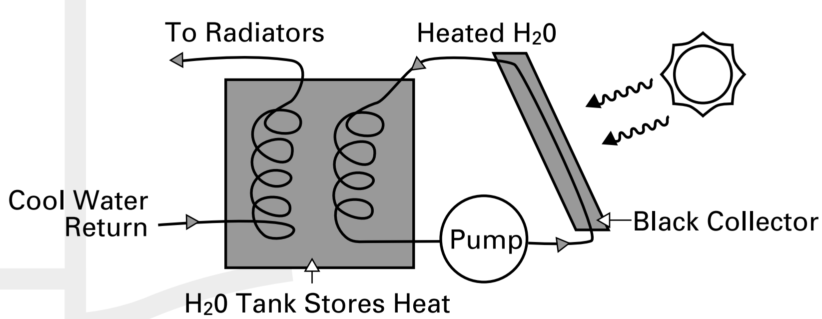
Solar Heating

The radiant energy from the sun can be captured, stored, and given back in the form of useful heat for a home or building. **Passive solar** systems allow the sun to shine on materials that will store heat, for example a concrete wall or floor, or a water tank painted black. Water and concrete have high specific heat values, they will hold a lot of heat compared to less dense substances such as wood. No mechanical energy is supplied to the system, convection and conduction do the work of transferring the heat. The heat stored during the day will be transferred to cooler surroundings at night. Blinds or shutters can control how much solar energy is stored. A wall can be designed to use convection caused by solar energy to move air to heat a room.



This cross section of a wall shows how the sun's energy will cause air to rise in the space between the glass and the concrete wall. As the air cools, and becomes more dense, it will fall and the cycle repeats. The wall will also store heat and release it to its surroundings.

An **active solar** heating system uses pumps and valves to transfer heat from a heat exchanger to a home heating system. Mechanical and/or electrical energy is needed to operate an active system. One way to do this is to design a heat storage tank that allows a heat exchanger to transfer its heat to a storage medium such as water. A pump keeps the flow going and more and more heat is contributed to the water in the storage tank. A separate coil leads to the radiators in the house and delivers heated water to the rooms. When the water cools it falls or is pumped back to be reheated in the storage tank.



Unit 3 – Heat

Topic 4 – Practice Questions

Question 1
Convection is not a method of heat transfer in solids because:

a) solids can't move.
b) heat is latent.
c) molecules in a solid can't move.
d) conduction is better.

Answer: c

Question 2
How is heat energy transferred from the sun to the Earth?

a) By conduction.
b) By convection.
c) By radiation.
d) By temperature increases.

Answer: c

Question 3
When a pot handle is too hot to hold in one's bare hands, what can be done to protect against being burned?

a) Take the pot off the fire.
b) Use an insulator around the handle.
c) Blow on it and use convection.
d) put out the fire.

Answer: b

Question 4
Which object will absorb more heat energy from the sun?

a) A black cat.
b) A white rabbit.
c) A patch of snow.
d) A white parka.

Answer: a

Topic 4 – Practice Questions

Question 5

Convection is used in home heating systems by including:

a) a fan to move the hot air.
b) a furnace to burn fuel.
c) insulation to prevent heat loss.
d) iron radiators to conduct heat.

Answer: a

Question 6

Which of the following is not part of a passive solar heating system?

a) A heat exchanger.
b) A solar energy collector.
c) A pipe that circulates water.
d) A pump.

Answer: d

Unit 4

Work, Energy and Machines

Topic 1 – Energy Conversion

Energy is the ability to do work. Energy can be converted from one form to another. For example, heat energy can be converted into mechanical energy in a car engine, solar energy can be converted into heat and light energy by photo electric cells on buildings, and by photosynthesis in plants. Work in the trades involves many energy conversion systems.

Matter can contain energy because matter has the ability to do work, for example when wood is burned, food is metabolized (a form of “burning” at biological temperatures), or when a sledge hammer hits a stake into the ground. Matter has the ability to be affected by force and to also exert force, and this fact connects energy conversion and force with the concept of work.

Unit 4 – Work, Energy and Machines

Topic 1 – Energy Conversion

Devices can be designed to use several sources of energy.

Examples

1. The electrical system in a hospital can be run by current from a distant hydroelectric plant which changes heat energy into electrical energy, or by a backup battery system that converts chemical energy into electrical energy. The battery may also be recharged by solar electric panels on the roof that convert solar energy into electrical energy.
2. A power plant may be powered by oil, coal, or radioactive material.
3. A car may be powered by solar energy, chemical energy, or electrical energy. Depending on fuels available, a car can be designed to permit the driver to switch between energy inputs.

Energy is converted-but never lost

Energy can be compared to a fluid that flows between containers but doesn't change its volume because energy is always conserved- never created or destroyed. Energy can be stored in different places, and in different forms (chemical, thermal, mechanical). When work is done, a force acts on an object to cause movement. Energy will be transferred in this process from one form to another and from one object to another- but no energy is lost or created. This principle is called the **conservation of energy**.

Work and Energy Conversion

Work = force x distance. The idea of work connects force with energy. When you think of force, think of pushing and pulling an object. A force acts on objects, but may not always succeed in doing work, i.e. in moving anything.[27] Energy, in contrast is not something done to an object, but is something exchanged between objects.

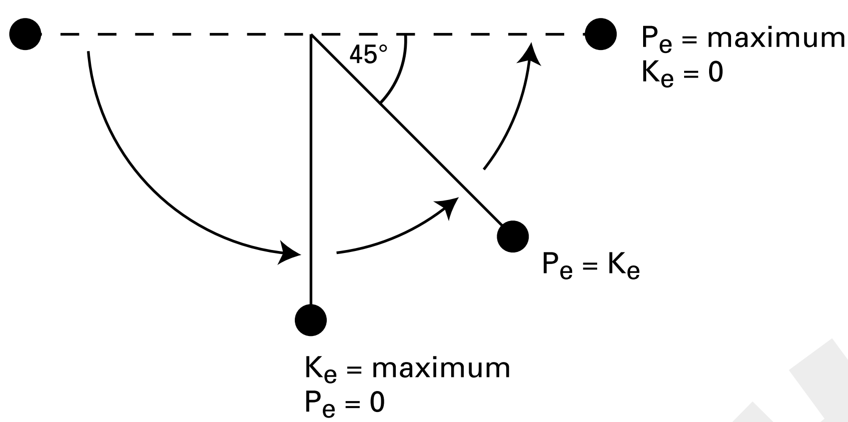
Energy may be present in an object or process, but still do no work. For example, an object held above the ground has potential energy, but until it is released, no work is done and no conversion of potential (i.e. stored energy) into kinetic (i.e. moving, or released) energy occurs.

27 Force, like velocity is a vector quantity. It has both magnitude(its size or strength) and direction (the direction in which the force is exerted) . In diagrams, force vectors are drawn as arrows with the tail of the vector on the object receiving the force.

Converting Potential Energy into Kinetic Energy: The Pendulum

A pendulum is an object allowed to swing on a string. A wrecking ball is an example of a pendulum. Thinking about what happens when a pendulum moves will illustrate the concepts of force and energy. You can make the following observations:

1. When the pendulum is at rest, it does no work, has no kinetic energy, and has only the potential energy due to its position above the ground.
2. When a force is applied to the pendulum, say by your hand, it can be lifted to a horizontal position. Work has been done on the pendulum because it has been raised the length of the string. As a result it has increased its potential energy in exchange for the loss of kinetic energy delivered by your hand.
3. When the pendulum is allowed to swing, it performs an arc with almost no friction or air resistance. At the bottom of each swing it has maximum kinetic energy, 0 potential energy, and at the top of each swing it has maximum potential energy and 0 kinetic energy. If there were no friction and no air resistance, the pendulum would swing forever.
4. Work is being done on the pendulum on each swing as the mass of the pendulum bob is moved through a distance. KE = PE, although at each point in the pendulums journey these quantities will change but always add to the same total energy. Kinetic energy + potential will be constant. Energy is conserved but changes form.



$P_e + K_e$ is constant

Unit 4 – Work, Energy and Machines

Topic 1 – Practice Questions

Question 1
A force is applied to lift a book from the floor onto a table. What has happened to the energy of the book?

a) Nothing.
b) It has doubled.
c) Its potential energy has increased.
d) Its kinetic energy has increased.

Answer: c

Question 2
Which kind of energy can do work?

a) Electrical.
b) Chemical.
c) Mechanical.
d) a, b, and c.

Answer: d

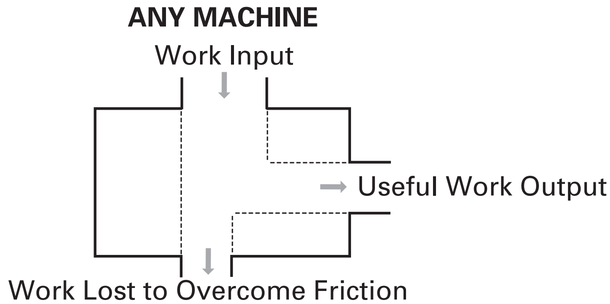
Question 3
Potential energy is due to:

a) height or position.
b) weight.
c) force.
d) work.

Answer: a

Unit 4 – Work, Energy and Machines

Topic 2 – Mechanical Advantage



Machines can multiply force but they cannot multiply work.

A machine will do work, and convert energy, but not with 100% efficiency. Some energy is "wasted" as heat due to friction. The study of machines looks at two questions: what is the advantage of using the machine? how efficient is the machine? The following summary of important formulas will show you how to find the mechanical advantage and the efficiency of a simple machine. The efficiency of machines and energy conversion is developed further in Section Three: Science Special topics. People working in a trade need to know how to use machines with maximum efficiency and advantage for a job.

Mechanical Advantage

Mechanical advantage tells how many times a machine will multiply the effort put into it. Input into a machine is an application of a force, and the actual mechanical advantage of a machine is defined as the force of resistance (the output force F_0) divided by the force of effort (the input force F_i). This produces a dimensionless number (i.e. a number with no units attached) that is useful for comparing the advantages of various machines.

Mechanical advantage is the number of times that a machine will multiply the force (i.e. effort) put into it

Actual Mechanical Advantage (AMA) = $\frac{F_o}{F_i}$

Ideal (or theoretical) Mechanical Advantage (IMA, or TMA) = $\frac{d_i}{d_o}$

and, $\frac{d_i}{d_o} = \frac{F_o}{F_i}$ **if we ignore friction**

Actual and theoretical mechanical advantages can be calculated. **Actual M.A.'s** take friction into account by comparing the force of resistance and the force of effort. The force of effort we measure is always an input force before friction is deducted. The output force will be less than the input force because some of the input force will be used to overcome friction.

Unit 4 – Work, Energy and Machines

Topic 2 – Mechanical Advantage

Remember: IMA compares distances, TMA compares forces.

Theoretical (or ideal) M.A.s ignore friction by comparing the distance an input force operates on with the distance the output force operates on. This comparison looks at the distances involved without allowing for any losses due to friction.

Sample Problems

1. An engineer in Inuvik works for an oil company and wants to design a machine that will put out 500 Newtons of force. For example, a special handtruck for moving rig equipment in narrow spaces. The engineer knows that the machine will have an input distance of 10 cm and an output distance of 2.5 cm. What minimum input force will be required to cause a machine fitting these specifications to work?

   This problem asks us to look for an ideal or theoretical amount of input force that must be available for the machine to work with no friction force subtracted from the input force. We can find the answer by calculating the IMA of a machine with these specifications.

   $IMA = \frac{d_i}{d_o}$ = 10 cm / 2.5 cm = 4.0

   This machine will multiply an input force four times in exchange for applying the input force over a greater distance (10 cm) than the output force (2.5 cm). We know that under ideal conditions, there is no friction, and therefore work input = work output and therefore

   $F_i d_i = F_o d_o$ and

   $IMA = \frac{d_i}{d_o} = \frac{F_o}{F_i}$ (only when there is no friction will AMA = TMA)

   Now we can substitute IMA = 4 and solve for F_i

   4 = 500 Newtons / F_i

   F_i = 500 Newtons / 4 = 125 Newtons

   The engineer now knows that he will require at least 125 Newtons of force to get the output the machine is designed for. He also knows that the actual mechanical advantage will be less than 4.0 due to friction. How much more force than 125 Newtons is required will depend on how much friction must be overcome.

2. After building the machine and trying it out on a rig, the engineer discovers that in reality it takes 175 Newtons of force input to get 500 Newtons of force output. With this information he can calculate the

   $AMA = \frac{F_o}{F_i}$

   AMA = 500 / 175 = 2.8

Topic 2 – Mechanical Advantage

This machine has an actual force multiplication of 2.8, the difference between IMA = 4 and AMA = 2.8 is 1.2 because 50 Newtons of input force is required to offset the force of friction in the machine.

3. A pulley system is used to lift a 60 pound load 5 feet. A force of 15 pounds is applied over 25 feet of line to accomplish this. What is the actual mechanical advantage? What is the ideal mechanical advantage? How much work was done? How much work was done to overcome friction?

First recall the formulas that we need:

$$AMA = \frac{F_o}{F_i}$$

$$IMA = \frac{d_i}{d_o}$$

Work output = work input - work to overcome friction

work = F x d

We are given the output force (force of resistance) when we are told that the load was 60 lbs, and we are given the output distance (distance moved by the resistance) when we are told that the load was raised 5 feet.

Here is what we are given:

F_o = 60 lb

D_o = 5 feet

F_i = 15 lb

D_i = 25 feet

This means that it takes 15 lbs of force pulling a rope over this pulley for 25 feet to move a 60 lb load 5 feet. We are given the input force (effort force) as 15 lbs. We can find the AMA by dividing output force by input force (or force of resistance by force of effort) 60/15 = 4

This machine multiplies our effort four times, but notice that the distance the effort is applied over is 25 feet and the distance that the load moves is only 5 feet. The trade off for our force multiplication is increased effort distance. We have our effort multiplied 5 times but our effort distance is decreased 5 times in the output.

We can find the ideal mechanical advantage by dividing the distance of the input force by the distance of the output force. This is 25ft/5ft = 5.

The difference between the ideal and actual advantage is 5 – 4 = 1. Some work is being done to overcome friction. We can find how much work was done to overcome friction by applying the formulas for work.

The input work that was done equals 15 lb x 25 feet = 375 ft/lbs. The output work is 5 ft. x 60 lb = 300 ft./lbs. This means that 75 foot pounds of work was used to overcome friction and did not contribute to the useful work output.

Topic 2 – Mechanical Advantage

To Summarize:

Work output (300 ft/lb) = work input (375 ft/lb) – work to overcome friction (75 ft/lb)

Unit 4 – Work, Energy and Machines

Topic 2 – Practice Questions

Question 1

What is the actual mechanical advantage of a lever that needs 30lb of force over 2 feet to move 60 pounds of load 1 foot?

a) 20
b) 2
c) 30
d) 60

Answer: b

Question 2

Why should the actual mechanical advantage of a machine be greater than one?

a) Less than one is too slow.
b) There is no useful advantage otherwise.
c) The input and output forces would be unable to equal each other.
d) The friction would be too great to overcome otherwise.

Answer: b

Question 3

A machine has a theoretical mechanical advantage of 3 and an actual mechanical advantage of 2.5. What best explains the difference?

a) AMA takes friction into account and TMA doesn't.
b) The TMA is an imaginary possibility.
c) The AMA is the result of greater distance divided by effort.
d) The TMA assumes a friction free machine.

Answer: a

Unit 4 – Work, Energy and Machines

Topic 3 – Efficiency

The efficiency of a machine is calculated by dividing the work output into the work input, or by dividing the AMA by the IMA. The resulting numbers are converted to percentages.

Due to friction, the output work that is useful will always be less than the input work. This means that the efficiency of any machine will always be less than 100%.

Efficiency compares work output to work input, or actual mechanical advantage to ideal mechanical advantage.

$$(\%)\ \text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} = \frac{\text{AMA}}{\text{IMA}} \quad (\times\ 100\%)$$

Sample Problems

1. A machine does 10,000 foot pounds of work based on on 15,000 foot pounds of input work. What is the efficiency of this machine?

   We know that Eff. = W_o/W_i

   W_o = 10,000 foot pounds

   W_i = 15,000 foot pounds

   Efficiency = 10,000/15,000 = 2/3

   Converting to a percentage 2/3 = 67%

   This machine does useful work that is equal to two thirds of the work put into it. It is 67% efficient.

2. A machine is 83% efficient and has a TMA of 3. What is the AMA?

   We know that Eff.= AMA/TMA, therefore

   83/100 = AMA/3

   $$\text{AMA} = \frac{3 \times 83}{100} = 2.5$$

   The AMA is less than the TMA by .5.
   17% of the input work is lost due to friction or other causes.

   The efficiency of a machine can be improved by lubrication and a choice of input energy that has the most useful output form.

Topic 3 – Practice Questions

Question 1

Machine A has an efficiency of 45%, and Machine B has an efficiency of 60%. What can be said about these machines?

a) Machine A loses more input work to friction than machine B.
b) Machine B loses more input work to friction than machine A.
c) Machine A has poorer lubrication than machine B.
d) Machine B has more input force than machine A.

Answer: a

Question 2

What is the efficiency of a machine with a theoretical mechanical advantage of 3 and an actual mechanical advantage of 2?

a) 5
b) 50%
c) 67%
d) 33%

Answer: c

Question 3

A machine has a work output of 450 joules and a work input of 600 joules. How efficient is this machine?

a) 35%
b) 65%
c) 75%
d) 50%

Answer: c

Topic 4 – The Mechanical Advantage of Simple Machines

Recall that there are three principles for all basic machines and combinations of machines: the principles of **the inclined plane, the lever, and the hydraulic press.**[28] The following formulas tell how to calculate mechanical advantage for each of them.

Topic 4.A – 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).

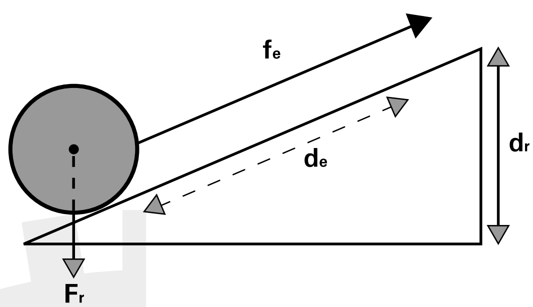
The input force (F_e) is applied to the object over the effort distance, or run. The output force will equal the weight of the load that is being lifted. The output work will equal the weight of the load times the height (rise) of the inclined plane.

Mechanical Advantage: The Inclined Plane

The Inclined Plane

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

Note:
F_r is simplified as the weight, with no normal force component.



[28] Review Science – Module 1, Unit 1 – Basic Machines.

Unit 4 – Work, Energy and Machines

Topic 4.A – Inclined Plane

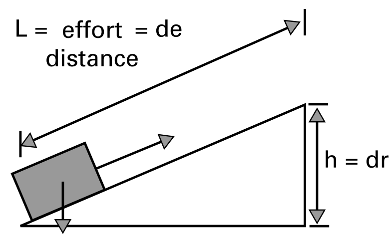
The Inclined Plane: A Second Look

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

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.

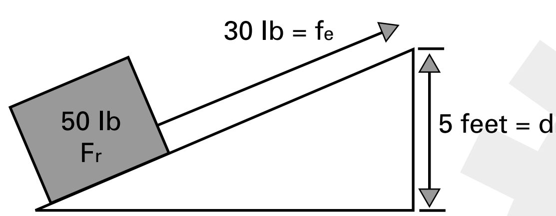


$IMA = \frac{de}{dr} = \frac{L}{h}$

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.

Sample Problems

1. What is the work input and output when a 50 pound crate is moved from ground level by a force of 30 pounds to a height of 5 feet over an inclined surface ten feet long? Also calculate the AMA, the IMA, and the efficiency of this inclined plane.
   Begin by sketching the problem:



Topic 4.A – Inclined Plane

Work is defined as force x distance, and work output = work input – work to overcome friction. Find the values for each variable in the formulas for work.

In this problem we know the work output (W0) equals the load to be moved (Fr = 50 lbs.) times the distance (h) **it will be lifted** (dr = 5 feet). This means that if the object were simply lifted, it would take 250 foot pounds of work. **This is the work output that will be required.**

We can expect that the work input will require more than 250 foot pounds to offset friction. The work input equals the work needed to offset friction plus the input(effort) force (Fe = 30 lb) times the input (effort) distance (de = 10 feet). This gives us a total work input of 300 foot pounds plus the work needed to overcome friction. We can use the formula that relates work input to work output to find the work needed to overcome friction (W_f):

$W_i - W_f = W_o$

$W_f = W_i - W_o$

$W_f = 300 - 250 = 50$ ft.lb

The AMA = Fr/Fe = 50/30 = 1.66

The IMA = de/dr = 10/5 = 2

The efficiency = AMA/IMA = 1.66/2 = 83.3%

Or Wo/Wi = 250/300 = 83.3%

Topic 4.A – Practice Questions

Question 1

The AMA of an inclined plane is 3. If the change in height for a 10 pound object rolled up a 15 foot ramp is 6 feet, how much is the output work done by this machine?

a) 18 foot lbs
b) 90 foot lbs
c) 60 foot lbs
d) 30 foot lbs

Answer: c

Question 2

What is the IMA of an inclined plane that is 10 feet high with a slope 20 feet long?

a) Can't tell from this information
b) 2
c) 1/2
d) 5

Answer: b

Question 3

Which inclined plane will require more input (effort) force to move an object?

a) A low slope ramp.
b) A steep slope ramp.
c) A long ramp.
d) A short ramp.

Answer: b

Topic 4.B – The Lever

The Lever

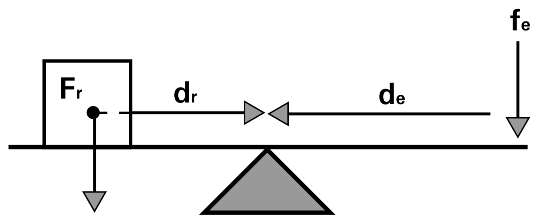
In order to do work the output force must equal or exceed the load, otherwise the load won't move. We can ignore friction for a lever.

IMA = AMA = $\frac{d_e}{d_r} = \frac{F_r}{F_e}$ **=** $F_e \times d_e = F_r \times d_r$

Note:

d_r and d_e are the lever arm distances from the resistance force (output force) to the fulcrum and from the effort force (input force) to the fulcrum

Remember: F_r **= the weight of the load, or weight of the resistance object that is to be moved.**



A Note of Explanation

dr is the lever arm distance from the resistance force (aka output force = weight of load) to the fulcrum. d_e is the distance from the effort force (aka input force) to the fulcrum. These distances are also referred to as the length of the lever arms, lever output (L_o), and lever input (L_i).

Strictly speaking, these definitions don't describe the vertical movement of the resistance or of the effort when a lever moves. This is because the lever arm lengths are directly proportional to the vertical distances of movement and can be substituted for them in our formula. Geometrically: the two arcs subtend the same angle, so si = L_iq, and $s_o = L_o$q so that $s_i/s_o = L_i / L_o$, and

$$IMA = \frac{F_o}{F_i} = \frac{d_i}{d_o} = \frac{s_i}{s_o} = \frac{L_i}{L_o}$$

Unit 4 – Work, Energy and Machines

Topic 4.B – The Lever

The Law of Levers

A lever that is in equilibrium is balanced. The sum of all the torques (twisting forces) acting on it in a clockwise direction must equal the sum of all the torques action on it in a counter-clockwise direction.[29]

All of the forces acting on a 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, which is a class one lever, 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.

Moments of torque are defined as the product of a force x the distance to the fulcrum. When there is no movement, as in equilibrium, there will be no work done by the lever, but we can still calculate the moments of torque acting on each lever arm.

A Lever in Equilibrium

Clockwise torque = counter clockwise torque

F x d = F x d

This means that the sum of the products of all forces x distances (aka **moments of torque**) on one side of the fulcrum must equal the sum of the products of all forces x distances on the other side for a lever in equilibrium.

Sample Problems

1. A 10 foot lever is going to be used to lift a 150 lb rock. The fulcrum is placed 3 feet from the rock. Find the force that must be applied to the other end of the lever to lift this rock. Find the mechanical advantage of the lever. (Neglect friction and the weight of the lever)

   As with other simple machines, we first identify what we are told:

   The distance (lever arm) to the resistance (load) is 3 feet = d_r

   The distance (lever arm) to the effort (input force) = 8 – 3 = 5 = d_e

   The force of the resistance (load = its weight = output force) is 150lb = F_r

   The force of the effort (input force) must be found F_e = ?

   Next identify the formula that relates what we know to what we seek.

[29] See Science – Module 1, Unit 1, Topic 7 – Centre of Gravity.

Topic 4.B – The Lever

We can solve for F_e by using the fact that work in must equal work out:

$F_e \times d_e = F_r \times d_r$

$F_e \times 5\ ft = 150\ lb \times 3\ ft$

$F_e = 90\ lb$

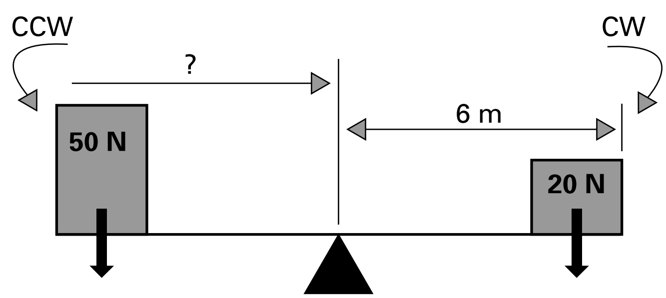
For levers, TMA = IMA = $\frac{F_o}{F_i}$ = 150 lb / 90 lb = 1.66

2. What is the mechanical advantage of a lever if it takes 200 N of effort to move a resistance of 600 N?

   We do not need to know the effort arm (effort distance) or the resistance distance to find the mechanical advantage. Use the formula

   TMA = IMA = $\frac{F_o}{F_i}$ = 600 N / 200 N = 3

3. To balance the lever in this diagram, how far from the fulcrum should the effort be applied?



We can use the law of levers to compare moments of torque. We know that the lever will only balance if the products of force times distance are equal for both sides of the fulcrum.

We are given the clockwise acting force of 20N and a distance of 6 metres. This means the cw moment of torque is 120 Nm. The ccw moment will be the product of 50N and the distance we seek. We construct this equation with what we know:

Ccw moment = 50 N x ? = 120 Nm = cw moment

? = 120 Nm / 50 N = 2.2 m

Topic 4.B – Practice Questions

Question 1

What force is needed to balance a lever 5 feet from the fulcrum that has 10kg 3feet from the fulcrum on the opposite side of the fulcrum?

a) 30 kg
b) 6 kg
c) 5 kg
d) 15 kg

Answer: b

Question 2

What is the mechanical advantage of a lever that uses 15N to lift 10N?

a) .33
b) 5
c) 2.6
d) .66

Answer: d

Question 3

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

Unit 4 – Work, Energy and Machines

Topic 4.C – 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. That Fr is also known as the output force, or the load, and that the load equals the weight of the object being moved.
2. That Fe is also known as the input force or applied force.
3. The de (effort distance) will equal the length of the line that pulled through the pulley system

Ideal (aka theoretical) Mechanical Advantage summary for pulleys

Single fixed pulley: TMA = 1

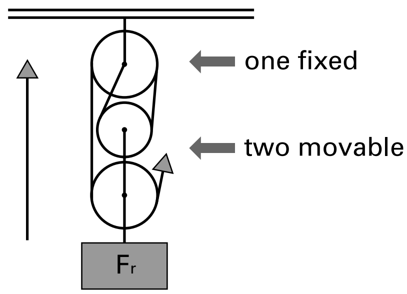
Single movable pulley: TMA = 2

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

Topic 4.C – Pulleys

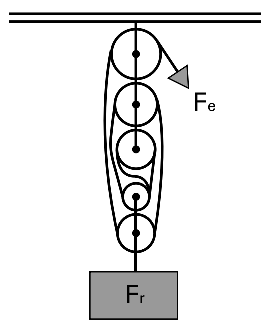
Sample Problems

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 three fixed and two movable pulleys. There are five 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 Fi = 500 lb/4 = 125 lb.

Topic 4.C – Practice Questions

Question 1
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

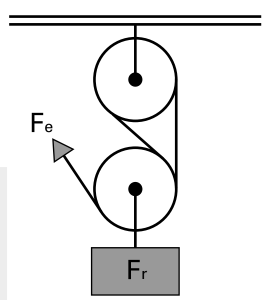
Answer: c

Question 2
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

Question 3
What is the TMA of this pulley system?



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

Answer: c

Topic 4.D – Gears

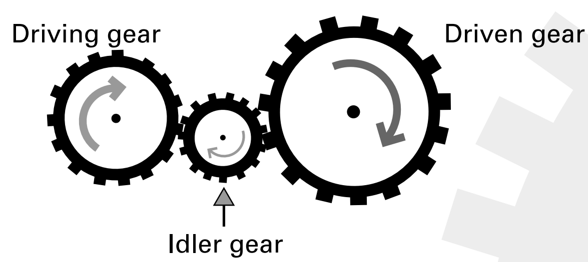
Gears are notched wheels that can be used to change the direction of motion, change the speed of motion, or change the magnitude (size) of the applied force. Like the pulley and the wheel and axle, **Gears apply the principle of the lever to give us mechanical advantages. The radius of a gear is its lever arm.** Gears are used to transmit power in machines. The gears on a drive shaft are connected to different gears in a transmission to change the speed of rotation and direction delivered from the shaft to the wheels.

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.
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.

Summary:

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.



Unit 4 – Work, Energy and Machines

Topic 4.D – Gears

Gear Speed Ratios and IMA

Gears of different diameters and numbers of teeth can mesh because their teeth are of the same size. The number of teeth on one gear can be compared with the number of teeth on a second gear of a different size to find out how many revolutions of one cause a revolution in the other. This is called the **speed ratio (SR)** of the two gears. A set of gears is often used to produce an increase or reduction in speed. This relationship can also tell us what the IMA is for the gear system.

Two Ways to Find IMA

Comparing number of teeth or number of revolutions for each gear gives the IMA.

1. $IMA = \frac{N_o \text{ Number of teeth in output (driven) gear}}{N_i \text{ Number of teeth in input (driving) gear}}$
2. $IMA = \frac{\text{Number of revolutions of input (driving) gear}}{\text{Number of revolutions of output (driven) gear}}$

The speed ratio compares input gear teeth to output gear teeth

$SR = \frac{N_i \text{ Number of teeth on input (driving) gear}}{N_o \text{ Number of teeth on output (driven) gear}}$

And,

IMA = 1/SR

Sample Problems

Study tip for problems on gears:

Given teeth: IMA = driven/driving

SR = driving/driven

Given revolutions per unit of time: IMA = driving/driven

1. A driving gear has 40 teeth and a driven gear has 20 teeth. What is the IMA? What is the speed ratio?

   In this problem, a larger gear drives a smaller (pinion) gear. The pinion gear is the output gear. We are given the number of teeth on each gear.

   Given number of teeth: IMA = driven/driving

   The IMA = 20/40 = .5

This number tells us that our input force (effort) is halved in the output force. In exchange the larger driving gear will have to turn only half as many times as the driven gear.

Given number of teeth: SR = driving/driven

The SR = driving gear teeth/ driven gear teeth = 40/20 = 2/1 or 2.

This tells us that the driving gear turns halfway for every complete revolution by the driven gear. The SR can be expressed as the ratio 2:1, or "two to one". The smaller pinion gear with 20 teeth turns twice as quickly as the larger driver gear with 40 teeth.

2. Change the roles of the gears in problem one:

   A driven (output) gear has 40 teeth and a driving (input) gear has 20 teeth. What is the IMA? What is the speed ratio?

   In this problem, a smaller (pinion) gear drives a larger gear. The larger gear is the output gear.

   Two ways to find IMA:

   1) The IMA = 40/20 = 2

   Or

   2) SR = 20/40 = .5 and,

   IMA = 1/SR = 1/.5 = 2

   This number tells us that our input force (effort) is doubled in the output force. In exchange the smaller driving gear will have to turn twice as many times as the driven gear.

   The SR = 20/40 = 1/2

   The SR = driving gear teeth/ driven gear teeth = 20/40 = 1/2

   This tells us that the driving gear turns twice for every revolution by the driven gear. There is a speed reduction of 1/2 in the output gear. The SR can be expressed as the ratio 1:2, or "one to two". The pinion gear turns twice as quickly as the driver gear.

3. A small gear turns 3 times for every time that a larger gear that it drives turns 1 time. What is the ideal mechanical advantage of this gear system?

   We are given the number of revolutions for the driving gear = 3 and for the driven gear = 1. **Given revolutions per unit of time: IMA = driving/driven and here IMA = 3/1 = 3.**

Topic 4.D – Practice Questions

Question 1
If a driving gear is designed to provide a gain in force and a loss in speed, what will the driving gear have?

a) A smaller diameter than the driven gear.
b) A larger diameter than the driven gear.
c) More teeth than the driven gear.
d) A larger circumference than the driven gear.

Answer: a

Question 2
What is the theoretical mechanical advantage of a gear system when the driving gear has 16 teeth, and the driven gear has 32 teeth?

a) 1/2
b) 2
c) 4
d) 16

Answer: b

Question 3
An idler gear is useful because:

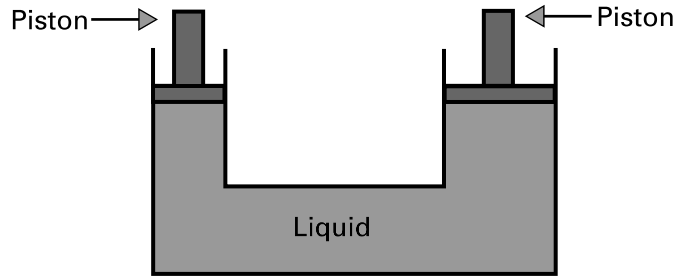
a) it doesn't change the TMA.
b) it doesn't create friction.
c) it changes the direction of motion.
d) it subtracts from the resistance.

Answer: c

Topic 4.E – Hydraulic Machines

The Hydraulic Press

$$IMA = \frac{d_i}{d_o} = \frac{A_o}{A_i}$$



Hydraulic Pressure

Hydraulic pressure is the force exerted by a liquid in a closed (contained) system.[30] When pressure is applied to any part of a contained liquid, the liquid does not compress (as would a gas) and the pressure is transferred equally in all directions.

You can demonstrate this fact by filling a balloon with water, placing it on a hard surface, putting several pin pricks into it at different places, and then applying pressure to any point with your finger. You will see streams of water exiting from each hole with equal force no matter where they are located. Your input force (pressure) is being transferred to all points equally.

Gases also obey this principle, but they undergo compression as well, and the pressure applied to a gas in a closed space is not transmitted as quickly as for a liquid.

Hydraulic Machines are Based on Pascal's Principle

1. Pascal's Principle

   Pressure applied to an enclosed fluid is transmitted throughout the fluid without loss and acts in all directions equally.

2. Liquids cannot be compressed
3. Liquids will transfer pressure applied at one point equally to all other points in a closed system
4. Pressure equals force divided by area

   $$P = \frac{F}{A}$$

In a hydraulic machine there will input and output pressures, Total forces, and areas, that determine mechanical advantage.

[30] See Unit 2, Topic 2 – Buoyancy and Topic 3 – Gas Laws.

Topic 4.E – Hydraulic Machines

Important Note:

Don't confuse pressure per unit of area (lb/in^2, or N/m^2) with the total force input or output (lbs, or N)

Pi = $\frac{F_i}{A_i}$ (pressure input = total input force divided by input area)

$P_o = \frac{F_o}{A_o}$ (output pressure = total output force (resistance) divided by output area)

Hydraulic pressure in machines uses the relationship between pressure, distance, and area to create mechanical advantages. Brakes in cars, hydraulic lifts in garages, and syringes, all use the principle of hydraulic pressure to create mechanical advantage. In general, when the area of the output is greater than the area of the input, the output force will be greater than the input force, but the input force will move through a greater distance than the output force.

As with other machines studied in this competency area, hydraulic machines are based on four considerations: input force, input distance, output force, and output distance. Area is a fifth consideration for hydraulic machines.

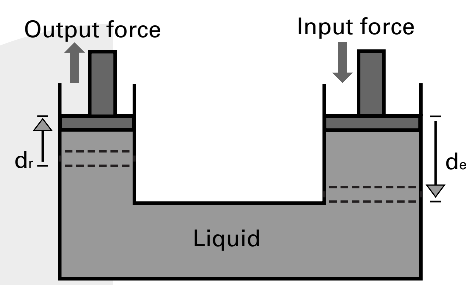
The difference between the input area that the input force acts on, and the output area that the output force acts on, is in the same direct proportion that gives us the IMA for the system. Friction can be ignored in our study of hydraulic pressure, and one formula summarizes everything you need to know about hydraulic pressure machines:

For a hydraulic system

$$\text{IMA} = \frac{F_o}{F_i} = \frac{A_o}{A_i} = \frac{d_i}{d_o}$$

Each ratio gives the IMA, and each ratio can be set equal to either of the other two.

A hydraulic pressure machine (hydraulic press) with two pistons will have the following parts:



Topic 4.E – Hydraulic Machines

This is the way a hydraulic lift works. A hydraulic lift with an IMA of five, will allow a force of 2000 N applied through 50cm to lift a load of 10,000N 10 cm. The output area will be five times greater than the input area to achieve this result.

A Note of Further Explanation

The fact that the volumes of liquid that will be displaced by each piston are equal, and the fact that each volume equals the distance the piston moves times the area of piston's surface, lead to these conclusions:

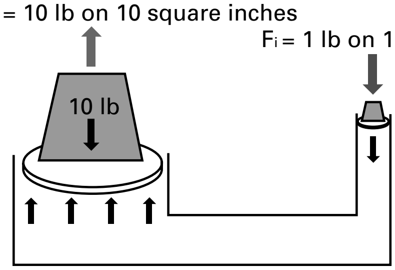
$V_i = V_o$ (input volume displaced = output volume displaced)

$V_i = d_i A_i$ and $V_o = d_o A_o$

Therefore: $d_i / d_o = A_o / A_i$

When motion is involved in a hydraulic press IMA = di/do

The size of the piston area on the input side can be less than, equal to, or larger than the area on the output side. The same is true for input distance, and input force. We can change (vary) the areas of the pistons in a hydraulic press to create a mechanical advantage.



Because F_i applies 1 lb of pressure to an area only 1/10 the area that F_o is applied to, a force multiplication of 10 times is achieved. In trade off, the smaller piston will have to move ten inches for every one inch that the larger piston moves.

Sample Problems

1. A hydraulic press has an output piston area of 600 square inches, and an input piston area of 60 square inches. Find the IMA, and the pressure that must be applied to support a load weighing 3600 pounds.

   The summary formula for hydraulic pressure can be used to determine what we know and what we need to find:

   $$\textbf{IMA} = \frac{F_o}{F_i} = \frac{A_o}{A_i} = \frac{d_i}{d_o}$$

   There are three ways to calculate the IMA, and since we are given the output and input areas we can see that

IMA = 600 in^2 / 60 in^2 = 10

We are also asked to calculate the input pressure (P_i). In order to find this, we must recall that pressure is force per unit of area and therefore P = F/A. We know the areas, but need to find the input force before we can calculate P_i.

We are given the output force of 3600 pounds. Since we have the IMA, we can select the relationship IMA = F_o / F_i in our summary formula and solve for Fi, then we can finish by finding P_i using $P_i = F_i / A_i$

IMA = F_o / F_i

10 = 3600 lb / F_i

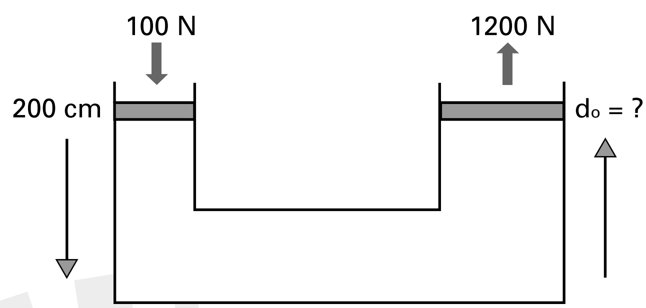
F_i = 360 lb

Next use $P_i = F_i / A_i$

P_i = 360 lb / 60 in^2 = 6 lb / in^2

In summary, this hydraulic press will need a pressure of 6 lb/in^2 applied to an area of 60 in^2 in order to support a load of 3600 lbs on an output piston with an area of 600 square inches. This input pressure on this area will deliver an input force totalling 360 lbs. The press has a mechanical advantage of 10, which means that the input piston will move ten inches for every one inch that the output piston moves.

2. Find the resistance distance in the following



We are given F_i = 100 N, d_i = 200 cm, and F_o = 1200 N. We need to find d_o. Select the relationship linking these givens from the summary formula:

$$\textbf{IMA} = \frac{F_o}{F_i} = \frac{A_o}{A_i} = \frac{d_i}{d_o}$$

$$\frac{F_o}{F_i} = \frac{d_i}{d_o}$$

Substitute givens and solve for d_o

$$d_o = \frac{d_i \times F_i}{F_o}$$

$$d_o = \frac{200cm \times 100N}{1200\ N} = 16.6\ cm$$

Unit 4 – Work, Energy and Machines

Topic 4.E – Hydraulic Machines

Summary

In this competency we study the effect of pressure on a closed fluid system, for example a hydraulic (oil filled)pump or automotive brake system. **Hydraulic pressure can be used to do work because fluids do not compress and therefore can transmit pressure without loss throughout a closed system.**[31]

1. **Pascal's principle**

   Pressure applied to an enclosed fluid is transmitted throughout the fluid without loss and acts in all directions equally.
2. **Liquids cannot be compressed**
3. **Liquids will transfer pressure applied at one point equally to all other points in a closed system**
4. **Pressure equals force divided by area**

   $$P = \frac{F}{A}$$

Hydraulic pressure will be measured in lb/in^2 and N/m^2. Recall that 1 Pascal (Pa) = $1N/m^2$.

Sample Problem

1. A force of 10 Newtons is applied to a piston above a fluid filled cylinder with an area of 2 cm^2. What will the pressure be on the bottom of the cylinder below the piston?

We know that P = F/A and that pressure transfers equally in a fluid in a all directions. This means the input pressure will equal the pressure on the bottom of the cylinder.

$P = 10 \text{ Newtons} / 2 \text{ cm}^2 = 5 \text{ N} / \text{cm}^2$

The pressure will equal 5 Newtons per square centimetre.

31 Hydraulic pressure used in machines (pumps) is studied further in Unit 2, Topic 2 – Pressure and Buoyancy.

Unit 4 – Work, Energy and Machines

Topic 4.E – Practice Questions

Question 1

In a hydraulic system, a one pound force applied to a piston with area of 1 square inch will support a 10 pound weight on a 10 in^2 piston because:

a) the pressure is greater underneath the 10 pound weight.
b) the pressure is multiplied.
c) one pound of pressure per square inch is transferred to the 10 in^2 piston.
d) the area times the force is the same.

Answer: c

Question 2

When pressure is exerted on a liquid at one end of a closed system, what amount of pressure will be exerted at the other end?

a) Twice as much.
b) Half as much.
c) An equal amount.
d) Depends on how viscous the liquid is.

Answer: c

Question 3

The ideal mechanical advantage of a hydraulic press can be found by:

a) testing it under conditions of equal pressure.
b) dividing the area of the output piston by the area of the input piston.
c) dividing the distance of the output by the distance of the input.
d) multiplying the force times the pressure.

Answer: b

Question 4

What is the resistance area of a hydraulic press with an input force of 100N, an output force of 350N, and an input area of 8 square centimetres?

a) 3.5 cm^2
b) 28 cm^2
c) 80 cm^2
d) 32 cm^2

Answer: b

Unit 5

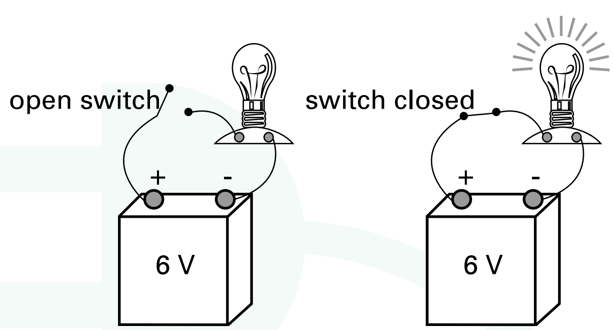
Electricity

Topic 1 – Circuit Concepts

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 the wire is cut, not connected, or if a switch is open, the current will not flow. The circuit must be closed for current to flow.

In order for current to flow through a circuit, there must be a **voltage** source to cause the flow of electrons. Electricity only flows when there is a potential difference that is maintained by a source of power, for example a battery. When the battery is "dead" because all of its electrical potential has been used (discharged) the flow of electrons in the circuit will stop.

A circuit can be closed or opened by a **switch**. When the switch is closed the current is able to flow.



When the battery loses enough of its electric potential through use so that it no longer can overcome the resistance offered by the bulb, the current will stop flowing and the light will go out. Flashlight batteries are sometimes rated by the number of hours they can keep a flashlight bulb lit.

Unit 5 – Electricity

Topic 1 – Circuit Concepts

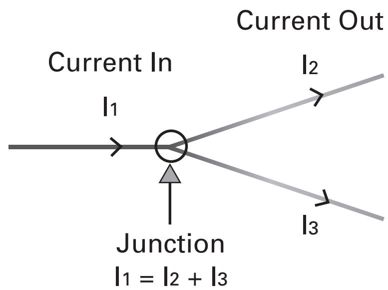
Junctions

Junctions are points in a circuit where three or more connected wires meet. A branch is a part of a circuit between two junctions that contains one or more circuit elements, for example a resistor.

Conservation of Energy in Circuits

The sum of the currents entering and leaving a junction are zero when we assign negative value to the currents leaving the junction. **The current in will equal the current out.**

Similarly, the sum of voltage rises and drops in a circuit will also equal zero. These two rules, called Kirchhoff's rules, apply the principle of the conservation of energy to circuits.



Electrical devices can cause harm or even death to a person if they deliver current through a person. Household current has enough voltage (110v-120v) to electrocute a person. In experiments it is safe to handle small amounts of current such as the current delivered by a 1.5 volt battery. A 12 volt car battery, however, with up to 40 amps flowing through a circuit can injure a person. Disconnect a battery before working on the electrical system in a vehicle.

Dangerous Procedures

1. Do not touch bare wires together that may carry current.
2. Do not grab a "live" wire, the current may short out through your body.
3. Do not overload a circuit with more than it is rated to handle
4. Do not plug in equipment with a frayed cord or plug that has had its ground removed.
5. Use the information given on the identifying plate found on every electrical device. Only plug the device into a power source for which it is rated. (i.e. voltage and amperage are within the correct limits).

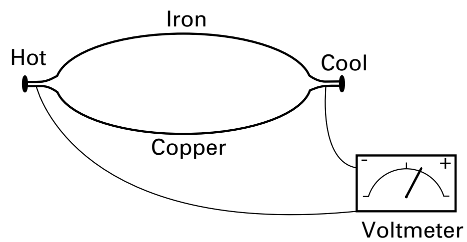
Safety with electricity is mostly common sense. For example, do not attempt to put out an electrical fire with water, the water will conduct the electricity. Electric current will always travel the path of least resistance- make sure you do not provide that path through your body.

Unit 5 – Electricity

Topic 1 – Circuit Concepts

Sources of Electricity: Chemical, Light, Heat

Electricity can be produced by chemical means in batteries, by light in photoelectric cells, and by heat in thermocouples. A **photoelectric cell** is made from a material that produces electron flow when light hits it. When light hits a metal surface electrons move (i.e. are emitted). A **thermocouple** is made from two different metals, for example copper and iron, that are joined at each end. When one end is heated, and a temperature difference results between the two ends, and electric current will flow. Thermocouples are used to switch devices on and off, and to measure temperature by relating amount of current produced to the temperature difference at the ends of the thermocouple.



The voltmeter will register a potential difference (voltage) when one end of a thermocouple is hotter than the other end.

A photoelectric cell or thermocouple can be used to activate a switch and open or close a circuit when the electric current begins to flow. “electric eyes” in security systems use this principle.

Insulation and Resistance

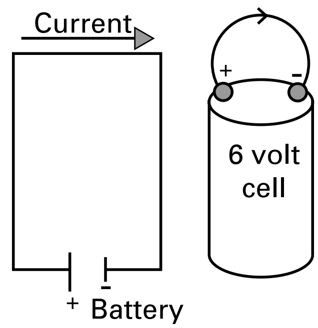
Electrical **insulators** are materials with very few electrons free to move. **Circuits** are continuous (i.e. unbroken) conducting paths. For example, a wire connecting the two terminals of a battery creates a simple electric circuit.

Electric charge is conserved.
When a positive or negative charge is produced on a body, an equal and opposite charge is also produced so that the net charge is zero. In an electrical circuit, the amount of charge entering will equal the amount leaving in one form or another (as heat, current, light, or radiation). The basic idea of conservation is that “what goes in equals what comes out and vice versa.”

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, or the wire touches ground and shorts out, 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.

Unit 5 – Electricity

Topic 1 – Circuit Concepts



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. Electric current can be compared to 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. This flow rate of charge is defined in terms of coulombs 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. The Coulomb is named for the work of Charles Coulomb (1736 – 1806). The Coulomb is defined in terms of the basic electric change carried by the proton (p+) and the electron (e-).[32]

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.

32 e- = -1.6×10^{-19} C, and the amount of charge on each of two objects that will result in each one exerting a force of 9.0×10^{9} N on the other is equal to 1 C. Current measures the flow of coulombs.

Unit 5 – Electricity

Topic 1 – Circuit Concepts

Electric Potential and Volts

Electrical potential is measured in volts (V). Electric potential is similar to gravitational potential, or to pressure on a fluid. Just as a mass has potential energy in a gravitational field due to its position (height) in that field, so an electric charge has potential energy due to its position in an electrical field. The amount of work that a charge can do based on its position is called its **electrical potential.**

Comparing electricity once again to a flowing river, voltage measures the "electrical pressure" of electric current.

An electrical charge will travel from an area of high potential to an area of lower potential just as water will flow downhill, or in the direction of an applied pressure. Voltage measures electrical potential, and a difference in voltage at two points means that there is a difference in electrical potential. A voltage source is also called an **electromotive force,** or emf. **A charge will always seek to move from an area of high potential to an area of lower potential.** It takes work to move a charged particle from an area of low potential to an area of higher potential.

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.

V = Electric Potential Energy / Electric Charge

Volts can be expressed in SI units as joules per coulomb.[33] Voltage can also be calculated from its relationship to current, power, and resistance. Voltage is measured b a **voltmeter**.

Electrical Resistance

Resistors are used to change the flow of current in a circuit. **A resistor will increase the voltage required to move a current through a circuit**. The amount of current that will flow in a wire depends on both the voltage and on the resistance offered by the wire. Compare the situation in a wire with a river. The rocks on the riverbed and the roughness of the banks can slow the flow of water.

Resistance is measured in units called Ohms. The definition of resistance in metal conductors using Ohm's law R = V/I, is discussed in Science – Module 3 – Special Topics. Every material has a **resistivity** measured in Ohms per meter that depends on its temperature and the structure of the material. Resistance will increase in a wire when it heats up.

A wire is a cylinder, and the resistivity of a wire depends on its length and cross sectional (i.e. circular) area. If the length of a wire is doubled, its resistance will also double. If the thickness (i.e. cross sectional area) increases, the resistance will decrease. Electricity behaves in a similar way to water flowing in a pipe. An electrician will use thicker wire on circuits that carry more current. Resistors have been designed to offer specific resistance (measured in Ohms) for use in circuits.

33 1 coulomb = the amount of charge on each of two objects that will result in each one exerting a force of 9.0×10^9 N on the other. Current measures the flow of coulombs.

Unit 5 – Electricity

Topic 1 – Circuit Concepts

Resistance (resistivity) depends on the kind of material, the temperature, and on the shape and size of the wire.

- a long wire will have more resistance than a short one.
- a thick wire (large cross-sectional area) will have less resistance than a skinnier wire (smaller cross-sectional area).
- a hot wire will offer more resistance than a cooler one.

A **rheostat** is a switch that controls how much resistance is offered to the current in a circuit. A light dimmer switch is an example. A variable resistor can be made by adding and subtracting the amount of a resistant material that the current flows through. You can do this in an experiment by changing the amount of carbon in a tube that is inserted as a resistor in a test circuit. An ammeter will show a decrease of current as more carbon is added.

Unit 5 – Electricity

Topic 1 – Practice Questions

Question 1

Which forms of energy can produce electricity:

a) mechanical.
b) heat.
c) light.
d) all of the above.

Answer: d

Question 2

A dimmer switch on a light is an example of a:

a) junction.
b) variable resistor.
c) current flow.
d) independent switch.

Answer: b

Question 3

Tapwater should not be used to put out an electrical fire because:

a) Water is not cold enough.
b) There is too much force involved.
c) water from the tap is an insulator.
d) Water from the tap is a conductor.

Answer: d

Question 4

Which meter will measure a voltage drop?

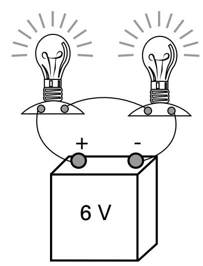
a) Ammeter.
b) Ohmmeter.
c) Voltmeter.
d) Kilowatt meter.

Answer: c

Topic 2 – Series and Parallel Circuits

Series Circuits

Series circuits connect electrical devices, for example light bulbs, in a single conducting path.



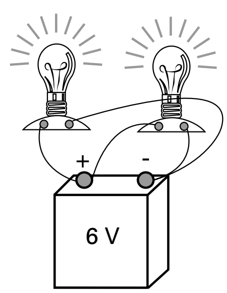
In a series circuit, the total resistance equals the **sum of the resistances** presented by the devices in the circuit.

For series circuits

Total or net R = R_1 + R_2… Rn
(R_n is the last component in the circuit)

In series circuits, the resistances and the voltages will add up and the amount of current will be the same everywhere in the circuit.

Parallel Circuits



In a parallel circuit each device is connected directly to the power source.

In a parallel circuit, 1/total resistance (net resistance) equals the **sum of the reciprocals of each resistance** presented by the devices in the circuit.[34]

1/Total resistance in a parallel circuit (1/R_p) is the sum of the reciprocals of the resistance of each component

$1/Rp = 1/R_1 + 1/R_2 + \ldots 1/R_n$

[34] For a discussion of reciprocals see Math Foundations – Unit 2, Topic 2, 4, Dividing Fractions.

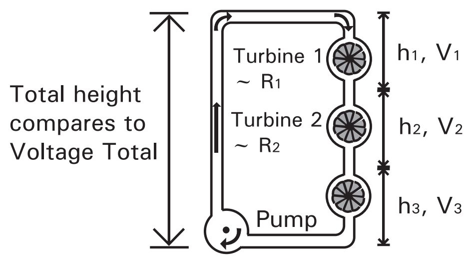
Unit 5 – Electricity

Topic 2 – Series and Parallel Circuits

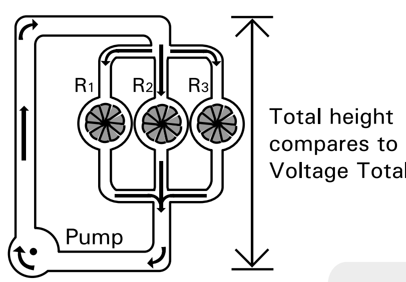
Bulbs connected to a power source in series will burn less brightly than they would if they are connected to the same source in parallel. In series circuits, the resistances add and less current reaches each bulb. There is a voltage drop between bulbs. The same amount of current flows through each bulb, but with less potential ("pressure") behind it. In a series circuit, the interruption of the circuit at any point will stop the current from reaching any of the appliances on it. If one bulb goes out on a series circuit, all the bulbs will go out.

A picture of a water filled circuit built on the ground can help you understand these ideas.

Compare voltage changes to changes in height



This diagram shows a series circuit. The pump is the battery, the water is the current and the turbines are the resistances. You can see that the battery increases the potential energy by lifting the water. This potential energy is changed into kinetic energy on the way down. Each resistance receives the same amount of current, but the pressure drops as the height decreases. This change can be compared to a drop in voltage. Also the total resistance offered to the current is the sum of the three resistances in series.



In a parallel circuit each device is connected directly to the power source. The current from the power source is divided between the resistances in the circuit.

In this model of a parallel circuit, 1/total resistance (net resistance) equals the **sum of the reciprocals of each resistance** presented by the devices in the circuit.

In parallel circuits, 1/total or net R = $1/R_1 + 1/R_2 + \ldots 1/R_n$

Bulbs in parallel will each burn with the same brightness, there is no drop in electric potential from one bulb to the next because they each are have a direct input from the source. Each bulb will get the same voltage. Houses are wired in parallel circuits so that each device will receive the same voltage, (120 V in Canada). One light can be turned off, but all the lights in the house don't go off with it.

Memory tip:

PRR + "in parallel circuits resistance reciprocals add to 1/R total" **Remember to "purr".**

Unit 5 – Electricity

Topic 2 – Practice Questions

Question 1

In a series circuit with 3 resistors:

a) the voltage drops are equal.
b) the current is equal.
c) the resistances are multiplied.
d) the voltage is doubled.

Answer: b

Question 2

What is the voltage drop in a series circuit across a 12 ohm resistance supplied by a 12 volt battery?

a) 6 volts
b) 12 volts
c) 3 volts
d) 4 volts

Answer: b

Question 3

What is the equivalent resistance in a series circuit that draws 6 amps for 3 bulbs that are 12 ohms, 6 ohms, and 3 ohms?

a) 9 ohms
b) 36 ohms
c) 18 ohms
d) 21 ohms

Answer: d

Question 4

A 12 volt battery supplies a circuit with 3 resistances in series. The voltage drop over the first resistance is 3 volts, and the voltage drop over the third is 2 volts. What is the voltage drop over the second resistance?

a) Can't tell from this information.
b) 5 volts
c) 7 volts
d) 6 volts

Answer: c

Topic 2 – Practice Questions

Question 5

A bulb burns out in a series circuit shared with 10 other bulbs. What will happen to the power supply to the other bulbs?

a) Only the downstream bulbs will go out.
b) Only the upstream bulbs will go out.
c) All of the bulbs will go out.
d) The remaining 9 bulbs will remain lit.

Answer: c

Question 6

What is the total resistance in a parallel circuit with 2 resistances of 8 ohms and 10 ohms?

a) 2 ohms
b) 18 ohms
c) 4.44 ohms
d) .225 ohms

Answer: c

Explanation:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{1}{8} + \frac{1}{10} = .225$$

R_T = 4.44 ohms

Unit 5 – Electricity

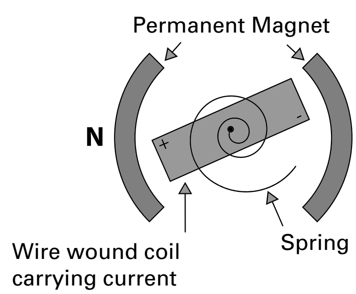
Topic 3 – Motors and Generators

Motors are a type of generator. **An electric motor is a generator run in reverse** as you will see below. Electromagnetic effects are the basis for motors and generators. Review electricity and magnetism in Science – Module 1 – Science Foundations for this topic. The fact that electricity is generated when a magnet moves through a coil carrying current, and the fact that magnetism is produced when current flows through a wire, is the basis for motors and generators.

The Galvanometer

The interaction between magnetic force and electrical force can be measured by a galvanometer. Generators use this interaction to change mechanical energy into electrical energy. Motors use this interaction to change electrical energy into mechanical energy.

The galvanometer measures the twisting force (torque) that results when a coil of wire has current flowing through it inside a magnetic field. This force is directly proportional to the amount of current flowing through the wire.



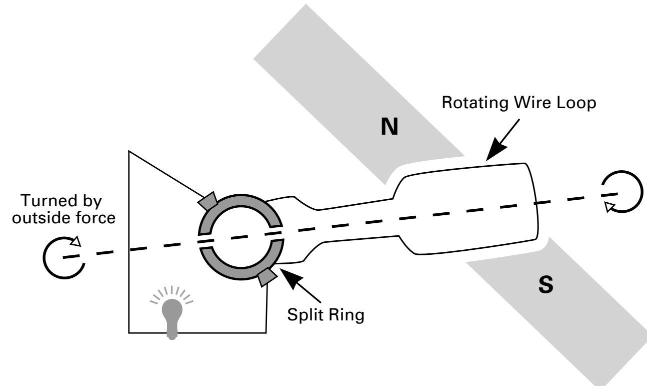
In this top view you can see how the spring will be twisted by the movement of the electromagnet (i.e. the wire wound coil). This happens because the poles of the permanent magnet attract and repel the ends of the electromagnet in direct proportion to how much current is flowing through the coil. The galvanometer is the basic component of ammeters and voltmeters.

You can construct a simple galvanometer with a compass and a copper wire attached to a battery. Form the wire into a loop and move the compass through it with the compass face perpendicular to the wire. The needle will move (deflect) to line up with the magnetic lines of force created by the current carrying wire. The movement of the compass needle indicates the presence of a magnetic force produced by the current in the wire. When no current flows through the wire, the needle will not respond.

Electrical Generators

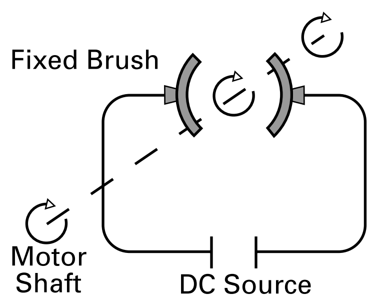
In a generator, mechanical energy produced by an engine (for example a fan belt in a car) or falling water is used to rotate a coil of wire in a magnetic field. As the coil rotates, the direction of the magnetic lines of force (flux) change direction producing an electromotive force that can be directed to a circuit outside the generator. A split ring called a commutator is used to keep the output voltage the same polarity (+, or -).

Topic 3 – Motors and Generators



Electric Motors

An electric motor does the reverse of a generator, it changes electrical energy into mechanical energy. In a motor a current is put into the rotating coil by a battery and the resulting magnetic force attracts and repels the permanent magnet's poles, causing the loop to rotate. When a shaft is connected to the rotating loop it can be attached to other devices and do work.



The carbon brushes remain fixed (i.e. stationary) while the split ring rotates with the shaft of the motor. Every half revolution, each commutator receives current of opposite polarity from the other brush. This reverses polarity every half turn in the coil so that unlike poles are always repelling each other and the rotation continues.

Topic 3 – Practice Questions

Question 1

A split ring commutator is used in a motor to:

a) keep resistance constant.
b) maintain rotation of the shaft.
c) change place with the brushes.
d) reduce friction.

Answer: b

Question 2

Why is a motor described as a generator in reverse?

a) A generator turned around is a motor.
b) A motor reverses direction.
c) A motor changes electrical energy into mechanical energy.
d) A motor reverses current.

Answer: c

Question 3

When current flows through a coil that is free to move in a magnetic field, what will happen?

a) The coil will rotate until unlike poles are lined up.
b) The field will change direction.
c) The coil will spin.
d) The field will strengthen.

Answer: a

Unit 6

Practice Exam Questions for Science – Module 2 – Science Development

This is the second of three sections in the science curriculum for trades entrance science exams. Science – Module 2 – Science Development builds on Science – Module 1 – Science Foundations. Each section 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 sections of the curriculum for any topics that you do not get right. After each answer the sections you should review are identified. Turn to the appropriate section of the curriculum whenever you need help.

The science curriculum is based on "need to know" competencies that are important for trades taking exams at levels 3, 4. 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

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 6 – Practice Exam Questions

Question 1
5.2 cubic feet of a substance has a mass of 240 lbs. What is its density?

a) 12.2 lb / ft^3
b) 1248 lb / ft^3
c) 52 lb / ft^3
d) 46.15 lb / ft^3

Question 2
Which object is more dense: object one weighs 30 g with a volume of 10cm3, object two weighs 65 g and has a volume of 15 cm^3 ?

a) Object one.
b) Object two.
c) Can't tell from this information.
d) They are equally dense.

Question 3
A substance has a density of 19.3 g/cm3. It weighs 9Kg. What is its volume?

a) .05 m^3
b) 171.3 g / cm^3
c) 11.3 g / cm^3
d) .47 g / cm^3

Question 4
The density of an object can be changed by:

a) increasing its temperature.
b) changing its pressure.
c) increasing its weight and decreasing its volume.
d) finding the centre of gravity.

Question 5
The specific gravity of a substance is found by:

a) multiplying its density times one.
b) dividing its density by the volume.
c) multiplying the weight by the specific volume.
d) dividing its density by the density of fresh water.

Question 6
A substance has a specific gravity of .7. How many times more dense is this substance than fresh water?

a) 7 times
b) .7 times
c) 70 times
d) Can't tell from this information.

Unit 6 – Practice Exam Questions

Question 7
Friction is a force that acts on an object over a distance. How do we calculate the amount of work it will take to overcome the force of friction?

a) Multiply force of friction times distance.
b) Divide the work needed by the distance.
c) Multiply the distance times the work and divide by force of friction.
d) Subtract weight from force.

Question 8
What does lubrication do to the coefficient of friction?

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

Question 9
One pair of materials has a coefficient of static friction equal to .78, while a second pair has a coefficient of static friction equal to 1.02. Which pair will require less force to start one moving over the other?

a) The first pair with μ = .78.
b) The second pair with μ = 1.02.
c) Both pairs will require the same amount of force.
d) It is impossible to tell.

Question 10
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.

Question 11
One liquid (a) flows at a rate of 30 ml per minute, and another (b) flows at 15 ml per minute at the same temperature and pressure. Which liquid has the higher viscosity?

a) B
b) A
c) They have the same viscosity because temperature and pressure are the same.
d) A seyboldt viscometer is required to find out.

Unit 6 – Practice Exam Questions

Question 12
Which fluid, when heated, will flow more slowly?

a) Hydrogen
b) Oil
c) Maple syrup
d) Water

Question 13
Energy is neither created nor destroyed. What is this principle called?

a) The equivalence of KE and PE.
b) The principle of thermodynamics.
c) The conservation of energy principle.
d) The net work formula.

Question 14
Force and energy are related by the fact that:

a) net work done equals change in kinetic energy gained by an object.
b) force times distance equals work done on an object.
c) kinetic energy is all important.
d) force is a kind of energy.

Question 15
An inefficient conversion of energy will:

a) harm the environment.
b) cost more.
c) produce energy that cannot be used.
d) all of the above.

Question 16
What is an example of a conversion from mechanical to electrical energy?

a) Eating food.
b) An electric generator.
c) A fire hose.
d) A clock.

Question 17
How does friction affect the actual mechanical advantage of a machine?

a) It increases it
b) It decreases it
c) It doesn't have anything to do with it
d) It depends on lubrication

Unit 6 – Practice Exam Questions

Question 18
What is the theoretical mechanical advantage of a machine that moves a 6 lb load 10 feet when an effort of 30 pounds is applied over 3 feet?

a) .3
b) .30
c) .6
d) 3

Question 19
A worker rolls a drum of oil weighing 400 lbs up an inclined plane that is 6 feet high and 12 feet long. If this plane is friction free, how much effort force must he apply?

a) 160 lbs
b) 72 lbs
c) 240 lbs
d) 200 lbs

Question 20
What is the IMA of the inclined plane in question nineteen?

a) 2.5
b) 1.66
c) 2
d) 3

Question 21
A machine is 35% efficient, and has a TMA of 5. What is its AMA?

a) 3.5
b) 2.5
c) 2.25
d) 1.75

Question 22
A machine can be made more efficient by:

a) decreasing friction.
b) increasing work input.
c) decreasing AMA.
d) increasing work output.

Unit 6 – Practice Exam Questions

Question 23
Five gears are driven by a master gear that rotates clockwise. How will the driven gear rotate?

a) Counter-clockwise.
b) Clockwise.
c) More quickly.
d) More slowly.

Question 24
Which gear system has a larger theoretical mechanical advantage?

a) One with more teeth in the driven gear than the driving gear.
b) One with more teeth in the driving gear than the driven gear.
c) One with more teeth in the idler gear than the driver gear.
d) One with a more powerful motor driving the driver gear.

Question 25
What amount of water will be displaced by a 3000 kg boat?

a) 9 cubic metres
b) 3 cubic metres
c) 300 cubic metres
d) 30 cubic metres

Question 26
How much less will an object appear to weigh in water than in air?

a) The weight of the water pressing down on it.
b) The weight of the water it displaces.
c) The weight of the force times the distance.
d) The weight of the water equal to its volume.

Question 27
A substance has a density of .7 and a liquid has a density of .4. Will the substance float in the liquid?

a) Yes
b) No
c) Partly
d) Can’t tell from this information.

Question 28
The buoyant force on an object is equal to:

a) The weight of the object in water minus it’s weight in air.
b) The pressure exerted by water on the bottom of the object.
c) The weight of the object in air minus it’s weight in water.
d) The volume of the displaced water.

Unit 6 – Practice Exam Questions

Question 29

The force needed to hold a volley ball under water is:

a) greater than the buoyant force.
b) equal to the buoyant force.
c) three times the density of the ball.
d) equal to the volume of the ball.

Question 30

How can we design objects that float?

a) Increase mass.
b) Decrease mass.
c) Increase density.
d) Decrease mass, increase volume, or do both.

Question 31

How much must the temperature of 20 L of a gas be increased to double the pressure if the volume is kept constant?

a) It must be doubled.
b) It must be halved.
c) It must be increased by two thirds.
d) It must be tripled.

Question 32

If the volume is kept constant, and 10 litres of a gas cool from 300 K to 150 K, what will be the pressure at 150 K if it measures 12 psi at 300 Kelvin?

a) 6 psi
b) 12 psi
c) 11.4 psi
d) 10.2 psi

Question 33

Pressure varies with both temperature and volume in a gas. If temperature is held constant, how will the pressure vary with volume?

a) In direct proportion.
b) In inverse proportion.
c) As a factor of two.
d) As a ratio.

Question 34

If the pressure of a gas is doubled from 15 mm Hg to 30 mm Hg, and the volume is kept constant, what was the temperature in Celsius degrees at 15 mm Hg if it measures 300 K at 30 mm Hg?

a) 27°C
b) 150°C
c) –123°C
d) –27°C

Question 35
Which temperature is the same as the boiling point?

a) The temperature of fusion.
b) The temperature of evaporation.
c) The temperature of condensation.
d) The temperature of melting.

Question 36
When a liquid boils the amount of heat being added can accelerate the phase change from a liquid to a gas because:

a) the temperature goes up dramatically as heat is increased.
b) the vapour pressure increases dramatically.
c) the latent heat of vaporization is transferred more quickly to the liquid.
d) the volume of the liquid is dramatically reduced.

Question 37
Salt is used to melt ice because:

a) It lowers the vapour pressure of the water.
b) It lowers the freezing point of ice.
c) It takes heat away from the ice.
d) It raises the freezing temperature of water.

Question 38
When a liquid reaches its freezing point it will begin to:

a) gain heat energy.
b) lose heat energy.
c) gain temperature.
d) make a phase change depending on whether heat energy is being lost or gained.

Question 39
A hydraulic press with a mechanical advantage of 10 moves the output piston 10cm. How far did the input piston have to move?

a) 20 cm
b) 2 cm
c) 100 cm
d) 10 cm

Question 40
40 pounds per square inch of pressure is applied to the 10 square inch surface of an oil reservoir in a hydraulic press. If this amount of pressure can support 400 pounds of resistance, what is the area of the output piston?

a) 10 in^2
b) 100 in^2
c) 400 in^2
d) 50 in^2

Question 41
If the area of the output piston in a hydraulic press is greater than the area of the input piston, what will be true about the output force?

a) It will be equal to the input force.
b) It will be less than the input force.
c) It will be greater than the input force.
d) It will double the input force.

Question 42
Potential energy is changed into kinetic energy when a stone rolls down a hill because:

a) the stone moved and did work.
b) the gravitational energy was stored.
c) the stone gained kinetic energy.
d) the stone lost kinetic energy.

Question 43
Which is not a form of kinetic energy?

a) Doing work.
b) Heating a dinner.
c) Lighting a room.
d) Gravity.

Question 44
Kinetic energy can not be increased by:

a) heat.
b) putting an object 100 feet in the air.
c) the radiant energy of the sun.
d) increasing speed.

Unit 6 – Practice Exam Questions

Question 45

Potential Electrical energy is released when a lightning bolt strikes the ground. What is moving from the sky to the earth?

a) An electric charge.
b) A convection current.
c) A wave.
d) Gravitational force.

Question 46

A stone is lifted and dropped on a stake to drive it into the ground. What does the kinetic energy of the stone depend on?

a) The temperature of the stone.
b) The height of the stone above the stake.
c) Its speed.
d) The weight and height of the stone above the stake.

Question 47

A force of 100 pounds is required to push a wheelbarrow of concrete 50 feet. How much work is done?

a) 5000 lbs
b) 500 ft./lb
c) 500 Newton/metres
d) 2 foot pounds

Question 48

How much work is being done by a man who holds a 2 pound flashlight 4 feet above the ground for 20 minutes in thirty below weather?

a) 60 foot pounds
b) 8 foot pounds
c) No work is done
d) 11 foot pounds

Question 49

How much work is done by 50 pounds of force that moves a fence post 6 inches into the ground?

a) 300 inch pound
b) 25 foot pounds
c) 56 Newton/metres
d) 300 joules

Unit 6 – Practice Exam Questions

Question 50
How much force was applied to a rock that moved 10 metres after 500 joules of work was done on it?

a) 5000 pounds
b) 5000 Newtons
c) 50 Newtons
d) 500 Newtons

Question 51
How far did a car move if 300 foot pounds of work was done on it by an applied force of 150 pounds?

a) 2 feet
b) 450 feet
c) 20 feet
d) 4500 feet

Question 52
How much output work is done by a machine if a resistance of 300lb is moved 10 feet?

a) 30 ft. lb.
b) 300 ft. lb.
c) 3000 ft. lb.
d) 310 ft. lb.

Question 53
What effect does temperature have on the resistance of a wire?

a) None.
b) The resistance increases with temperature.
c) The resistance decreases with temperature.
d) The resistance doubles with temperature.

Question 54
An ohmmeter measures:

a) voltage.
b) current.
c) kilowatts.
d) electrical resistance.

Unit 6 – Practice Exam Questions

Question 55
When two 6 volt batteries are connected in series, what happens to the voltage?

a) It adds up to 12 volts.
b) It stays at 6 volts.
c) It heats the wires.
d) It adds up to 36 volts.

Question 56
A frayed wire is dangerous because:

a) it can cause a short circuit.
b) it will heat up.
c) it will break.
d) it will insulate the resistance.

Question 57
A thermocouple will produce a voltage only when:

a) the two metals are heated uniformly.
b) there is a temperature difference between the two ends.
c) the metals are pre heated.
d) the metals are used to detect a voltage.

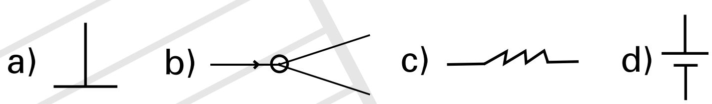
Question 58
What happens when two 6 volt batteries are connected in series?

a) The resistance adds up.
b) The current adds up.
c) The voltage adds up.
d) The temperature increases.

Question 59
A switch is used in a circuit to:

a) Increase current
b) Decrease voltage
c) Open and close the circuit
d) Prevent shorts

Question 60
What is the symbol for a battery in a circuit diagram?



Unit 6 – Practice Exam Questions

Question 61
The equivalent resistance in a series circuit is:

a) the product of the individual resistances.
b) the sum of the individual resistances.
c) the difference between the individual resistances.
d) the sum of the current through each resistance.

Question 62
A circuit will not conduct current if:

a) the breaker is open.
b) the resistances are in series.
c) the battery is connected.
d) the wire has junctions.

Question 63
A junction allows current to be:

a) distributed to more than one path.
b) returned to the battery.
c) divided after each resistance.
d) put into a parallel circuit.

Question 64
The current entering a junction is 27 amps. The current leaving the junction follows three branches. How many amps will travel down each branch?

a) 81
b) 27
c) 9
d) 3

Question 65
The electrical potential measured for a 12 volt battery is 0 volts. When this battery is connected to a circuit with two 4 amp bulbs in series, what will be the voltage across each bulb?

a) 3 volts
b) 8 volts
c) 12 volts
d) 0 volts

Question 66
What force is needed to balance a lever 5 feet from the fulcrum that has 10 kg 3 feet from the fulcrum on the opposite side of the fulcrum?

a) 30 kg
b) 6 kg
c) 5 kg
d) 15 kg

Question 67
What is the mechanical advantage of a lever that uses 15 N to lift 10 N?

a) .33
b) 5
c) 2.6
d) .66

Question 68
When three bulbs are wired in parallel, how many amps will each receive in a 12 volt 5 amp circuit?

a) 2.2 amps
b) 7 amps
c) 5 amps
d) 17 amps

Question 69
If you want to reduce the total resistance in a circuit, how would you connect three bulbs?

a) In series.
b) In parallel.
c) One at a time.
d) In alternation.

Question 70
What does the joule measure?

a) Force.
b) Work.
c) Resistance.
d) Friction.

Unit 6 – Practice Exam Questions

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

Unit 6 – Practice Exam Questions

Answers	Study Topics
31) a	Unit 2, Topic 3
32) a	Unit 2, Topic 3
33) b	Unit 2, Topic 3
34) c	Unit 2, Topic 3
35) c	Unit 3, Topics 1 and 2
36) c	Unit 3, Topic 4
37) b	Unit 3, Topics 2 and 3
38) d	Unit 3, Topics 1 and 3
39) c	Unit 4, Topic 4.E
40) a	Unit 4, Topic 4.E
41) c	Unit 4, Topic 4.E
42) a	Unit 4, Topic 4
43) d	Unit 4, Topics 1 and 2
44) b	Unit 4, Topic 1
45) a	Unit 4, Topic 1
46) d	Unit 4, Topic 1
47) b	Unit 4, Topic 1
48) c	Unit 4, Topic 1
49) b	Unit 4, Topics 1 and 2
50) c	Unit 4, Topic 1
51) a	Unit 4, Topic 1
52) c	Unit 4, Topic 1
53) b	Unit 5, Topic 1
54) d	Unit 5, Topic 2
55) a	Unit 5, Topic 1
56) a	Unit 5, Topic 1
57) b	Unit 5, Topic 1
58) c	Unit 5, Topic 2
59) c	Unit 5, Topic 2
60) d	Unit 5, Topic 2

Unit 6 – Practice Exam Questions

Answers	Study Topics
61) b	Unit 5, Topic 2
62) a	Unit 5, Topic 2
63) a	Unit 5, Topic 2
64) c	Unit 5, Topic 2
65) d	Unit 5, Topic 1
66) b	Unit 4, Topic 4.B
67) d	Unit 4, Topic 4.B
68) c	Unit 5, Topic 2
69) b	Unit 5, Topic 2
70) b	Unit 3, Topic 2

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Appendix: Alberta List of Competencies

Part Two of this science curriculum, Science Development, reviews the following core requirements from the Alberta trades entrance curriculum. The numbers in brackets indicate the exam levels that include these competencies.

Outcome: Recognize the potential dangers of electricity. (3, 4)

1. Assess the potential danger of an electrical device by referring to the voltage and amperage of the device.
2. Distinguish between devices that might be used safely in experimental studies and those that would not be appropriate.
3. Recognize dangerous procedures.
4. Recognize equipment that is in an unsafe condition for use. (D. The Production of Current Electricity Based on Chemical, Photoelectric or Thermoelectric Principles.

Outcome: Describe specialized technologies for the production of current electricity based on chemical, photoelectric or thermoelectric principles. (3, 4)

1. Describe the general design and function of a simple wet cell.
2. Describe a process for testing the effectiveness of different materials for use within a wet cell.
3. Describe the design of cells and batteries in common usage.
4. Identify practical problems that designers of batteries have attempted to solve, and describe approaches that have been used to solve these problems
5. Construct a thermocouple and demonstrate its effectiveness.
6. Identify practical applications appropriate for the use of photoelectric or thermoelectric devices. (E. Conversion of Energy

Outcome: Demonstrate how electromagnetic effects provide a means for conversion of mechanical energy to electrical energy, or electrical energy to mechanical energy. (3, 4)

1. Describe evidence of electromagnetic effects.
2. Construct a simple galvanometer using a compass and wire.
3. Use a meter to measure voltages and amperages within a circuit.
4. Demonstrate the generation of electricity by movement of a magnet through a coil.
5. Interpret the operation of a simple generator.
6. Describe the design of a simple electric motor.

7. Interpret the operation of an electric motor.
8. Design and construct a device that operates on the basis of electromagnetic force. (F. Electrical Devices Are Based On Circuits

Outcome: Demonstrate that electrical devices are based on circuits. (3, 4)

1. Construct a simple circuit using materials provided.
2. Design and construct series and parallel circuits.
3. Predict the effects of linking electrical loads in series and in parallel.
4. Use materials provided to design a circuit that will perform a given function.
5. Construct and interpret circuit diagrams.
6. Identify short circuits in a sketch of a circuit or in an actual circuit. (G. Electrical Resistance)

Outcome: Explain how electrical resistance can be used to control the flow of electricity in a circuit or to produce heat and light. (3, 4)

1. Construct and use a simple variable resistor with materials provided.
2. Describe the effect of resistance on electron flow in a simple circuit.
3. Predict the effects of resistors on electron flow in series and parallel circuits.
4. Interpret the design of devices that produce heat and light based on electrical resistance. (H. Electromechanical Systems

Outcome: Describe how electromechanical systems can be designed to perform simple or complex functions. (3, 4)

1. Describe the operation of various kinds of switches and control devices; use these in a simple circuit.
2. Design a circuit that will perform a function then shut off when the function has been completed.
3. Design a circuit that will perform one function and proceed to a second function when the first is completed.
4. Design a circuit that will respond to a changing environmental condition.
5. Recognize systems and subsystems within household electromechanical devices.
6. Interpret the function and operation of electronic control devices in common domestic applications.

E. Power Transmission Within A System

Outcome: Describe the various kinds of linkages used to transmit power between different parts of a system. (3, 4, 5)

1. Identify the source of power in some familiar mechanical devices.
2. Identify power linkages within a mechanical system.
3. Analyze a gear system to identify the effect of different gear ratios on relative speeds of a driving and driven shaft.
4. Build or adapt a mechanical system to provide for different turning ratios between a driving and a driven shaft. (F. Energy Conversion)

Outcome: Explain how mechanical systems convert energy from one form to another. (3, 4, 5)

1. Identify examples of energy conversion.
2. Identify modifications to a device that would enable it to use more than one form of energy input. (G. Mechanical Efficiency)

Outcome: Identify ways to improve the efficiency of mechanical devices often through changes in design and by alterations that reduce friction. (3, 4, 5)

1. Construct a device that makes efficient use of energy.
2. Identify changes in the design of a mechanical device that would improve its overall efficiency.
3. Identify improvements in the design of a mechanical device that would improve its safety and ease of operation.
4. Improve the efficiency of a device by troubleshooting.
5. Interpret information on energy efficiency of different devices or products.
6. Identify impacts of inefficient energy use on environments and resources.

F. Heat As Energy Gain Or Loss

Outcome: Define the term "heat" as used in reference to energy gained or lost by a material as it interacts with other materials. (3, 4, 5)

1. Recognize heat gain or heat loss in practical activities.
2. Distinguish between heat and temperature.
3. Interpret temperature changes in terms of particle theory.
4. Identify heat losses or gains in terms of number of joules. (G. Movement of Heat)

Outcome: Explain the movement of heat energy from hot bodies to cooler ones. (3, 4, 5)

1. Predict temperature changes that will result from mixing various quantities of water of different temperatures.
2. Interpret information regarding the specific heats of materials.
3. Compare the specific heat of solids, liquids and gases. (H. Heat Transfer)

Outcome: Describe heat transfer by conduction, convection and radiation. (3, 4, 5)

1. Interpret conduction and convection in terms of particle theory.
2. Compare conduction rates of materials based on experimental data.
3. Identify and interpret applications of heat conduction.
4. Predict the flow pattern of a fluid as it is heated.
5. Identify and interpret applications of heat convection.
6. Identify factors that affect rates of radiation.
7. Identify and interpret examples of heat radiation. (I. Control of Heat Transfer)

Outcome: Describe how heat transfer can be controlled through selection of appropriate materials and by use of appropriate design. (3, 4)

1. Identify applications in which heat transfer is controlled.
2. Design and construct an insulated container.
3. Compare the effectiveness of alternative materials and designs for heat transfer in domestic applications.
4. Compare the effectiveness of alternative materials and approaches to insulation in domestic applications.
5. Interpret the effect of clothing materials and design on the retention or transfer of heat.
6. Describe and demonstrate a technique for comparing the effectiveness of different kinds of insulating materials.
7. Identify effective insulating materials. (J. Solar Heat)

Outcome: Explain the absorption and transfer of energy from solar radiation. (3, 4)

1. Describe general principles of passive and active solar heating.
2. Identify functions of components used in a solar heating system.
3. Design and construct a model solar heating device.

B. Properties Of Liquids And Gases

Outcome: List the fluid properties liquids and gases exhibit that are significant to their application in technological devices. (3, 4, 5)

1. Describe the compressibility of liquids and gases.
2. Interpret the compressibility of liquids and gases in terms of particle theory.
3. Compare the viscosity of different liquids by use of a simple lab test.
4. Predict the effects of temperature changes on viscosity of fluids.
5. Recognize flow rates as an indicator of the viscosity of liquids.
6. Identify applications where viscosity of fluids is a significant.
7. Distinguish between applications that require a compressible fluid (gas) and applications that require a non-compressible fluid. (C. Forces Within Fluids)

Outcome: Explain how forces within fluids are transferred in all directions. (3, 4, 5)

1. Describe the response of fluids to gravity.
2. Predict the response of fluids to external pressure.
3. Recognize the relationship between gravity and buoyancy.
4. Measure a buoyant force.
5. Construct and calibrate a simple hydrometer.
6. Use a hydrometer in measuring the density of a liquid.
7. Predict changes in liquid density that result from temperature changes and from changes in solution concentration.
8. Predict changes in buoyant force that result from changes in fluid density.
9. Identify and interpret technologies that are based on buoyant. (D. Hydraulic Systems)

Outcome: Explain how hydraulic systems provide the basis for the application and transfer of forces. (3, 4, 5)

1. Determine the force exerted on a surface based on knowledge of pressure and surface area.
2. Predict changes in force exerted resulting from an increase in the surface area over which pressure acts.
3. Explain the need for strength in pressurized vessels.

E. Technologies Used In The Movement And Control Of Fluids

Outcome: Describe various technologies used in the movement and control of fluids. (3, 4, 5)

1. Identify fluid systems in living things and manufactured devices.
2. Interpret the function of fluid systems within living things and manufactured devices.
3. Construct a diagram to illustrate components in a fluid system.
4. Construct a functional fluid system using materials provided.
5. Interpret the operation of various kinds of valves.
6. Interpret the operation of valves in the human heart.
7. Interpret and explain the operation of pumps. (F. Aerodynamic and Hydrodynamic Design)

Outcome: Explain how the study of fluid movement has led to development of aerodynamic and hydrodynamic design. (3, 4, 5)

1. Predict the effect of design on drag around an object traveling through a fluid.
2. Design a streamlined device.