Module 7.1

Energy Transfer and Transformations
What is the role of energy in our world?

CT Science Framework Topics

Energy Transfer and Transformations – What is the role of energy in our world? **7.1 - Energy provides the ability to do work and can exist in many forms.** ♦ Work is the process of making objects move through the application of force. ♦ Energy can be stored in many forms and can be transformed into the energy of motion.	**C 12.** Explain the relationship among force, distance and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. **C 13.** Explain how simple machines, such as inclined planes, pulleys and levers, are used to create mechanical advantage. **C 14.** Describe how different types of stored (potential) energy can be used to make objects move.

SCIENCE CONTENT STANDARD 7.1

CONCEPTUAL THEME: *Energy Transfer and Transformations – What is the role f energy in our world?* CONTENT STANDARD: **7.1 – Energy provides the ability to do work and can exist in many forms.**	**GRADE-LEVEL CONCEPT** 1: ◆ Work is the process of making objects move through the application of force. **GRADE-LEVEL EXPECTATIONS:** 1. In order for an object to change its motion, a push/pull (force) must be applied over a distance. 2. Forces can act between objects that are in direct contact, such as pulling directly on a string or friction acting on a sliding block. Forces can act over a distance, such as gravity or magnetism. Forces are measured in newtons or pounds using scales. 3. Work is a scientific concept that expresses the mathematical relationship between the amount of force needed to move an object and how far it moves. For work to be done, a force must be applied for a distance in the same direction as the motion. An object that does not move has no work done on it, even if forces are being applied. 4. Work (measured in Joules) is calculated by multiplying the force (measured in newtons) times the distance (measured in meters). When an object is lifted, the work done is the product of the force of gravity (weight) times the height the object is lifted. The amount of work done is increased if more force is applied or if the object is moved a greater distance. 5. Simple machines can be used to move objects. People do "input" work on a simple machine which, in turn, does "output" work in moving an object. Simple machines are not used to change the amount of work to move or lift an object; rather, simple machines change the amount of effort force and distance for the simple machine to move the object. 6. Simple machines work on the principle that a small force applied over a long distance is equivalent work to a large force applied over a short distance. 7. Some simple machines are used to move or lift an object over a greater output distance (snow shovel), or change direction of an object's motion, but most are used to reduce the amount of effort (input force) required to lift or move an object (output force). 8. An inclined plane is a simple machine that reduces the effort force needed to raise an object to a given height. The effort force and distance and output force and distance depend on the length and height (steepness) of the inclined plane. 9. A pulley is a simple machine that reduces the effort force needed to lift a heavy object by applying the force through a greater distance (pulling more rope through the pulley). The effort force and distance, output force and distance, and direction of motion all depend on the number of pulleys and their position. 10. A lever is a simple machine that reduces the effort force needed to lift a heavy object by applying the force at a greater distance from the fulcrum of the lever. The effort force and distance,	**CMT EXPECTED PERFORMANCES** **C.12** Explain the relationship among, force, distance, and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. **C.13** Explain how simple machines, such as incline planes, pulleys and levers, are used to create mechanical advantage. **C14.** Describe how different types of stored (potential) energy can be used to make objects

	output force and distance, and direction of motion all depend on the position of the fulcrum in relationship to the input and output forces. 11. The mechanical advantage of a simple machine indicates how useful the machine is for performing a given task by **CONTENT STANDARD 7.1 - continued** comparing the output force to the input force. The mechanical advantage is the number of times a machine multiplies the effort force. The longer the distance over which the effort force is applied, the greater the mechanical advantage of the machine. 12. The mechanical advantage of a machine can be calculated by dividing the resistance force by the effort force. Most of the time the resistance force is the weight of the object in newtons. 13. Simple machines always produce less work output than work put in, because some motion energy is converted to heat and sound energy by friction. **GRADE-LEVEL CONCEPT** 2: ◆ Energy can be stored in many forms and can be transformed into the energy of motion. 1. Energy is the ability to cause objects to change position (motion). Energy exists in different forms, such as potential, kinetic, heat, electrical, light, sound, all of which can be measured in different units, such as Joules, Calories, BTUs or kilowatt-hours. 2. Energy can be stored for future use (potential energy), and it exists in several forms; for example, gravitational energy (lifting an object up a hill), elastic energy (winding a rubber band) and chemical energy (eating food). When the object later moves, the potential energy changes into the energy of motion (kinetic energy). 3. Energy can be changed (transformed) from one form to another. For example, potential chemical energy of foods, which is often measured in Calories, is transformed by cells into heat, electrical and kinetic (motion) energy used in the body. 4. When energy is transformed, the total amount of energy stays constant (is conserved). Work is done to lift an object, giving it gravitational potential energy (weight x height). The gravitational potential energy of an object moving down a hill is transformed into kinetic energy as it moves, reaching maximum kinetic energy at the bottom of the hill. Some kinetic energy is always transformed into heat by friction; therefore, the object will never reach the same height it started from again without added energy. **SCIENTIFIC LITERACY TERMINOLOGY:** Force, friction,	move.

	gravity, weight, newton, scale, work, Joule, effort (input) force, output force, simple machine, lever, fulcrum, pulley, inclined plane, mechanical advantage, energy, potential energy, kinetic energy, energy transformation, conservation of energy.	

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MODULE 7.1 ENERGY TRANSFER AND TRANSFORMATIONS

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GLOSSARY AND BACKGROUND

Energy: is an amount of activity in things. Or, it is the amount potential energy that is stored ready to make activity. A stretched rubber band has energy stored in it. A heavy object has energy stored in it as it is in a position to fall, this amount stored is equal to the weight of the object multiplied by the height it may fall.

Force: a push, pull, or other action between two objects. Forces can be large, small, and in between. Forces can make objects move and can change the objects movement. A force that makes something move faster is adding energy to the motion. A force that slows something down is taking energy out of the object's motion.

Friction: is a force that slows an object down or stops an object from moving. Friction takes energy out of a moving object. This energy is often heard as sound or felt as heat. The sound of the 'F' in Friction reminds us of the sound of rubbing. Rub your hands together and you will hear an Fffff sound, and you will soon feel the energy as your hands are heated.

Fulcrum: (pivot, hinge) is the position on a lever that is fixed in place. The lever rotates about the fulcrum. There are often large forces at a fulcrum. When you lever the lid off a paint can with a screwdriver, the rim of the can where the screwdriver pushes down is the fulcrum. The fulcrum on a wheelbarrow is the front wheel.

Gravity: The pulling between objects due to their mass. **Weight** is the force of gravity and is proportional to mass. An object that moves downwards gains energy. Gravity provides an amount of energy equal to the force times distance. A ball falling down stairs gains energy from the height it has gone down.

Lever: is a bar that is in contact with a strong fixed object that it can push against. A lever can be used to produce a force much stronger than the force that is applied. A can opener has a hinge a wheel for cutting into the tin, and handles. The hinge is the unmoving fixed point and the force applied to the handles is much less than the force applied at the wheel to the tin. A spade is a lever when the handle is pulled back with one force and the blade pushes forward with a much larger force.

Mass: The more mass the more difficult it is to move or change the motion. Shake an object side to side and you will get a feel for the amount of mass. The weight of an object is proportional to its mass.

Potential Energy: is stored energy. A lifted mass, a wound or compressed spring, a stretched rubber band, a battery, a banana, and candle wax all have stored, or 'potential' energy. This energy can not be directly seen in motion, felt as heat, sound, or light, however potential energy can be transformed into other types of energy.

Pulley / Pulley System: A pulley is a wheel that takes a rope or string. In a pulley system the rope goes back and forth between the object to be moved and a strongly fixed location. The back and forth results in the same force (tension in the rope) being applied many times to the object, once for each time the rope goes to or from the object.

Speed is a measure of how quickly something changes its position. Speed is an indication of the energy a moving object has.

Work: is how much energy we put into changing an object's motion. Push something and it moves. Push it harder and it moves faster. Push it for a longer distance and it moves faster too. Work is proportional to the strength of the force. Work is proportional to the distance you are pushing for. Work is equal to the size of the force multiplied by the distance pushed. W=FxD The same amount of work is done for (W & F), (½ W & 2F), (1/3 W & 3F), (2/3 W & 3/2 F). Work is subtly different from energy; this is the same difference that there is between money in a bank account and a check that is being cashed. The check is the amount of change. The bank account is the amount that is there. Similarly Work is the amount of energy that is being put into or out of the motion of an object. Other forms of energy, such as kinetic energy or potential energy are amounts that exist in an object.

Inquiry Lesson 7.1.1 **Force x Distance is Work (Energy Transferred)**

Energy Transfer and Transformations – What is the role of energy in our world? **7.1 - Energy provides the ability to do work and can exist in many forms.** ♦ Work is the process of making objects move through the application of force.	**C 12.** Explain the relationship among force, distance and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. [*The purpose of this lesson is to establish that the greater the force the greater the work done, and that the greater the distance the force is applied over, the greater the work done.]*

Science Materials: 8 shatterproof plastic rulers, 2 sheets of paper, rubber band, scotch tape.
Student Handout 7.1.1: *Force x Distance is Work (Energy Transferred)*
Vocabulary: energy, force, distance, work

Inquiry: In this inquiry, students will explore how increasing both force and distance pushed will increase the amount of energy put into a pushed object. Energy put into a moving object is 'work'.

Procedures and Directions: If you want to introduce this topic with a discussion, you might ask students what they think energy is, and how energy can be put into an object to make it move. Ask for examples where objects are made to move. Avoid all hitting of objects, there is extra complicating physics in collisions. Arrange students in group to investigate what effects the amount of work done on an object.

Questions to Guide Student Inquiry
If you push back and bend the side ruler, are you storing energy in it?
If you push it further back do you expect more energy to go into the ruler?
Your push is one example of a whole class or group of things. Are they called forces, energies, works, tensions, or potatoes?
Does your experiment keep control over the amount of force?
Does your experiment keep control over the amount of distance?
Does the work done (or distance the top ruler slides) depend on force alone, distance alone, or both force and distance.

Science Concepts: To put energy into things we need to apply a force while the object moves in the direction of the force. The amount of energy that is put in is called the "Work". And the amount of work done is equal to the product of the force and the distance. We can write this as the equation:

$$\text{Work} = \text{Force x Distance.}$$

We can see part of this when we use a constant force. In that case the further we push the object, the faster the object goes. (Faster moving objects have more kinetic energy.) The dependence on force can be seen because if we push two objects the same distance, the more force we put on an object the faster it travels. Stronger and longer means faster; and faster means more energy.

Application Problems

Lesson 7.1.1

Force x Distance is Work (Energy Transferred)

These assessment items are intended to provide closure for each lesson and help teachers determine how well the students understand the science concepts. The assessments are also intended to provide students additional practice with the lesson content. Teachers should use the assessment items as they deem appropriate. For example, teachers may wish to assign them for homework, assign them as an additional class activity or "quiz" at the end of a lesson, or ask students to answer them individually as they leave the class (as "exit passes"). Teachers may wish to use the problems as a closing class activity, asking students to solve the problem in groups and then share their answers in a whole group closing activity.

1. When riding a bicycle you can be in a low gear where your pedals are easy to turn, or in higher gear where your pedals are harder to turn. In this case the force used in the high gear is three times the force used in the low gear. The following will get you up to certain speeds. Rank them from slowest to fastest, use numbers from 1 for the slowest to 4 for the fastest.

a)	Low gear and five pedal strokes.	1 x 5 = 5	Third fastest.
b)	High gear and two pedal strokes.	3 x 2 = 6	Second fastest.
c)	High gear and one pedal stroke.	3 x 1 = 3	Smallest work done therefore slowest.
d)	Low gear and seven pedal strokes.	1 x 7 = 7	Largest work done therefore fastest.

2.a A slingshot is pulled back 10cm and again but this time 20cm. Which of these puts more energy into the ball that is fired? 20cm is a larger distance and more work is done.

2.b A 20g ball is fired with the slingshot pulled back 10cm and a 40g ball is fired with the slingshot pulled back 20cm. Which ball is given the greater energy or do they both get the same? Explain your answer by referring to 'work'. The mass of the ball does not change the energy, the 20cm pull has more energy. The mass will mean the more massive ball will go slower than a lower mass ball would have but this is beyond our current analysis.

3. Does the work done when exercising depend on:
   a. force alone,
   b. distance alone, or
   c. both force and distance?

4. Give an example from exercising where the amount of energy you use up depends on distance. Swimming two laps is more exhausting than swimming one.

5. Give an example from exercising where the amount of energy you use up depends on force. Swimming fast requires more force so racing the length of a pool takes more out of you than going slowly.

Handout 7.1.1 Page 1/4 **Force x Distance is Work** Name.......................
Date ....

Task: You are going to study how far you can fire one ruler by using springs.

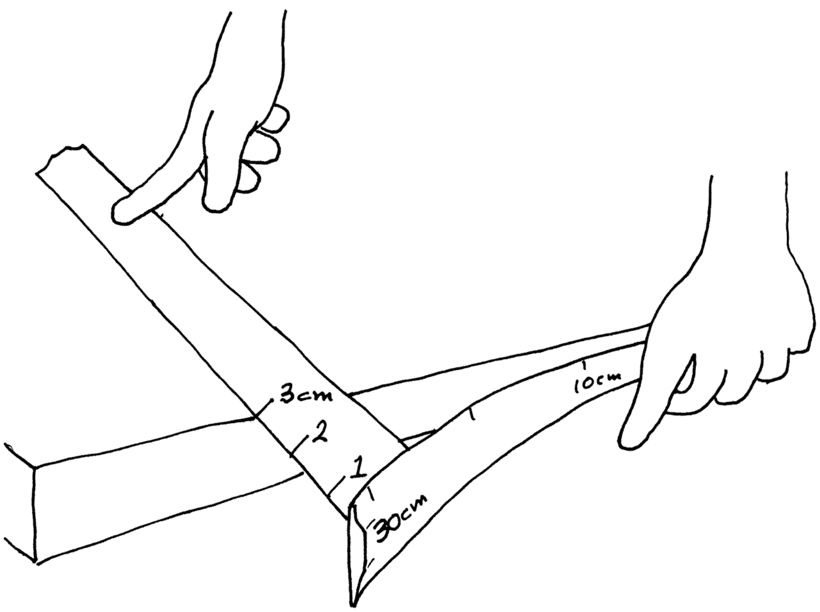
Question: How do you expect that the distance that an object is pushed will affect the amount of energy it is given?
……

………………………Any answer……………………………………………………

Question: How do you expect that the amount of force that is pushing an object will affect the amount of energy it is given?
……

……………………… Any answer…………………………………………………………………

Explore: Use your rulers to develop evidence to support your answers.



The next pages provide a step by step method of getting evidence which you may use, but you may have discovered a better method by yourself.

Set up: Work in pairs, one of you is person A and the other is person B, take one ruler each. Put a sheet of paper on the desk, with the edge of the paper lined up with the edge of the desk.

Person A: Take a good look at your desk, the surface comes across the top to the edge, goes down the side a bit and later it goes back underneath. Take one ruler and put it flat against the side of the desk. This (side) ruler is going to be the spring that flicks another ruler across the paper. Hold this ruler firmly against the side of the desk in the region between zero and 5cm on the ruler. To test your spring, pull the 30cm end away from the desk about 2cm and let go. Your ruler should snap back on the side of the desk.

Person A: Raise the 30cm end of your ruler so that about half of its width is above the top of the desk. You are ready.

Person B: Take another ruler and place it on the paper so that it is perpendicular to the side ruler and with the 0 cm end of your ruler touching the 30cm mark of the side ruler.

Person B: Slide the top ruler so that it pushes on the side ruler at the 30cm mark, and bends the 30cm end about 2cm away from the side of the desk. Let go of the top ruler. If you do this cleanly the top ruler should slide across the paper a short distance because it was pushed by the side ruler. Repeat this until you are good at releasing the ruler. You are now ready.

Testing for the effect of distance.

Task 1: (1 spring, 1cm)
Person B: Slide the top ruler so that its 1cm mark is above, (aligned with), the edge of the desk.
Check that the top ruler is touching at the 30cm mark of the side ruler, then quickly release.
Person A: Record your data by marking the position of the 0cm end of the top ruler.
Write “1 spring, 1cm” next to this mark.
Repeat three times.

Task 2: (1 spring, 2cm)
Person B: Slide the top ruler until the 2cm mark is above (aligned with) the edge of the desk.
Check that it still touches at about 30cm on the side ruler, and then release it cleanly.
Person A: Mark the position of the 0cm end of the top ruler.
Write next to the mark “1 spring, 2cm”.
Repeat three times.

Task 3: (1 spring, 3cm)
This time slide the top ruler to align the 3cm mark of the top ruler with the edge of the desk. This will force the side ruler back further. Release the top ruler and mark the position of the 0cm end of the top ruler stopped, and write “1 spring, 3cm”.
Repeat three times.

Do you agree with your partner on the effect that distance has on the speed of the top ruler?

Testing for the effect of force.

Task 4: (2 springs, 1cm.)
Person A: Put a second ruler alongside your ruler so that the pair is like one double thick ruler.
Hold this double thickness ruler in the 0 to 5cm zone.
Hold this pair firmly with the 30cm ends coming above the desk.
Make sure both rulers are pushing.

Person B: Position the top ruler so that its 1cm mark is aligned with the edge of the desk.
Release the top ruler.
Mark the position of the end of the top ruler.
Write "2 springs, 1cm" against your position mark.
Repeat three times.

If you are having difficulty with your side rulers slipping apart then you might like to think about how to improve your equipment.

Task 5: (2 springs, 2cm)
With the two rulers on the edge of the desk put the top ruler where its 2cm mark is at the edge of the desk. Fire this ruler three times and mark its positions and write "2 springs, 2cm"

Task 6: (2 springs, 3cm)
Launch the top ruler when its 3cm mark is aligned with the edge of the desk. Repeat three times, marking its positions and writing "2 springs, 3cm".

Tasks 7,8,&9: (using 3 springs)
Repeat this process but now with 3 rulers.
Mark each of the positions for pulling the spring back 1, 2, & 3 cm.
Mark them "3 rulers, 1cm", "3 rulers, 2cm", & "3 rulers, 3cm".

Write a statement describing the effects that force and distance had on motion.

………More force more motion
More distance more motion
Force proportional to motion
Distance proportional to motion…………………

Describe two facts that you observed.

Fact one ………………………………………………………………………………………

………………………………………………………………………………………………

Fact two ………………………………………………………………………………………

Analysis

Look at the marks on your paper. For each mark multiply the number of springs by the number of cm that the spring pushed. For example, 3spring, 1cm = (3).

Write these numbers down next to the marks and circle them. Look at these numbers and notice how they change as they go up the page.

Complete this statement about those numbers you just calculated.

The product of **force** (number of springs) *times* **distance** is a good way to predict ……..………...

Use a table or graphing method from math or science to analyze your data.

Task 10: Heat from work
Put your hands together palm on palm. Hold one still and slide the other forward about 5cm then back about 5cm. Count this as one cycle. Do this quickly while you count to ten cycles.

What do your hands feel like? …………Hot, higher temperature………………………………..

……

What form of energy are you feeling in your hands? …Heat or thermal energy……………………

You pushed a total distance of ten x 10cm, (which is a 100cm).

Now push your hands together hard and slide them past each other, but only count to four cycles. You pushed a total distance of only four x 10 cm (which is 40cm). This is less than 100cm yet there was more heat. Explain using

the idea of work = force x distance. ……………………………………………………………….

…………The work done pushing over 0.40m was more than the work done pushing over 1.0m because work is the product of force times distance and the increased force more than compensated for the reduced distance.………..

Inquiry Lesson 7.1.2 SIMPLE MACHINES - SLOPES

Energy Transfer and Transformations – What is the role of energy in our world? **7.1 - Energy provides the ability to do work and can exist in many forms.** a. Work is the process of making objects move through the application of force. b. Energy can be stored in many forms and can be transformed into the energy of motion.	**C 12.** Explain the relationship among force, distance and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. **C 13.** Explain how simple machines -- inclined planes -- are used to create mechanical advantage. [*The purpose of this lesson is to investigate how an inclined plane allows the same work to be done with less force.*]

Science Materials: 1 Block (weighing about 2.2N) with cup hooks, 6 straws for rollers, 1 3ring binder for a ramp (as long as possible from the rings to the open edge), 1 ruler, 1 spring balance.
Teachers may want to have protractors handy to measure angles.
Student Handout
Vocabulary: inclined plane, force, work, energy
Prior Knowledge: Students will need to know how to use a spring balance

Inquiry: In this inquiry, students will explore how an inclined plane (slope) makes it easier to lift heavy objects, where 'easier' means less force.

Procedures and Directions: If you want to introduce this topic with a discussion, you might ask students if they have ever biked up a steep hill. Explain that it is easier to climb a shallow slope up the same hill, where easier means needing less force. Ask them which path they think takes more force to climb and which takes more energy to climb. The second question is a false choice; it actually takes the same amount of energy to climb each. Arrange students in group to investigate how to make work easier (use less force) by experimenting with slope. Note the amount of energy will be the same, even though one path is short and hard and the other long and easy.

You might like to mention that 'machine' is not always complicated. The very basic machines are what allow us to produce a force greater than the force we are applying directly.

Questions to Guide Student Inquiry

1. How can you put a value on how difficult it is to lift blocks?
2. What physical property do we associate with lifting being easy or difficult?
3. What happened when you pulled the block up the ramp?
4. How could you use the straws to let you pull with less force?
5. What did you discover when you used a longer ramp?
6. What could you say about the slope of the longer ramp?
7. What is the relation between the length moved along the ramp and the force used?

Science Concepts: It takes less force to move up a gentle slope, than it does to move up a steep slope. When someone tries to lift a heavy object straight up, it is difficult. But when an inclined plane is used to make a less steep slope, less force is needed.

Application Problems

Lesson 7.1.2

Simple Machines - Slopes

These assessment items are intended to provide closure for each lesson and help teachers determine how well the students understand the science concepts. The assessments are also intended to provide students additional practice with the lesson content. Teachers should use the assessment items as they deem appropriate. For example, teachers may wish to assign them for homework, assign them as an additional class activity or “quiz” at the end of a lesson, or ask students to answer them individually as they leave the class (as “exit passes”). Teachers may wish to use the problems as a closing class activity, asking students to solve the problem in groups and then share their answers in a whole group closing activity.

1. Explain why mountain roads often are constructed in such as way as to wind around the mountain, rather than go straight up a mountain. Use scientific terminology in your explanation.

Climbing a mountain requires you to put in a certain amount of energy. This is done through work, the product of force times distance. If the distance you move is short (taking the steep path or road) then the amount of force must be correspondingly large. This force may be too much for engines on the way up and breaks on the way down. (The amount of energy gained/lost is the same in both cases, ignoring friction.)

2. A person on the top of a hill with a bike can freewheel down the hill, gaining kinetic energy from the energy that was stored because they were at the top. Explain why the energy they have is the same regardless of whether they went up a long shallow slope, or a short steep slope.

If you consider the energy that can be given back out we see it must be the same.

3. Which of the following correctly expresses the relationship among force, distance, and work?

a) force x distance = work

b) work = force + distance

c) force = distance = work

d) work = distance / force

 Simple Machines – Slopes Name.......................
Date ....

For many tens of thousands of years humans have been building things. However, there is a limit to how much a human or group of humans can lift by hand. About five thousand years ago humans in Africa started to build pyramids using very heavy stones, stones that they could not simply lift. To do this they needed a machine (a tool that uses a smaller force to produce a bigger one). Today we look at slopes, this is one way to do this.

Standard Task: Attach the spring balance to the block. Lift it 5cm by pulling slowly straight up with the balance. Record the following results.

Our block has a weight of ………………… Newtons.

We pulled the block a distance of ……………. meters. (This is the vertical distance.)

Use this data to calculate the energy you put into the block.

We put …Multiply the force in Newtons by the distance in meters to get the work in Joules.…………………… Joules of energy into the block by doing work (force x distance).

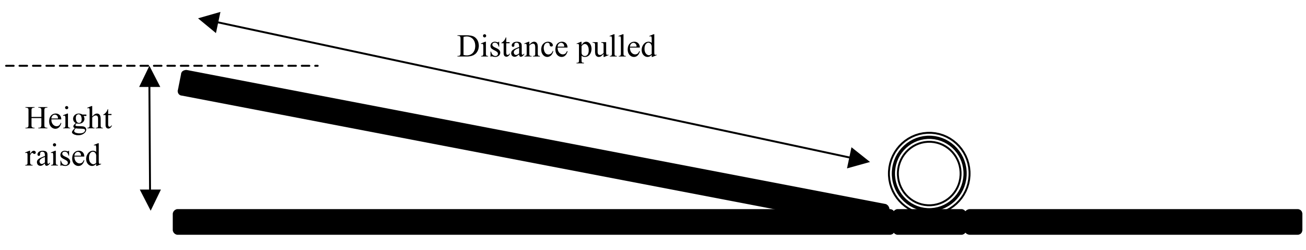
Now imagine that the block is so big that you can not lift it by hand.

Task 1: Explore to find a way of lifting your block a height of 5cm while using less force. You will need to check by measuring with the balance.

Try using just the **three-ring binder, some straws**, and the **block and balance**.

If you succeed you will be inventing a machine.

The ramp or slope is the machine we will explore today.



Task 2: Open the binder so that it lies flat on the desk with its rings up. Put the block on rollers (straws) on one of the covers of the binder, and raise the edge of the cover to make a slope.

Adjust the angle of the binder cover so that the edge of one cover is 5cm above the desk.

Measure how much force it takes to pull your block along this slope.

I could move the block if I pulled with a force of about ………………… Newtons.

Measure the distance along the slope that your block has to move to gain a height of 5cm. You do not actually have to move the block; you can work with the slope as one side of a triangle.

The distance pulled was …………………. cm, which is ……………. m.
(This is the distance along the slope, not the 5cm vertical distance.)

The work that I did on the block was …………………. Joules. (You will have to calculate this.)

Task 3: Adjust the slope so that the edge of the binder is 10cm above the desk

Measure how much force it takes to pull your block along this slope, and the distance that the block has to travel to gain a vertical height of 5cm.

I could move the block if I pulled with a force of about ………………… Newtons.

The distance pulled was …………………. cm, which is ……………. m.

The work that I did on the block was …………………. Joules.

Task 4: Adjust the slope so that the edge of the binder is 20cm above the desk

Measure how much force it takes to pull your block along this slope, and the distance that the block has to travel to gain a vertical height of 5cm.

I could move the block if I pulled with a force of about ………………… Newtons.

The distance pulled was …………………. cm, which is ……………. m.

The work that I did on the block was …………………. Joules.

Repeat tasks 2-4 three times each and record your results using a table or graphing method from math or science.

Task 5: Take the spring balance off the block and let the block roll back down the slope a little bit. Notice that it gains speed and so it is gaining energy. Ask yourself: Where was the energy when the block was at the top of the slope? Where did that energy come from?

Analysis: Complete the sentence by circling your choices.

Even though the force used changed a lot, and the distance moved changed a lot, we saw that the product of force x distance was **changed greatly / about the same**.

Write your reasonable conclusions that explain the benefit of using a ramp.

…………The benefit is that we can achieve our goal using a smaller force.

However, we have to compensate by applying that force over a larger distance.

……………………………………………………………………………………………………

Give evidence for your conclusions based on your experimentation.

……

……

……

……

Give an example from outside of class where you have seen someone using a ramp.

………Heavy yard equipment going up onto a truck.

An entrance ramp to the highway is not steep so cars and trucks can get up to speed.

……

………………………………………………………………………………………………………

Inquiry Lesson 7.1.3 SIMPLE MACHINES – LEVERS

Concepts	*Performance Expectations(Objectives*
Energy Transfer and Transformations – What is the role of energy in our world? **7.1 - Energy provides the ability to do work and can exist in many forms.** c. Work is the process of making objects move through the application of force.	**C 12.** Explain the relationship among force, distance and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. **C 13.** Explain how simple machines – levers -- are used to create mechanical advantage. [*The purpose of this lesson is to explore how levers allow the same work to be done with less force.]*

Science Materials: 1 Block with cup hooks, rigid ruler (Westcott), 2 plastic rulers, 1 spring balance.
Student Handout 7.1.3: *Another Simple Machine – The Lever*
Vocabulary: lever, fulcrum, force, energy, work

Inquiry: In this inquiry, students will investigate how levers make work easier.

Procedures and Directions: Ask students if they ever remember riding on a see-saw (teeter-totter) on the playground. Ask them if they remember what they did to get the see saw to balance a bigger person with a smaller person. (Shift their weight towards or away from the fulcrum). Were they ever able to balance the see saw so that both playmates were in the air? Remind students what that work = force x distance.
Ask: if the lighter student sits where they can go down while the heavier student goes up, does the lighter student go down further, less far, or the same distance as the heavier student. Note that the smaller force (lighter weight) has to move further, because the product of force and distance is equal.

Arrange students in groups to conduct the experiments with the blocks and lever bars.

Questions to Guide Student Inquiry
1. Can you use the lever bar like a spade digging earth?
2. Which moves further the handle or the spade tip?
3. Which has more force acting the handle or the spade tip?
4. Can you use the lever bar with one end staying on the table?
5. Give other examples of using simple machines to make work easier.

Science Concepts: Levers exploit the play off between force and distance. You can achieve the same result (work done) by using more force and less distance, or less force and more distance, but the product must always be the same.

We often want to use a human scale amount of force to achieve superhuman effects. We do this by applying a lower force and moving a longer distance. Digging with a spade allows us to pull back on the handle, moving perhaps half a meter, while the soil or a rock is pushed a much smaller distance but with a correspondingly larger force. Lifting a heavy load in a wheel barrow does a similar thing. We raise the handles by 10cm but the load is lifted only about 2cm, but we used less force. Mathematically, the product, Force x Distance, calculated for the load and Force x Distance calculated for the person always remain equal.

Application Problems

Lesson 7.1. 3

Simple Machines – Levers

These assessment items are intended to provide closure for each lesson and help teachers determine how well the students understand the science concepts. The assessments are also intended to provide students additional practice with the lesson content. Teachers should use the assessment items as they deem appropriate. For example, teachers may wish to assign them for homework, assign them as an additional class activity or "quiz" at the end of a lesson, or ask students to answer them individually as they leave the class (as "exit passes"). Teachers may wish to use the problems as a closing class activity, asking students to solve the problem in groups and then share their answers in a whole group closing activity.

6. Levers let you lift heavy objects most easily when

a) the fulcrum is in the middle
b) the fulcrum is close to the heavy object
c) <u>the length of the lever is long</u> It is the ratio of the length of the lever between you and the fulcrum to the length of the lever from the fulcrum to the load that establishes the reduction in force. However, the longer lever you have in your hand the lower the force you have to put in.
d) the lever is very short

2. Explain how a light weight person can lift up a heavy person on a see saw. Explain how this does not put more energy into the heavy person than was put out by the light person.

Light weight person has to be further from the fulcrum. The work done (energy put in/taken out) is the same because the light weight person moves further with a smaller force. The product of force and distance remains the same.

3. Why is it easier to cut cardboard when the cardboard is closest to the hinge (fulcrum) of the scissors?

The shorter the distance from the load to the fulcrum the more force it receives. (Everything else being unchanged.)

4. Explain how the Egyptians could have used levers as simple machines to construct the pyramids. Use scientific terminology in your answer. They could have lifted very heavy stones by putting a lever bar under them so that the load is close to the fulcrum while they lifted at a place further away.

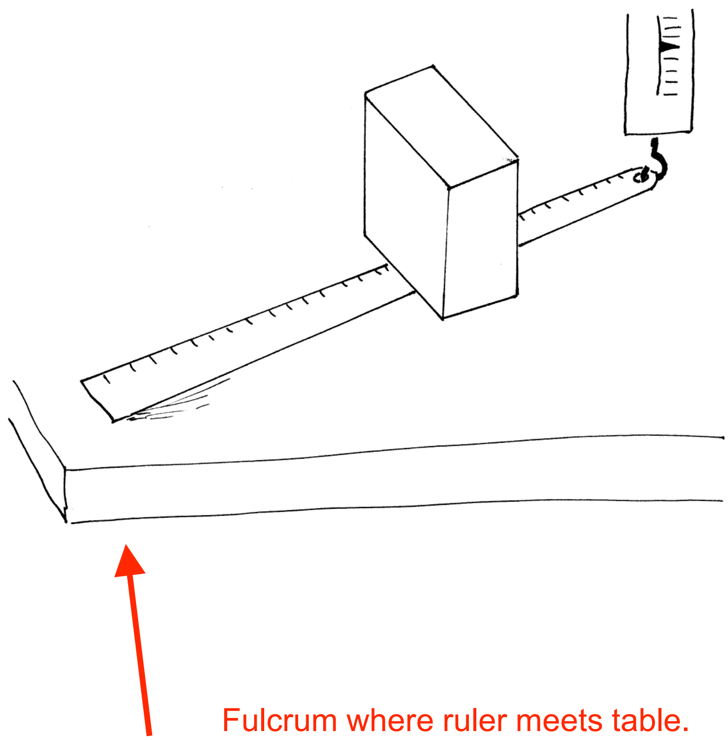
Handout 7.1.3 page 1/2 ***Simple Machines – Levers* (W = F x D)** Name......................

Date ....

Investigate (play): Use the metal ruler, the wooden block, and the force balance to raise the block 3cm by pulling up with less than the weight of the block. Do not slide the block up a ramp.

Hint: how can you lift a heavy load in a wheelbarrow?

If the block is 3cm above the table is the hook also 3cm above the table?



Fulcrum where ruler meets table.

Imagine that you set up your equipment on the desk as is shown here. Will the spring balance

measure a force **greater than / less than / equal to** the weight of the block? Make a choice.

Task 1: Set up the equipment as it is shown and get evidence to decide the correct answer for the following statement of observed fact. Circle the correct words.

The balance measured a force **greater than / less than / equal to** the weight of the block.

Raise and lower the balance, and watch how the system moves. There is one place on the lever that does not move, we will call that the ‘fulcrum’. Mark the diagram with the position of the fulcrum.

Task 2: Put the wood block on the ruler up against the spring balance and as far from the fulcrum as possible. Lift the block 3cm by pulling up on the spring balance. Measure the force shown on the spring balance. Record your results.

I measured the force to lift the block and the lever to be ……………………………… Newtons

I pulled up on the spring balance the distance of ………**0.03**……….. meters.

Task 3: Now place the block half way between the fulcrum and the balance. Pull up on the spring balance until the block is lifted 3cm. Notice that you have to move the spring balance more than 3cm. Record your results.

I measured the lifting force to be ……………………………… Newtons

I pulled up on the spring balance the distance of ……………….. meters.

Task 4: Now place the middle of the block two thirds of the way from the spring balance to the fulcrum. Pull up on the spring balance until the block is lifted 3cm. Notice the increased distance you had to move the spring balance. Record your results.

I measured the force to be ……………………………… Newtons

I pulled up on the spring balance the distance of ……………….. meters.

Repeat Tasks 2-4 to get three sets of results for each task, record results in a table.

Analyze your data. Calculate the average (mean) value for each of your three trials.

Describe the relationship between the force and the distance you move the spring balance. You might review what you concluded in previous classes about work, force, and distance.

…As the distance you have to move increases the amount of force decreases.

The same amount of work was being done to the block, it was going up 3cm against its weight.

However, the applied forces changed and so did the distances that applied force moved. What

evidence from your experiment supports the conclusion that you wrote above?

The product of applied force and applied force distance is about the same in each task.

……………………………………………………………………………………………………

Inquiry Lesson 7.1.4 SIMPLE MACHINES – PULLEY SYSTEMS

	Performance Expectations (Objectives)
Energy Transfer and Transformations – What is the role of energy in our world? **7.1 - Energy provides the ability to do work and can exist in many forms.** d. Work is the process of making objects move through the application of force.	**C 12.** Explain the relationship among force, distance and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. **C 13.** Explain how simple machines --, pulleys -- are used to create mechanical advantage. *[The purpose of this lesson is to explore how pulleys make it possible to do the same work using less force.]*

Science Materials (for each group) : Block with 2 cup hooks, 1 three-ring binder, 2.1m of string, 2 single pulleys, 2 rulers, 1 spring balance.
Student Handout 7.1.4: *Simple Machines – Pulley Systems*
Vocabulary: pulley system, force, energy, work, distance

Inquiry: In this inquiry, students will investigate how pulleys enable work to be done using less force.

Procedures and Directions: Introduce the lesson by asking students if they can snap a thin piece of thread. (Yes) Then ask how they could tie up the hands of a strong person with one thin piece of thread. How can the weak thread withstand the strong force? (Being wound around many times the large force is divided by (spread over) a large number of threads. Now think of another type of simple machine that makes creates a large force by using the smaller force in a long string or rope. Ask if anyone has ever watched a crane pick up heavy objects and lower them onto construction sites, or has seen ropes used in pirate movies. Ask if anyone knows how cranes or pulleys work. Then assign students to groups, where they will conduct experiments to learn how pulleys work.

Questions to Guide Inquiry:
1. Where is the idea of force hidden within the word pulley? (A pull is a force.)
2. Why do you think wheels or rollers make work easier? (Review the principle of friction in Module 4.1)
4. If you count two strings going from the block, how strongly will you need to pull the string?
5. With two strings going from the block, how much string would you pull to raise the block 10 cm?
6. If you count three string going from the wooden block, what fraction of the weight do you need to pull with?

Science Concepts: A pulley system allows one string to pull many times on one object. The force on the object is therefore many times the force applied to the string. If the string pulls three times on a hanging block then you can lift the block with one third of its weight. However, you will have to pull the string three times as far as the block moves. The corresponding increase in distance leads to the work done remaining the same.

The wheel aspect in a pulley wheel is used to reduce the friction in the system.
The <u>number</u> of times the string acts is what reduces the force needed. Seeing the pulley system this way is the key to quickly solving pulley problems.

Application Problems

Lesson 7.1. 4

Simple Machines – Pulley Systems

These assessment items are intended to provide closure for each lesson and help teachers determine how well the students understand the science concepts. The assessments are also intended to provide students additional practice with the lesson content. Teachers should use the assessment items as they deem appropriate. For example, teachers may wish to assign them for homework, assign them as an additional class activity or "quiz" at the end of a lesson, or ask students to answer them individually as they leave the class (as "exit passes"). Teachers may wish to use the problems as a closing class activity, asking students to solve the problem in groups and then share their answers in a whole group closing activity.

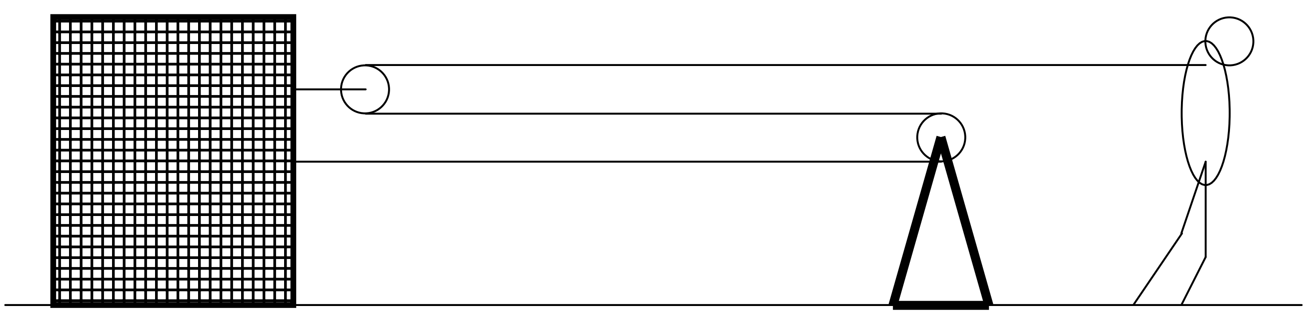
1. You have available an empty spool of thread, a wire, a shoe that you want to lift, and string. Describe how you could make a pulley system that lifts the shoe using a force less than its weight. Draw a picture.

The description and picture must have more than one string going up from the shoe.

2. Which of the following is NOT true about a pulley system?

a) Pulleys make work easier, and you get more energy out than you put in. False
b) Pulleys depend on wheels to make them work.
c) You have to pull the string further when you use a pulley.
d) With a pulley, a smaller force can be used to lift a larger mass.

3. It takes 150 Newtons to drag a crate along the road. The fire department set up a pulley system as shown. The triangle holds one pulley wheel fixed in place. How many Newtons of force does the fireperson pull with?



There are three strings pulling the block to the right. Therefore each string provides one third of the force. Answer 150/3 = 50N

Investigate (play): Tie one end of the string to the hook on the balance. Then arrange the block, balance, string and pulley / pulleys so that you can complete task 1.

Task 1: Lift the block while pulling on the balance with a force that is smaller than the weight of the block.

Measure three values from your balance and calculate the average (mean).

Our measured average value from the balance was ………….. Newtons.

Measure three values for the weight of the block.

Our measured average value for the weight of the block is ……….. Newtons.

Now calculate the ratio of average force from the balance over average weight of the block.

Our ratio for force in string over weight of block is ………………

Why is this not measured in Newtons? …………The ratio has units of Newtons over Newtons, this is unitless.

Count how many strings go up from your block. This number is ……………..

Analysis: Write a reasonable conclusion relating the number of strings to the ratio of forces.

……………They will be about reciprocal, 2 string ½ the weight, 3 strings, about 1/3 the weight.

……………………………………………………………………………………………………

Hold everything still, and then pull just one end of the string by moving the balance up 30cm. Observe and measure how far the block moved.

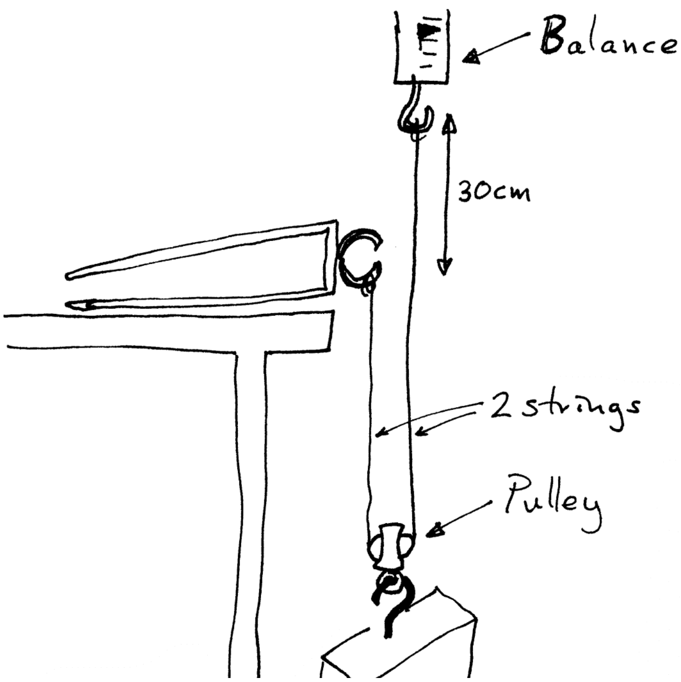
When we pulled the balance 30cm our block moved ……………… cm.

The ratio of the distance the block moved to the distance the balance moved is ………………….

Look for similarities in your data.

Task 2: Work done in raising a block.

Set up: Tie one end of the string to the balance, run the other end of the string through one pulley and hold it at a fixed place. (You may tie it to the ring of the three ring binder if that helps.) Hook the pulley to the block of wood. You should have a set up similar to the diagram below. (If this is what you did for task 1 then simply record your data in a table and do Task 3.)



Pull the balance up 30cm and measure the following things.

Number of pulleys …………

Number of strings ………..

Height the block was lifted……………… cm

Force on the balance ………………Newtons

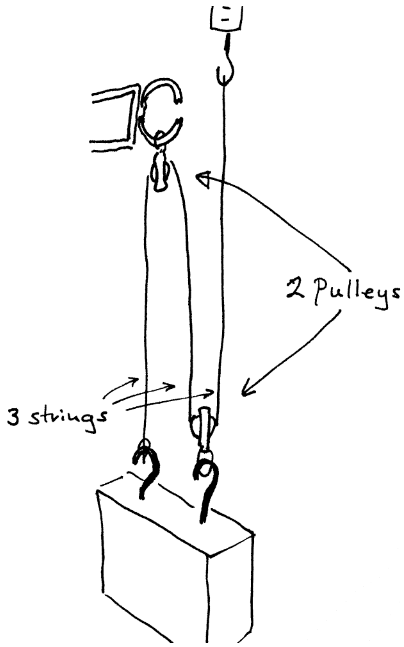
Weight of the block …………………Newtons

Make a data table.

Repeat your measurements to get three separate measurements.

Record your data.

Task 3: Have one end of the string attached to the balance. The string then runs through one pulley that is attached to the block. The string continues and runs through a second pulley that is hooked onto the three ring binder. The string then runs from that second pulley down to where it is tied onto the block. You should have a set up similar to the diagram below.
(If this is what you did for task 1 then simply record the following data in a table.)



Pull the balance up 30cm and measure the following things.

Number of pulleys ……………..

Number of strings ……………..

Height the block was lifted……………… cm

Force on the balance ………………Newtons

Weight of the block …………………Newtons

Make a data table, repeat your measurements three times, and record your data.

Use your data to decide between these two ideas. One of them is wrong. When you lift a weight with a system of pulleys you pull with a force that is less than the weight. In an ideal world where there was zero friction:

A) The force you pull with is equal to the weight divided by the number of pulleys.

B) The force you pull with is equal to the weight divided by **the number of strings**.

Notice that the work done when lifting the balance 30cm is different when the force that being supplied is different. Analyze your data and show that the difference in the work done by the balance is matched by a similar change in work done on the block. Complete the following sentences by putting a line through the incorrect words.

When the force used to raise the balance was decreased, the work done by the balance was **increased / the same / decreased**. This is consistent with the work done on the block because the weight of the block **increased / was the same / decreased** but the height it rose was **increased / the same / decreased**.

The same work was done at the balance and at the block, however, by using a pulley system

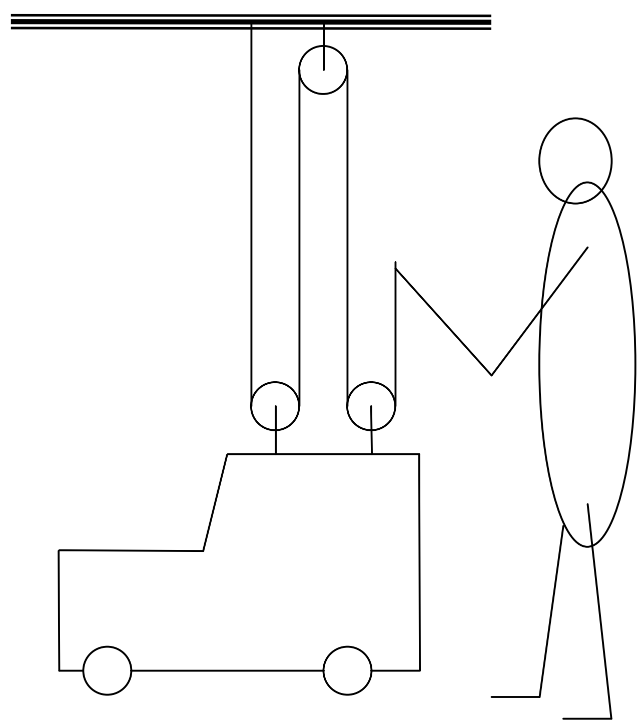
we have the benefit of …………Achieving our goal by using less force than by simply lifting.
……………………………………………………………………………………………………

Answer this question.

The car in the diagram weighs 240N.

How much force does the person lift with?

- a. 480 N
- b. 240 N
- c. 120 N
- d. 80 N
- e. 60 N



Divide the force by the number of strings!

Works every time.

Inquiry Lesson 7.1.5 GETTING STORED ENERGY BACK

Concepts	*Performance Expectations (Objectives)*
Energy Transfer and Transformations – What is the role of energy in our world? **7.1 - Energy provides the ability to do work and can exist in many forms.** e. Work is the process of making objects move through the application of force. f. Energy can be stored in many forms and can be transformed into the energy of motion.	**C 12.** Explain the relationship among force, distance and work, and use the relationship (W=F x D) to calculate work done in lifting heavy objects. **C 13.** Explain how simple machines, such as inclined planes, pulleys and levers, are used to create mechanical advantage. **C 14.** Describe how different types of stored (potential) energy can be used to make objects move. *[The purpose of this lesson is to explore how potential energy can be transformed.]*

Science Materials (for each group): 1 block with hooks, string, 2 drinking straws one fitting inside the other, 1.5m of string, plastic cup, 2 marbles, ruler, 40cm of foam pipe insulation.
Student Handout 7.1.4: *Getting Stored Energy Back*
Vocabulary: force, potential energy, work, movement

Inquiry: In this inquiry, students will investigate how potential energy can be turned into other forms of energy, in particular sound, wind, and motion. They will observe that by driving a fan, a falling block uses some of its potential energy to power the fan and therefore it has less kinetic energy than it would have if it fell by itself.

Procedures and Directions: Introduce the term *potential energy* through analogies. When students save their allowance, their money has the potential to buy things. When they spend their allowance, they use their savings they stored up over time. Potential energy is energy stored for later use. Assign students to groups to investigate how stored up energy can be released to move objects.

Questions to Guide Inquiry

1. What do the following have in common, a book on a high shelf, a ruler bent over the edge of a table, and a stretched rubber band?
2. Do you see any energy in the block sitting on the table?
3. Can you get the fan to turn by hand?
4. Can you use the energy stored somewhere to get the fan to turn?
5. Where is energy stored in a battery operated fan?

Science Concepts: Energy in the forms of light, heat, sound, and movement can be experienced quite directly. However, much energy is stored in a stable form that we can not directly experience. Such stored energy is called potential energy. We know that there is energy in gasoline but we only experience it once the gasoline is burnt. Energy stored in batteries can be taken out through electrical circuits. Other forms of potential energy include the energy stored when a spring is stretched, such as when a ruler is bent over a table. A mass that is lifted up against the force of gravity has potential energy. That energy is released when the object falls back down.

Application Problems

Lesson 7.1. 5

Getting Stored Energy Back

These assessment items are intended to provide closure for each lesson and help teachers determine how well the students understand the science concepts. The assessments are also intended to provide students additional practice with the lesson content. Teachers should use the assessment items as they deem appropriate. For example, teachers may wish to assign them for homework, assign them as an additional class activity or "quiz" at the end of a lesson, or ask students to answer them individually as they leave the class (as "exit passes"). Teachers may wish to use the problems as a closing class activity, asking students to solve the problem in groups and then share their answers in a whole group closing activity.

1. List three different ways you could store energy so it could be used later?
Plants store light energy for us.
Pumping water to the top of a hill will keep the energy for later.
Pulling back on a slingshot keeps energy in the rubber band.

2. Which of the following describes potential energy?
   a) energy traveling as sound
   b) heat energy in a hot object
   c) energy stored up for future use
   d) the energy a moving object has

3. Design an experiment to show how potential energy can get an object moving.

4. Write the name of an object that transforms energy from the type of energy in the left hand column to the type in the right hand column.

Electric Potential Energy	to	Wind Energy	by	…a fan…………………………
Electric Potential Energy	to	Light	by	…a lamp…………………………
Kinetic Energy	to	Heat Energy	by	…breaks on a car or bike……
Wind Energy	to	Sound Energy	by	…wind chimes, or a flute recorder etc.
Kinetic Energy	to	Gravitational Potential Energy	by	…a bat hitting a pop fly……

 Getting Stored Energy Back Name ....
Date ....

Task 1: Split the last 2 or 3 cm of one end of your narrower straw and feed the other end into your wider straw. This is now your model fan. Put the loop of string around one blade then wind up the string around the inner straw. Hook the other end of the string to your block. Let the block drop to the floor so that the energy stored in your block drives the fan. This is an example of getting energy of motion back from stored or potential energy.

Drop the block from about table height a few times. Observe the speed of the falling block. Is it faster when it falls by itself or when it is driving the fan? Use the ideas of energy to explain your observation by completing this sentence.

Potential energy from the block was turned into energy in two moving objects: one was the

……fan…….. and the other was the ……block itself (could include the string as a third object).

Task 2: Hold a plastic cup in front of you and then drop a marble into the cup from a distance of about 3cm (0.03m), then 9cm (0.09m),and then 27cm (0.27m) from the bottom of the cup. Listen to the amount of sound that is being made in each case. The force of gravity on a 17mm diameter marble is about 0.06N. Use Work = Force x Distance to calculate the amount of energy released when a marble falls 3, 9, and 27 cm. To get energy measured in Joules you must use force in Newtons and distance in meters. Use this information to argue that sound is a form of energy.

Falling 3cm released …0.06 x 0.03 = 0.0018 Joules of energy; this was the **loudest / middle / quietest**.

Falling 9cm released …0.0054...Joules of energy; this was the **loudest / middle / quietest**

Falling 27cm released …0.0162……Joules of energy; this was the **loudest / middle / quietest**

Task 3: Put one end of the foam gutter on the table and the other end propped up about 5cm on a pile of books. Release two marbles at the same time, one marble from about half way up and the other from the top. Observe what happens as they run down the ramp and across the table. Change your arrangement until you can have the top marble catch up with the bottom marble on the table. Sometimes a top marble catches up with the bottom marble on the ramp. Look carefully at your ramp, does it have the same steepness all along? Try again with the ramp held so that it is straight and not sagging in the middle.

Explain how the top marble can leave the ramp with more speed and kinetic energy than the bottom marble. Use the word 'work' and the word 'potential' in your explanation.

……Because it moved further along the ramp the top marble was pushed for a longer distance so more work was done on it. Also, because it was higher up and fell a greater distance, more gravitational potential energy was put into its motion. ……………………..

Potential energy can be stored in many places. Examples include: bent or stretched springs (like rulers and rubber bands), food and other chemical fuels (like wood, candle wax, or gasoline), electric batteries, and high (elevated) objects (like water up above a dam). List other forms of energy that are not 'potential' energy, but can be seen or felt.

……Heat…………………………….. …………Light………………………

…………Sound…………………………. ……………………………………………

………………………………………………. ……………………………………………

Give examples where energy has been transformed from these various forms into potential energy ....

.....Heat in burnt gasoline in a car engine can drive a car up a hill (gravitational potential energy).

.....Light through a photovoltaic cell can charge a battery (electrical potential energy).

…Sound can compress our ear drum or push and deform a plastic cup. There is spring potential energy in both our pushed ear drum and a deformed cup.

Give examples where potential energy has been transformed into some of the various other forms of energy you listed. ……………………………………………………………………….

...........Wood (chemical potential energy) burns to make heat.

..........Electric potential energy in a battery can make a flashlight make light.

..........A falling object can make sound from gravitational potential energy.

……………………………………………………………………………………………………

…………………………………………………………………………………………………….

 Force x Distance is Work Name........................
Date ....

Task: You are going to study how far you can fire one ruler by using springs.

Question: How do you expect that the distance that an object is pushed will affect the amount of energy it is given?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

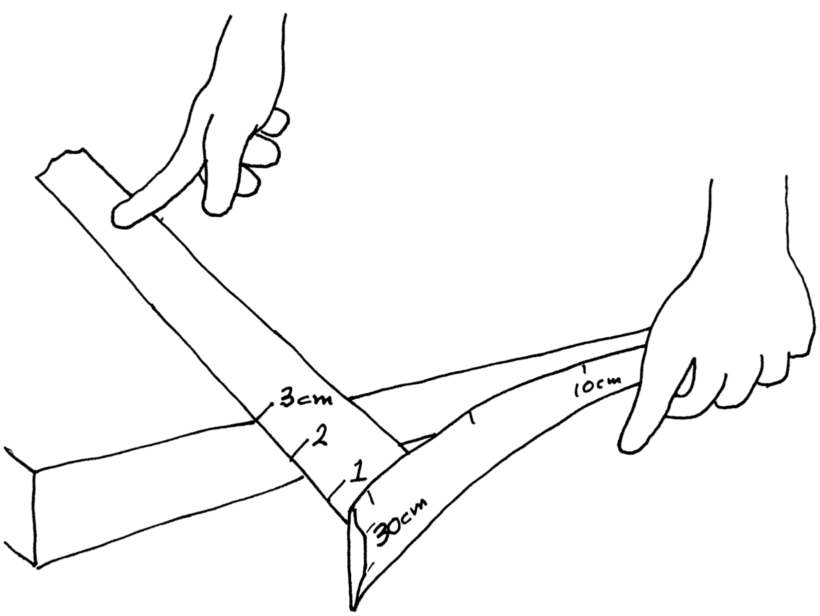
Question: How do you expect that the amount of force that is pushing an object will affect the amount of energy it is given?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Explore: Use your rulers to develop evidence to support your answers.



The next pages provide a step by step method of getting evidence which you may use, but you may have discovered a better method by yourself.

Set up: Work in pairs, one of you is person A and the other is person B, take one ruler each.

Put a sheet of paper on the desk, with the edge of the paper lined up with the edge of the desk.

Person A: Take a good look at your desk, the surface comes across the top to the edge, goes down the side a bit and later it goes back underneath. Take one ruler and put it flat against the side of the desk. This (side) ruler is going to be the spring that flicks another ruler across the paper. Hold this ruler firmly against the side of the desk in the region between zero and 5cm on the ruler. To test your spring, pull the 30cm end away from the desk about 2cm and let go. Your ruler should snap back on the side of the desk.

Person A: Raise the 30cm end of your ruler so that about half of its width is above the top of the desk. You are ready.

Person B: Take another ruler and place it on the paper so that it is perpendicular to the side ruler and with the 0 cm end of your ruler touching the 30cm mark of the side ruler.

Person B: Slide the top ruler so that it pushes on the side ruler at the 30cm mark, and bends the 30cm end about 2cm away from the side of the desk. Let go of the top ruler. If you do this cleanly the top ruler should slide across the paper a short distance because it was pushed by the side ruler. Repeat this until you are good at releasing the ruler. You are now ready.

Testing for the effect of distance.

Task 1: (1 spring, 1cm)
Person B: Slide the top ruler so that its 1cm mark is above, (aligned with), the edge of the desk.
Check that the top ruler is touching at the 30cm mark of the side ruler, then quickly release.
Person A: Record your data by marking the position of the 0cm end of the top ruler.
Write “1 spring, 1cm” next to this mark.
Repeat three times.

Task 2: (1 spring, 2cm)
Person B: Slide the top ruler until the 2cm mark is above (aligned with) the edge of the desk.
Check that it still touches at about 30cm on the side ruler, and then release it cleanly.
Person A: Mark the position of the 0cm end of the top ruler.
Write next to the mark “1 spring, 2cm”.
Repeat three times.

Task 3: (1 spring, 3cm)
This time slide the top ruler to align the 3cm mark of the top ruler with the edge of the desk. This will force the side ruler back further. Release the top ruler and mark the position of the 0cm end of the top ruler stopped, and write “1 spring, 3cm”.
Repeat three times.

Do you agree with your partner on the effect that distance has on the speed of the top ruler?

Testing for the effect of force.

Task 4: (2 springs, 1cm.)
Person A: Put a second ruler alongside your ruler so that the pair is like one double thick ruler.
Hold this double thickness ruler in the 0 to 5cm zone.
Hold this pair firmly with the 30cm ends coming above the desk.
Make sure both rulers are pushing.

Person B: Position the top ruler so that its 1cm mark is aligned with the edge of the desk.
Release the top ruler.
Mark the position of the end of the top ruler.
Write "2 springs, 1cm" against your position mark.
Repeat three times.

If you are having difficulty with your side rulers slipping apart then you might like to think about how to improve your equipment.

Task 5: (2 springs, 2cm)
With the two rulers on the edge of the desk put the top ruler where its 2cm mark is at the edge of the desk. Fire this ruler three times and mark its positions and write "2 springs, 2cm"

Task 6: (2 springs, 3cm)
Launch the top ruler when its 3cm mark is aligned with the edge of the desk. Repeat three times, marking its positions and writing "2 springs, 3cm".

Tasks 7,8,&9: (using 3 springs)
Repeat this process but now with 3 rulers.
Mark each of the positions for pulling the spring back 1, 2, & 3 cm.
Mark them "3 rulers, 1cm", "3 rulers, 2cm", & "3 rulers, 3cm".

Write a statement describing the effects that force and distance had on motion.

………

………

Describe two facts that you observed.

Fact one …………………………………………………………………………………………………

………

Fact two …………………………………………………………………………………………………

………

Analysis

Look at the marks on your paper. For each mark multiply the number of springs by the number of cm that the spring pushed. For example, 3spring, 1cm = (3).

Write these numbers down next to the marks and circle them. Look at these numbers and notice how they change as they go up the page.

Complete this statement about those numbers you just calculated.

The product of **force** (number of springs) *times* **distance** is a good way to predict ……..………...

Use a table or graphing method from math or science to analyze your data.

Task 10: Heat from work
Put your hands together palm on palm. Hold one still and slide the other forward about 5cm then back about 5cm. Count this as one cycle. Do this quickly while you count to ten cycles.

What do your hands feel like? ………………………………………………………………………..

………

What form of energy are you feeling in your hands? ………………………

You pushed a total distance of ten x 10cm, (which is a 100cm).

Now push your hands together hard and slide them past each other, but only count to four cycles. You pushed a total distance of only four x 10 cm (which is 40cm). This is less than 100cm yet there was more heat. Explain using

the idea of work = force x distance. ……………………………………………………………….

………..

Simple Machines – Slopes

Name.......................
Date ....

For many tens of thousands of years humans have been building things. However, there is a limit to how much a human or group of humans can lift by hand. About five thousand years ago humans in Africa started to build pyramids using very heavy stones, stones that they could not simply lift. To do this they needed a machine (a tool that uses a smaller force to produce a bigger one). Today we look at slopes, this is one way to do this.

Standard Task: Attach the spring balance to the block. Lift it 5cm by pulling slowly straight up with the balance. Record the following results.

Our block has a weight of ………………… Newtons.

We pulled the block a distance of ……………. meters. (This is the vertical distance.)

Use this data to calculate the energy you put into the block.

We put ……………………… Joules of energy into the block by doing work (force x distance).

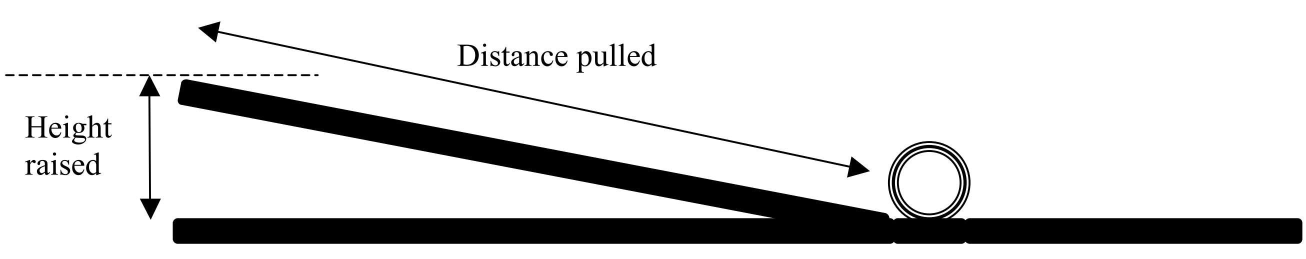
Now imagine that the block is so big that you can not lift it by hand.

Task 1: Explore to find a way of lifting your block a height of 5cm while using less force. You will need to check by measuring with the balance.

Try using just the **three-ring binder, some straws**, and the **block and balance**.

If you succeed you will be inventing a machine.

The ramp or slope is the machine we will explore today.



Task 2: Open the binder so that it lies flat on the desk with its rings up. Put the block on rollers (straws) on one of the covers of the binder, and raise the edge of the cover to make a slope.

Adjust the angle of the binder cover so that the edge of one cover is 5cm above the desk.

Measure how much force it takes to pull your block along this slope.

I could move the block if I pulled with a force of about ………………… Newtons.

Measure the distance along the slope that your block has to move to gain a height of 5cm. You do not actually have to move the block; you can work with the slope as one side of a triangle.

The distance pulled was …………………. cm, which is ……………. m.
(This is the distance along the slope, not the 5cm vertical distance.)

The work that I did on the block was …………………. Joules. (You will have to calculate this.)

Task 3: Adjust the slope so that the edge of the binder is 10cm above the desk

Measure how much force it takes to pull your block along this slope, and the distance that the block has to travel to gain a vertical height of 5cm.

I could move the block if I pulled with a force of about ………………… Newtons.

The distance pulled was …………………. cm, which is ……………. m.

The work that I did on the block was …………………. Joules.

Task 4: Adjust the slope so that the edge of the binder is 20cm above the desk

Measure how much force it takes to pull your block along this slope, and the distance that the block has to travel to gain a vertical height of 5cm.

I could move the block if I pulled with a force of about ………………… Newtons.

The distance pulled was …………………. cm, which is ……………. m.

The work that I did on the block was …………………. Joules.

Repeat tasks 2-4 three times each and record your results using a table or graphing method from math or science.

Task 5: Take the spring balance off the block and let the block roll back down the slope a little bit. Notice that it gains speed and so it is gaining energy. Ask yourself: Where was the energy when the block was at the top of the slope? Where did that energy come from?

Analysis: Complete the sentence by circling your choices.

Even though the force used changed a lot, and the distance moved changed a lot, we saw that the product of force x distance was **changed greatly / about the same**.

Write your reasonable conclusions that explain the benefit of using a ramp.

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Give evidence for your conclusions based on your experimentation.

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Give an example from outside of class where you have seen someone using a ramp.

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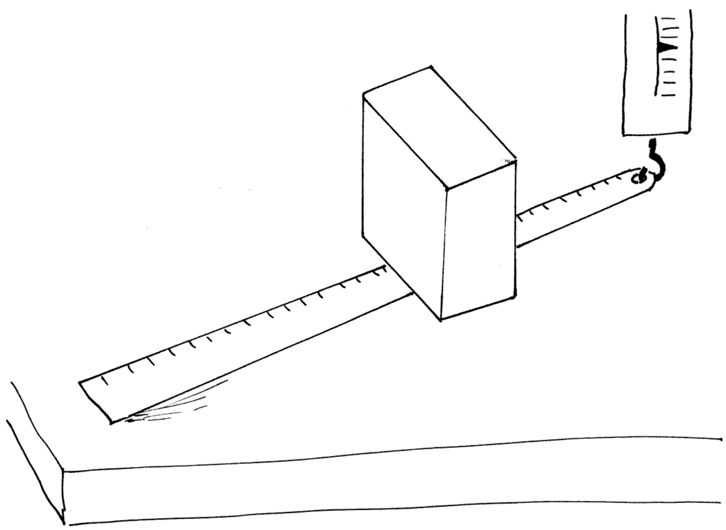
 ***Simple Machines – Levers* (W = F x D)**

Name......................
Date ....

Investigate (play): Use the metal ruler, the wooden block, and the force balance to raise the block 3cm by pulling up with less than the weight of the block. Do not slide the block up a ramp.

Hint: how can you lift a heavy load in a wheelbarrow?

If the block is 3cm above the table is the hook also 3cm above the table?



Imagine that you set up your equipment on the desk as is shown here. Will the spring balance

measure a force **greater than / less than / equal to** the weight of the block? Make a choice.

Task 1: Set up the equipment as it is shown and get evidence to decide the correct answer for the following statement of observed fact. Circle the correct words.

The balance measured a force **greater than / less than / equal to** the weight of the block.

Raise and lower the balance, and watch how the system moves. There is one place on the lever that does not move, we will call that the 'fulcrum'. Mark the diagram with the position of the fulcrum.

Task 2: Put the wood block on the ruler up against the spring balance and as far from the fulcrum as possible. Lift the block 3cm by pulling up on the spring balance. Measure the force shown on the spring balance. Record your results.

I measured the force to lift the block and the lever to be ……………………………… Newtons

I pulled up on the spring balance the distance of ………**0.03**……….. meters.

Task 3: Now place the block half way between the fulcrum and the balance. Pull up on the spring balance until the block is lifted 3cm. Notice that you have to move the spring balance more than 3cm. Record your results.

I measured the lifting force to be ……………………………… Newtons

I pulled up on the spring balance the distance of ……………….. meters.

Task 4: Now place the middle of the block two thirds of the way from the spring balance to the fulcrum. Pull up on the spring balance until the block is lifted 3cm. Notice the increased distance you had to move the spring balance. Record your results.

I measured the force to be ……………………………… Newtons

I pulled up on the spring balance the distance of ……………….. meters.

Repeat Tasks 2-4 to get three sets of results for each task, record results in a table.

Analyze your data. Calculate the average (mean) value for each of your three trials.

Describe the relationship between the force and the distance you move the spring balance. You might review what you concluded in previous classes about work, force, and distance.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

What evidence from your experiment supports the conclusion that you wrote above?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Name.......................
Date ....

Investigate (play): Tie one end of the string to the hook on the balance. Then arrange the block, balance, string and pulley / pulleys so that you can complete task 1.

Task 1: Lift the block while pulling on the balance with a force that is smaller than the weight of the block.

Measure three values from your balance and calculate the average (mean).

Our measured average value from the balance was ………….. Newtons.

Measure three values for the weight of the block.

Our measured average value for the weight of the block is ……….. Newtons.

Now calculate the ratio of average force from the balance over average weight of the block.

Our ratio for force in string over weight of block is ………………

Why is this not measured in Newtons? ……………………………………………………………….

……

Count how many strings go up from your block. This number is ……………..

Analysis: Write a reasonable conclusion relating the number of strings to the ratio of forces.

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Hold everything still, and then pull just one end of the string by moving the balance up 30cm. Observe and measure how far the block moved.

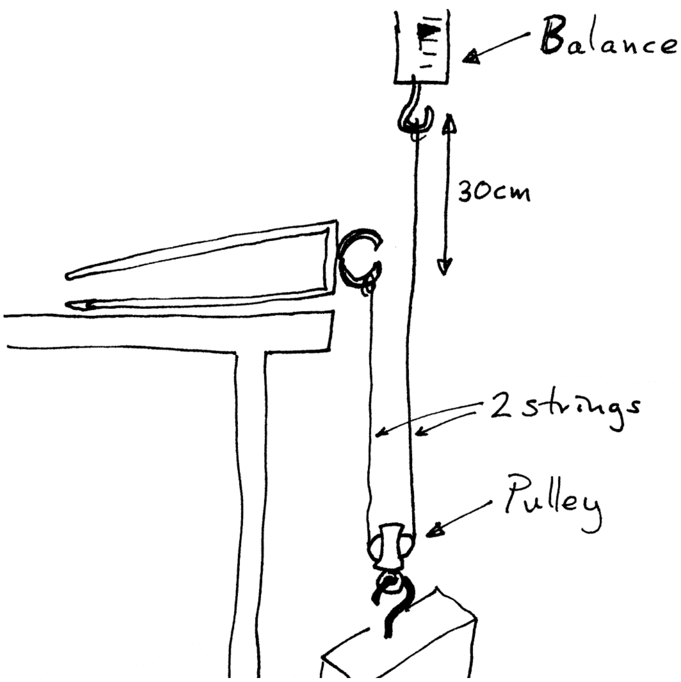
When we pulled the balance 30cm our block moved ……………… cm.

The ratio of the distance the block moved to the distance the balance moved is ………………….

Look for similarities in your data.

Task 2: Work done in raising a block.

Set up: Tie one end of the string to the balance, run the other end of the string through one pulley and hold it at a fixed place. (You may tie it to the ring of the three ring binder if that helps.) Hook the pulley to the block of wood. You should have a set up similar to the diagram below. (If this is what you did for task 1 then simply record your data in a table and do Task 3.)



Pull the balance up 30cm and measure the following things.

Number of pulleys …………

Number of strings ………..

Height the block was lifted……………… cm

Force on the balance ………………Newtons

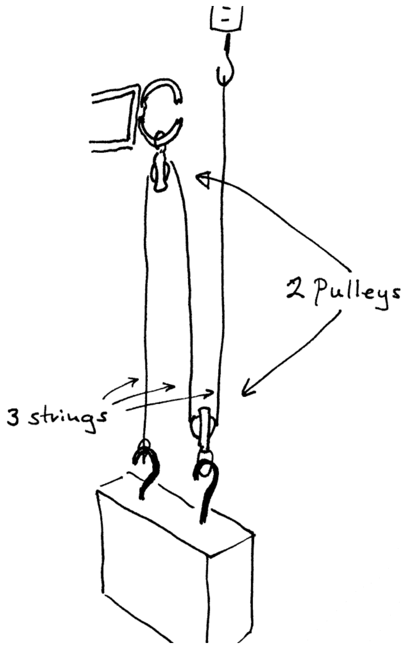
Weight of the block …………………Newtons

Make a data table.

Repeat your measurements to get three separate measurements.

Record your data.

Task 3: Have one end of the string attached to the balance. The string then runs through one pulley that is attached to the block. The string continues and runs through a second pulley that is hooked onto the three ring binder. The string then runs from that second pulley down to where it is tied onto the block. You should have a set up similar to the diagram below.
(If this is what you did for task 1 then simply record the following data in a table.)



Pull the balance up 30cm and measure the following things.

Number of pulleys ……………..

Number of strings ……………..

Height the block was lifted……………… cm

Force on the balance ………………Newtons

Weight of the block …………………Newtons

Make a data table, repeat your measurements three times, and record your data.

Use your data to decide between these two ideas. One of them is wrong. When you lift a weight with a system of pulleys you pull with a force that is less than the weight. In an ideal world where there was zero friction:

A) The force you pull with is equal to the weight divided by the number of pulleys.

B) The force you pull with is equal to the weight divided by the number of strings.

Notice that the work done when lifting the balance 30cm is different when the force that being supplied is different. Analyze your data and show that the difference in the work done by the balance is matched by a similar change in work done on the block. Complete the following sentences by putting a line through the incorrect words.

When the force used to raise the balance was decreased, the work done by the balance was **increased / the same / decreased**. This is consistent with the work done on the block because the weight of the block **increased / was the same / decreased** but the height it rose was **increased / the same / decreased**.

The same work was done at the balance and at the block, however, by using a pulley system

we have the benefit of ………………………………………………………………………………

……

Answer this question.

The car in the diagram weighs 240N.

How much force does the person lift with?

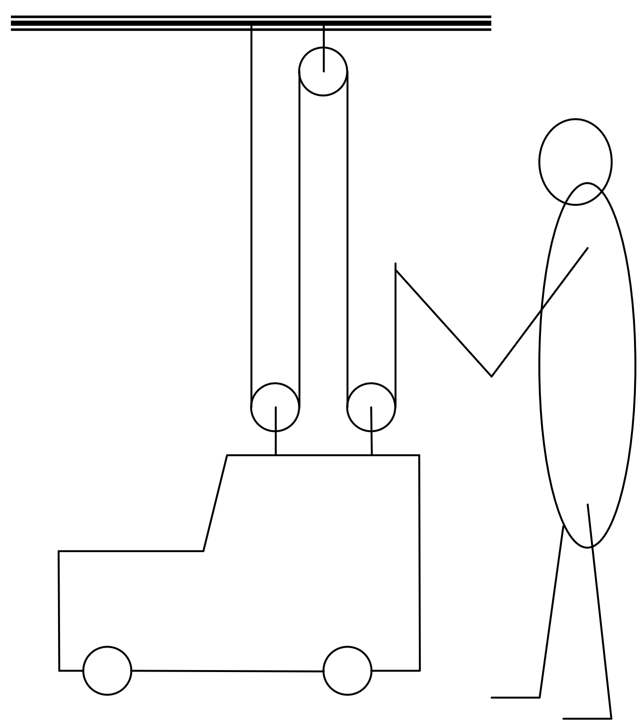
e) 480 N

f) 240 N

g) 120 N

h) 80 N

i) 60 N



Getting Stored Energy Back

Name ....
Date ....

Task 1: Split the last 2 or 3 cm of one end of your narrower straw and feed the other end into your wider straw. This is now your model fan. Put the loop of string around one blade then wind up the string around the inner straw. Hook the other end of the string to your block. Let the block drop to the floor so that the energy stored in your block drives the fan. This is an example of getting energy of motion back from stored or potential energy.

Drop the block from about table height a few times. Observe the speed of the falling block. Is it faster when it falls by itself or when it is driving the fan? Use the ideas of energy to explain your observation by completing this sentence.

Potential energy from the block was turned into energy in two moving objects: one was the

…………………………….. and the other was the ……………………………………………….

Task 2: Hold a plastic cup in front of you and then drop a marble into the cup from a distance of about 3cm (0.03m), then 9cm (0.09m),and then 27cm (0.27m) from the bottom of the cup. Listen to the amount of sound that is being made in each case. The force of gravity on a 17mm diameter marble is about 0.06N. Use Work = Force x Distance to calculate the amount of energy released when a marble falls 3, 9, and 27 cm. To get energy measured in Joules you must use force in Newtons and distance in meters. Use this information to argue that sound is a form of energy.

Falling 3cm released ……………….Joules of energy; this was the **loudest / middle / quietest**.

Falling 9cm released ………………...Joules of energy; this was the **loudest / middle / quietest.**

Falling 27cm released ……………….Joules of energy; this was the **loudest / middle / quietest.**

Task 3: Put one end of the foam gutter on the table and the other end propped up about 5cm on a pile of books. Release two marbles at the same time, one marble from about half way up and the other from the top. Observe what happens as they run down the ramp and across the table. Change your arrangement until you can have the top marble catch up with the bottom marble on the table. Sometimes a top marble catches up with the bottom marble on the ramp. Look carefully at your ramp, does it have the same steepness all along? Try again with the ramp held so that it is straight and not sagging in the middle.

Explain how the top marble can leave the ramp with more speed and kinetic energy than the bottom marble. Use the word ‘work’ and the word ‘potential’ in your explanation.

………. ………………………………………………………………………………………………

…………………………………………………………………………………………………….

Potential energy can be stored in many places. Examples include: bent or stretched springs (like rulers and rubber bands), food and other chemical fuels (like wood, candle wax, or gasoline), electric batteries, and high (elevated) objects (like water up above a dam). List other forms of energy that are not 'potential' energy, but can be seen or felt.

……………………………………………. ……………………………………………

……………………………………………. ……………………………………………

……………………………………………. ……………………………………………

Give examples where energy has been transformed from these various forms into potential energy ....

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Give examples where potential energy has been transformed into some of the various other forms of energy you listed. ………………………………………………………………………….

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

Module 7.1

Energy Transfer and Transformations
What is the role of energy in our world?

These assessment items are intended to provide closure for each lesson and help teachers determine how well the students understand the science concepts. The assessments are also intended to provide students additional practice with the lesson content. Teachers should use the assessment items as they deem appropriate. For example, teachers may wish to assign them for homework, assign them as an additional class activity or "quiz" at the end of a lesson, or ask students to answer them individually as they leave the class (as "exit passes"). Teachers may wish to use the problems as a closing class activity, asking students to solve the problem in groups and then share their answers in a whole group closing activity.

Application Problems

Lesson 7.1.1

Force x Distance is Work (Energy Transferred)

1. When riding a bicycle you can be in a low gear where your pedals are easy to turn, or in higher gear where your pedals are harder to turn. In this case the force used in the high gear is three times the force used in the low gear. The following will get you up to certain speeds. Rank them from slowest to fastest, use numbers from 1 for the slowest to 4 for the fastest.

j) Low gear and five pedal strokes.
k) High gear and two pedal strokes.
l) High gear and one pedal stroke.
m) Low gear and seven pedal strokes.

2.a A slingshot is pulled back 10cm and again but this time 20cm. Which of these puts more energy into the ball that is fired?

2.b A 20g ball is fired with the slingshot pulled back 10cm and a 40g ball is fired with the slingshot pulled back 20cm. Which ball is given the greater energy or do they both get the same? Explain your answer by referring to ‘work’.

2. Does the work done when exercising depend on:
   a) force alone,
   b) distance alone, or
   c) both force and distance?

3. Give an example from exercising where the amount of energy you use up depends on distance.

4. Give an example from exercising where the amount of energy you use up depends on force.

Application Problems
Lesson 7.1.2

Simple Machines - Slopes

1. Explain why mountain roads often are constructed in such as way as to wind around the mountain, rather than go straight up a mountain. Use scientific terminology in your explanation.

2. A person on the top of a hill with a bike can freewheel down the hill, gaining kinetic energy from the energy that was stored because they were at the top. Explain why the energy they have is the same regardless of whether they went up a long shallow slope, or a short steep slope.

3. Which of the following expressed the relationship among force, distance, and work?

a) force x distance = work

b) work = force + distance

c) force = distance = work

d) work = distance / force

Application Problems
Lesson 7.1. 3

Simple Machines – Levers

1. Levers let you lift heavy objects most easily when

   a) the fulcrum is in the middle

   b) the fulcrum is close to the heavy object

   c) the length of the lever is long

   d) the lever is very short

2. Explain how a light weight person can lift up a heavy person on a see saw. Explain how this does not put more energy into the heavy person than was put out by the light person.

3. Why is it easier to cut cardboard when the cardboard is closest to the hinge (fulcrum) of the scissors?

4. Explain how the Egyptians could have used levers as simple machines to construct the pyramids. Use scientific terminology in your answer.

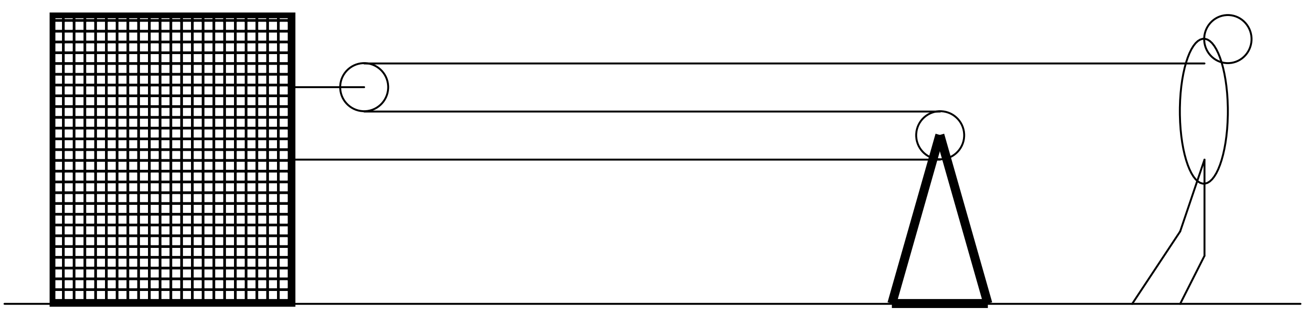
Application Problems
Lesson 7.1. 4

Simple Machines – Pulley Systems

1. You have available an empty spool of thread, a wire, a shoe that you want to lift, and string. Describe how you could make a pulley system. Draw a picture.

2. Which of the following is NOT true about a pulley system?
   a) Pulleys make work easier, and you get more energy out than you put in.
   b) Pulleys depend on wheels to make them work.
   c) You have to pull the string further when you use a pulley.
   d) With a pulley, a smaller force can be used to lift a larger mass.

3. It takes 150 Newtons to drag a crate along the road. The fire department set up a pulley system as shown. The triangle holds one pulley wheel fixed in place. How many Newtons of force does the fireperson pull with?



Application Problems
Lesson 7.1. 5

Getting Stored Energy Back

1. List three different ways you could store energy so it could be used later?

2. Which of the following describes potential energy?
   a) energy traveling as sound
   b) heat energy in a hot object
   c) energy stored up for future use
   d) the energy a moving object has

3. Design an experiment to show how potential energy can get an object moving.

4. Write the name of an object that transforms energy from the type of energy in the left hand column to the type in the right hand column.

Electric Potential Energy	to	Wind Energy	by	……………………………………
Electric Potential Energy	to	Light	by	……………………………………
Kinetic Energy	to	Heat Energy	by	……………………………………
Wind Energy	to	Sound Energy	by	……………………………………
Kinetic Energy	to	Gravitational Potential Energy	by	…………………………………