Science 7/8 Unit B: Systems in Action

Textbook chapters: Pearson 8, Ch4,5,6.

Big Ideas to take away from this unit:

- Systems are designed to accomplish tasks
- All systems include an input and an output
- Systems are designed to optimize human and natural resources

Overall Expectations to compare your knowledge an understanding to as we go through the unit:

1. Assess the personal, social, and environmental impacts of a system, and evaluate improvements to a system and/or alternate ways of meeting the same needs.
2. Investigate a working system and the ways in which components of the system contribute to its desired function.
3. Demonstrate an understanding of the different types of systems and the factors that contribute to their safe and efficient operation.

A **system** is a group of individual parts or procedures that work together to accomplish a desired task. All different parts of a system are called **components**. There are two categories of systems:

- **Mechanical systems** are composed of physical parts working together. (Ex?)
- **Non-mechanical systems** are composed of a set of procedures, methods, or rules that accomplish a task (Ex?)

Some systems occur naturally (like?), and some are developed to meet the needs of society (like?).

Class discussion: Activity B2 (page 92).

Sub-unit: Mechanical Systems use forces to transfer energy (Force, Work, Energy, and Mechanical Advantage)

What are some examples of mechanical systems?

A **force** is a push or pull that acts on an object. What are some examples?

Forces can be classified as either **contact forces** or **non-contact forces**. Contact forces mean that the object they are acting on must be in contact (ex. Hitting a tennis ball). **Friction** is a force that opposes the relative motion of an object (ex?). Non-contact forces can push or pull an object without being in direct contact (ex. Gravity, static electricity, magnetism). The most common example of non-contact forces is **gravity**, which is the attraction between two objects due to their mass. The amount of attraction depends on the mass of each object (proportional to each mass) and the distance between the two objects (inversely proportional to the distance). (Ex)

Mass is the amount of matter in an object. Mass is measured in kilograms (kg), and variations on the kg like grams and metric tons. Since mass is the amount of matter in an object, it does not change as a result of gravity. Ex. Your mass on the moon is the same as it is on Earth.

Weight is the force of gravity acting on an object. Alternatively, weight is equivalent to the force of gravity on an object. Therefore, weight does change as a result of gravity. Ex. Your weight would be less on the Moon than it would be on Earth.

Force is measured with the Newton (N), named after Sir Isaac Newton (1643-1727) who first theorized gravity and is the author of Newton's 3 Laws of motion (a tale for another grade!). Newton was an isolated individual – revered as one of the great thinkers of his time, but prone to anxiety and paranoia. There is also significant evidence that he was gay (he never married, but "had a very close friendship with" Swiss mathematician Nicolas Fatio de Dullier). Read more about his life here: https://www.biography.com/scientist/isaac-newton

What are some common ways to measure weight and/or force?

- **Spring scales** consist of a spring with a hook on the end. As more force is applied to the hook, the spring stretches farther. Each spring scale is calibrated to show the force as it relates to the distance of stretch. What can we measure with spring scales?

Mass and weight are proportional. Ie. If object A has twice the mass of object B, it also also twice the weight. For an object on Earth, the force of gravity, in Newtons, is the product of the object's mass, in kilograms, and the gravitational field as measured on the surface of the Earth - so a 1.0kg mass has a weight of 9.8N, a 2.0kg mass has a weight of 19.9N, etc. So if you multiply any mass by 9.8N, you have the weight on Earth. This is called the gravitational field strength, and on Earth we use $g = 9.8Nkg^{-1} = 9.8ms^{-2}$. We can also write this as:

$$(Weight\ in\ Newtons) = (Mass\ in\ kilograms) \times (Earth's\ gravitational\ field\ strength)$$
$$\rightarrow F_{E\ on\ m} = mg$$

Let's compare!

Location (surface)	Mass (kg)	Weight (N)	Weight (lbs)
Earth ($\sim 6 \times 10^{24} kg$)	50	490	110
Moon ($\sim 7 \times 10^{22} kg$)	50	80	18
Mars ($\sim 6 \times 10^{23} kg$)	50	160	36
Jupiter ($\sim 2 \times 10^{27} kg$)	50	1140	256

What is *g* in each case?

Lab: Combine B7 and B8

Work is done when a force causes something to move and energy is transferred. Alternatively, it is the amount of effort spent when a force causes an object to move a distance. (Ex?)

Energy is the ability to do work.

The units for energy are Joules (J), named after James Joule (1818-1889). He worked in his family's brewery, and made a lab there. (https://www.britannica.com/biography/James-Prescott-Joule)

Whenever work is done on an object, there is a change in the object's energy. When work is done, energy is transferred from one object to another, and may even change form. During any transfer of energy, the total amount of energy remains constant – energy cannot be created or destroyed. This is the **law of conservation of energy**.

What forms of energy are there?

- Kinetic energy is the energy due to an object's motion. (Ex. Electricity, thermal)
- Potential energy is stored energy. (Ex. chemical)

Gravitational potential energy is the potential energy of an object that is able to fall (Ex?).

What kind of energy does friction create? Does friction do work?

All mechanical systems include frictional forces. As energy is transferred by a mechanical system, some amount of thermal energy is always produced.

Work and energy are both measured by the Joule. When a force causes an object to move a distance in the same direction as the force, then we can calculate work with:

$$(Work\ in\ Joules) = (Force\ in\ Newtons) \times (Distance\ in\ metres)$$
$$\rightarrow W = Fd$$

Ex1. Jennifer pushes a box with a force of 150N and the box moves 3.0m. How much work does Jennifer do on the box? If the box is 25kg, how much work will it take Jennifer to lift the box from the floor to 2.0m in the air?

Ex2. Simon lifts a rock 1.5m by applying a force of 20N. How much work does Simon do on the rock?

A **machine** is a mechanical system that reduces the force required to accomplish work. (Ex?)

Machines make work easier by:

- increasing the force that can be applied to an object (Ex. Nutcracker (pg 114))
- increasing the distance over which the force is applied (Ex. Ramp)
- changing the direction of the force (Ex. Pulley)

The force applied to the machine is called the **input force** (F_{in}), and the force applied by the machine is called the **output force** (F_{out}). Sometimes these are called the effort force and load force, respectively.

<u>Class discussion: B16 (page 116)</u>

The amount by which a machine can multiply an input force is called **mechanical advantage**.

Mechanical advantage can be calculated by $MA = \frac{F_{out}}{F_{in}}$. It does not have specific units, and as such the numerator and divisor can be in any units but must be in the same units as each other (why? Can we extend this to any ratio we come across in this unit?).

Ex 1. Wei pushes on the handle of a car jack with a force of 250N and the jack applies 3000N to the car. What is the mechanical advantage of this car jack?

Ex 2. Jason and his wheelchair have a total weight of 910N. A force of 130N is required to push Jason up the ramp into a TTC bus. What is the mechanical advantage of the ramp?

What does a mechanical advantage of 1 mean? If a machine has a mechanical advantage of 1, is it still useful?

The mechanical advantage of a machine that has no friction is the **ideal mechanical advantage (IMA)**. (Is this possible?) The ideal mechanical advantage can be found by finding the ratio between the distance over which the input force is applied (d_{in}) and the distance over which the output force is exerted on the object (d_{out}). When can calculate ideal mechanical advantage with:

$$(Ideal\ mechanical\ advantage) = \frac{input\ distance}{output\ distance}$$

$$\rightarrow IMA = \frac{d_{in}}{d_{out}}$$

Ex1. Padma uses a hammer to pull a nail. If she moves the handle of the hammer 30cm and the nail moves 5.0cm, which is the ideal mechanical advantage of the hammer?

No real machines have zero friction, however certain machines have very little friction because they don't have any sliding parts. For machines like the hammer, the mechanical friction is very close to the ideal mechanical friction (other examples?).

What does an ideal mechanical advantage of 1 or less than 1 mean? Could these machines still be useful? (->increased speed, hockey sticks, rakes)

Lab: B20, modified -> use

http://www.glencoe.com/sec/math/t_resources/lab_manual/pdfs/mac3_04/scimath_lab13.pdf take home and then do in class.

Sub unit – Mechanical systems involve machines that are designed to do work efficiently (simple machines and mechanisms, efficiency, design, and construction)

A **mechanism** is made up of several different types of machines that work together to perform a specific function. A **simple machine** is a machine that requires the application of single force to do work (Ex?).

Class discussion: B24 (page 130)

There are six types of simple machines: (figure5.6, page 131)

- lever
- pulley
- wheel and axle
- inclined plane
- screw
- wedge

A **lever** is a rigid bar that is supported at one point, called the **fulcrum**. Levers can be classified into three categories, which are defined by the location of the fulcrum:

1. **First class lever**: the fulcrum is always between the input and output forces. Additionally, the output force is always in the opposite direction to the input force. (ex)
2. **Second class lever**: the fulcrum is at the very end of the lever, away from the input force. The input and output forces are in the same direction. (Ex, bottle opener)
3. **Third class lever**: the fulcrum is at the end of the lever, with the input force between the fulcrum and output force, and the input and output forces are in the same direction. (ex. Rake). A third class lever always produces a mechanical advantage less than 1 (what does this mean?).

The ideal mechanical advantage of simple machines can be determined without measuring the input and output forces. (When is ideal mechanical advantage a good approximate for mechanical advantage?). The ideal mechanical advantage of a lever can be calculated by dividing the length of the **input arm**, which is the distance between the location of the input force to the fulcrum, by the length of the **output arm**, which is the distance from the location of the output force to the fulcrum.

$$Ideal\ Mechanical\ Advantage = \frac{length\ of\ input\ arm}{length\ of\ output\ arm}$$

$$\rightarrow\ IMA = \frac{L_{in}}{L_{out}}$$

For example: Jasmine tries to lift a rock using a 1st class lever made of a smaller rock and a stick. The stick is 2m long in total, and the fulcrum lies on the small rock 0.5m up from the large rock. What is the ideal mechanical advantage?

Class discussion: B26 (pg 135), Take it Further

A **pulley** is a grooved wheel with a rope or cable looped around it, with the wheel free to spin. A pulley can change the direction of the force OR increase the output force. **Fixed pulleys** change only the direction of the force (what is the ideal mechanical advantage?). **Moveable pulleys** (with one end of the rope of cable fixed instead) double the input force due to the tension in the rope (what is the ideal mechanical advantage? Figure 5.18). In general, the IMA of a pulley is equal to the number of support ropes (why?,Ex. Figure 5.19).

The **wheel and axle** are a shaft (axle) that is attached to a disk (wheel). (Ex. Screw driver -> handle is the wheel, shaft is the axle, other examples?). The wheel and axle rotate around the centre of the axle, and so the IMA depends on where the input force is applied. (If you want a high IMA, where should you apply the input force?) An input force can be applied to either the wheel or the axle, giving different results. Therefore, we have two ways to calculate the IMA for a wheel and axle:

Input force applied to the axle: the ideal mechanical advantage is less than one (why?) and can be calculated by dividing the radius of the axle by the radius of the wheel $Ideal\ Mechanical\ Advantage = \frac{radius\ of\ axle}{radius\ of\ wheel}$ $\rightarrow IMA = \frac{r_a}{r_w}$	Input force applied to the wheel: the ideal mechanical advantage can be calculated by dividing the radius of the wheel by the radius of the axle $Ideal\ Mechanical\ Advantage = \frac{radius\ of\ wheel}{radius\ of\ axle}$ $\rightarrow IMA = \frac{r_w}{r_a}$

Ex. The handle of a garden tap has a radius of 3.0cm and is connected to a shaft of radius 0.50cm. What is the IMA?

An **inclined plane** is a sloping surface on which an object can move (ex). A **ramp** is another name for an inclined plane, and while it reduces the force needed to move, the distance over which the movement must happen has increased. The ideal mechanical advantage of a ramp can be calculated by dividing the length of the ramp by the height of the ramp:

$$Ideal\ Mechanical\ Advantage = \frac{length\ of\ ramp}{height\ of\ ramp}$$

$$\rightarrow IMA = \frac{l}{h}$$

Ex. A box of toy cars is raised 1.0m by pushing it along a loading ramp 6.0m long. What is the IMA?

An extension of the inclined plane is a **screw**, which is an inclined plane wrapped around a rod. The inclined plane is called the **thread**, and its length is much greater than that of the screw. (what does that mean for it's MA? Ex?)

A **wedge** is an inclined plane that travels through an object or material. The longer and narrower the wedge, the greater the MA (why?, Ex?).

Two or more simple machines that operate together form a mechanism, which can further be classified as mechanical systems.

Lab B27

Class discussion: B28 (if there's time)

The work done by a machine is less than the work put into the machine. (why?)

Class discussion: B30

The **efficiency** of a machine can be calculated by dividing the output work by the input work. The **useful output work** is the work that the machine is designed to perform. (which is larger and why?).

Some of the input energy is always converted into heat and other forms of energy. In particular, the moving parts in a machine will always have friction that converts some of the input energy into heat.

A machine's efficiency can be increased by reducing the friction that produces heat. An ideal machine is one in which there is no friction, and can never truly exist.

Efficiency can be calculated by dividing the useful output work by the input work:

$$Efficiency = \frac{useful\ output\ work}{input\ work} \times 100\%$$

$$\rightarrow Efficiency = \frac{W_{out}}{W_{in}} \times 100\%$$

Ex1. A machine is capable of doing 35J of work when 50 J is put into the machine. What is the efficiency?

Ex2. (Combine knowledge) A 500N crate is moved up a 5.0m long ramp. What is the efficiency of the ramp if the person pushes with a force of 400N in order to raise the crate 2.0m?

Ex3 B31.

Class discussion: Table 5.3

What are some ways to reduce friction in machines? (Ex. When physical parts are in contact and sliding vs non-contact like light bulbs).

Sub-unit: Systems have an impact on our society (non-mechanical systems)

Class discussion: B35

As in a mechanical system, components of a non-mechanical system interact to perform a task. Specifically, components must interact in an organized manner, which is normally overseen by a person, company, or government.

Many non-mechanical systems are designed because of the needs of society. (examples?)

Once a system is in place, it needs to be monitored frequently to make sure it is meeting the needs of its **consumers**, or individuals who use the goods and services provided by a system. Consumers must be provided with information and support on how to use the system. Information and support are required to keep a system working efficiently (why?).

Productivity is the amount of output that is produced per unit of time. Increased productivity allows a task to be accomplished faster or allows more tasks to be done at the same time.

<u>Class discussion: B41+B42, compare the pros and cons and productivity of the building of the 2 tunnels and physical vs. mall shopping.</u>

In the past, many consumer goods were made by hand (Ex), however now many are produced by a system called **mass production**, in which each employee repeatedly performs a small task on a conveyor belt. The system (raw materials to final product) is called an **assembly line**. This results in products being made faster and for less cost, however they are usually lower in quality.

An **automated system** replaces human workers with machines that operate without human intervention, say by being controlled by a computer. (Ex)

Automation has had an impact on our society, the environment, and our economy. A **social impact** is how automation affects how people live, work, and interact with each other in society. **Economic** impacts are regarding money. **Environmental** impacts are how automation affects biotic and abiotic elements of ecosystems. (What are some that you can think of?)

Criteria are standard rules or tests on which a decision or judgement can be based. The criteria for assessing a system includes efficiency, safety, cost, and impact on the environment. They may be assessed **quantitatively** (analysis of numerical data, Ex?) and/or **qualitatively** (made by observations and general trends, Ex?).

When considering alternative ways of meeting the needs of society, we must assess both the current system and the proposed system.

<u>Class discussion: transporting groceries and food (pg. 169-170)</u>