

INCLINED PLANE

&

WEDGES

Materials:

- Inclined Plane (Page 1) BLM 2.1
- Inclined Plane (Page 2) BLM 2.2
- Inclined Plane tables BLM 2.3
- Friction & Mechanical Advantage BLM 2.4
- Mechanical Advantage Discussion BLM 2.5
- Mechanical Efficiency BLM 2.6
- Mechanical Efficiency Discussion BLM 2.7
- Perpetual Motion Machine BLM 2.8
- masking tape
- various found materials
- spring scales of varying strengths
- rectangular blocks of wood with a hook attached
- kilogram mass
- 1m ramps with width larger than block
- metre sticks
- several textbooks

Overall Expectation(s): 3. Demonstrate an understanding of different types of systems and the factors that contribute to their safe and efficient operation. (8s20); 2. Investigate a working system and the ways in which components of the system contribute to its desired function (8s19).

Structures and Mechanisms – Systems in Action

– Inclined Plane and Wedges -

Description: This subtask will involve students using an inclined plane to understand how it makes work easier.

They will:

- manipulate variables in order to reduce the amount of friction between objects.
- be introduced to the terms *mechanical advantage* and *mechanical efficiency*.
- be introduced to the formulas for *calculation of work*, and for *mechanical advantage* and *mechanical efficiency* and will be asked to complete calculations using these formulas.

ACTIVITY 1 - FORCE

1. Review the concept of an inclined plane and the formula for *calculation of work* ($W = F \times d$).
2. In small groups, students will conduct an investigation related to the inclined plane. Have students arrange materials as shown in the blackline master (BLM 2.1- Inclined Plane).
3. To set up this activity, refer to BLM 2.1, diagram 3. Create a ramp using a board and a pile of books. The board should be longer than one metre. Check to ensure the ramp is stable. From the bottom of the ramp, measure exactly one metre along the ramp. Attach a one kilogram mass to the wooden block and place the block at the bottom of the ramp. Attach the spring scale to the hook, and drag the block up the ramp, until the bottom of the block passes the one metre mark. Students must note the measurement on the spring scale as the block passes the one metre mark. Record this measurement on table BLM 2.3 - Inclined Plane.
4. Students are to make a table in their notebook to record their data before the investigation begins. An example has been included (BLM 2.3- Inclined Plane tables).
The table must include: height of the ramp, work accomplished (Force [N], Distance [m], Work [J]) as well as work accomplished with the ramp and without the ramp.
5. Make sure to always check the spring scale to ensure that it is calibrated to zero.
6. Set the block of wood on its bottom edge so that the hook attached to the block is pointing towards the ceiling. This is so that the block can be lifted vertically (refer to diagram 1 BLM 2.1).
7. Attach the kilogram mass to the block of wood using masking tape (BLM 2.1, diagram 2).
8. Using the metre stick as a measurement guide, attach the spring scale to the hook, and raise the block vertically to a height of 0.75 m. Measure the force, in Newtons, required to lift the block, by reading the spring scale. Record this measurement on Inclined Planes Table - BLM 2.3. Remind students to maintain the block at a height of exactly 0.75 m while taking the measurement, and to measure accurately.
9. Repeat this process, raising the block to 0.5 m, then to 0.25 m. Each time measure the force required to lift the block, and record the results on table BLM 2.3. You are measuring the force required to move the block up a ramp (inclined plane).
10. Create a graph to illustrate your findings. Force (Newtons) on the vertical axis and distance along the ramp (metres) on the horizontal axis.

DISCUSSION QUESTIONS:

1. As the height of the ramp decreases, what happens to the amount of force necessary to drag the wooden block for the measured distance along the ramp?
2. Compare the amount of work required to lift the wooden block a specific vertical distance with the amount of work required to drag the same wooden block up a ramp with the same vertical distance (height).
3. What forces are being exerted on the block of wood and the kilogram weight as the block moves up the ramp?
4. How could the ramp be modified to reduce the amount of force needed to drag the wooden block?

ACTIVITY 2 - FRICTION

Activity 1 is a prerequisite for this activity. Ensure students understand the concepts from the previous activity.

1. Begin this activity with a general discussion of friction, using the information in your classroom notes and textbook as a guide. Review the suggestions for reducing the amount of force required to drag the block up the ramp (reducing friction).
2. Refer to diagram 4- BLM 2.1, page 2 to set up this activity. For this activity, the height of the inclined plane, the weight of the wooden block, and the distance the block moves remain constant (height 0.25 m, mass - Kg, distance - 1 m). Explain to students that the task is to reduce the amount of friction on the inclined plane (ramp) by covering it with different materials and then measuring the amount of force required to drag the wooden block up the ramp over each material. The students will have three attempts.

Procedure:

1. Set up the ramp (Diagram 4 - BLM 2.1 - Page 2)
2. Cover the ramp with the first material selected
3. Drag the block up the ram, using the spring scale. Measure the force required on table BLM 2.4- Friction and Mechanical Advantage, in the friction section. Note the type and amount of material used and calculate the input force.
4. Repeat this procedure using the other two materials selected. Complete the table BLM 2.4 each time. One of the challenges of this investigation will be to figure out a way to attach the materials to the ramp. For example, if the students want to use crayons, they would have to find a way to keep them in line on the ramp (probably by having a lot of crayons all piled side by side). This may take a while. Allow students to problem solve since they will need these skills in order to complete the summative task.
5. As a group, compare results. Discuss which materials worked the best and suggest some reasons.
6. Create a note that summarizes the ideas of inclined plane and friction.
7. Once all students understand the concept of FORCE as it relates to the inclined plane, discuss the concept of MECHANICAL ADVANTAGE.

OUTPUT FORCE [N] = LOAD FORCE [N] = FORCE PRODUCED **BY** the machine

(e.g., machine resisting pull) ($W = F \times d$)

INPUT FORCE [N] = EFFORT FORCE [N] = FORCE EXERTED **ON** the machine

(e.g., pulling up ramp) ($W = F \times d$)

MECHANICAL ADVANTAGE = OUTPUT FORCE [N] / INPUT FORCE [N] = LOAD / EFFORT

8. As a group, discuss the idea of something being *advantageous* and when one might use this word. For example, it might be advantageous to study before a test, to learn to skate before playing hockey, etc. Then have the class discuss the meaning of *mechanical* (i.e. using a machine, machine parts joined together to perform a function, etc.). Finally, have the students put the two ideas together so that they understand what is meant by *mechanical advantage*. Afterwards, explain that *mechanical advantage* is expressed as a ratio that compares output force and input force. It does not have any standard units.
9. Use the four examples below with the group to calculate mechanical advantage. Compile the Mechanical Advantage Ratio section of BLM 2.4- Friction & Mechanical Advantage. The first number is the output or load force and the second number is the input or effort force. The calculation is mechanical advantage. The following are examples of how mechanical advantage is calculated:
 - tow motor 5000 N 1000 N $5000/1000 = 5$
 - pencil sharpener 100 N 50 N $100/50 = 2$
 - remote controlled car 240 N 60 N $240/60 = 4$
 - slow conveyor belt 450 N 500 N $450/500 = 0.9$
10. For the sake of argument, have students assume that the wooden block used in these activities produced an output or load force equal to 10 N. Note that 10 N has been recorded in the Output Force column of the Mechanical Advantage Table BLM 2.4 to indicate the force required to drag the wooden block up the inclined plane 0.25 m in height. Use the data from the Input Force column of the Friction table to compile the Input Force column, and then have the students calculate and record the Mechanical Advantage Ratio.

DISCUSSION QUESTIONS

These questions have been produced on BLM 2.5 Mechanical Advantage Discussion Questions, and may be used as a handout.

1. What is mechanical advantage and how is it measured?
2. What happens to the mechanical advantage if the ratio of load force to effort force increases? What happens to the mechanical advantages if the ration of load force to effort force decreases?
3. Which of the examples on the chart has the best mechanical advantage?
4. Why is mechanical advantage important?
5. In what types of careers might use mechanical advantage?

ACTIVITY 3 - MECHANICAL EFFICIENCY

Students need to understand that *mechanical efficiency* is related to the amount of work done **BY the machine** compared to the amount of work supplied **TO the machine**. In other words, OUTPUT WORK compared to INPUT WORK times 100. It is always calculated as a percent.

1. Start with Question 1 in Discussion Questions in BLM 2.7- Mechanical Efficiency Discussion Questions. Using BLM 2.8- The Perpetual Motion Machine as a reference, have students respond to Question 1.
2. Have students complete the blackline master BLM 2.6- Mechanical Efficiency which has a table that includes examples of machines, OUTPUT WORK, INPUT WORK, Mechanical Efficiency Calculation (%).
3. Have students complete BLM 2.7.

DISCUSSION QUESTIONS BLM 2.7

These questions have been produced on BLM 2.7 Mechanical Efficiency Questions, and may be used as a handout.

1. Can you ever have a machine that is 100% efficient? Explain.
2. What is mechanical efficiency and how is it measured?
3. What is the relationship between mechanical efficiency and the percentage that is calculated?
4. Which of the machines in the table (BLM 2.6) has the best mechanical efficiency?
5. Why is mechanical efficiency important?
6. What is the difference between mechanical efficiency and mechanical advantage?
7. In what types of situations might you calculate or at least consider mechanical efficiency?

DISCUSSION ANSWERS

ACTIVITY 1 - DISCUSSION ANSWERS:

1. As the height of the ramp decreases, LESS force is needed to drag the wooden block up the ramp.
2. When lifting a block vertically, the FORCE needed to lift the object should remain constant; however, the amount of WORK required will change as the distance traveled changes. $W = F \times d$ so more work is required to lift an object higher. As the vertical height of the ramp decreased, the amount of force required to move the block decreased, as did the distance along the ramp.
3. The forces exerted on the block of wood are gravity, friction, tension, supporting force, etc. Refer to diagram 5 on BLM 2.2- Inclined Plane as a reference.
4. Changing the surface of the ramp by making it smoother or by adding rollers or wheels, etc. will reduce the amount of friction. Reducing the incline by lowering the ramp will also reduce the force required to move the block.

ACTIVITY 2 - DISCUSSION ANSWERS

1. Mechanical advantage is a comparison between the OUTPUT (Load) Force measured in Newtons and the INPUT (Effort) Force measured in Newtons. It is expressed as a ratio and does not have standard units of measurement.
2. If you divide the Output force by the Input force, the higher the quotient, the better the performance of the machine. In other words, the higher the level of mechanical advantage.
3. Answers may vary depending on the results students achieved in their inclined plane experiments. However, based on the examples given the tow motor with a quotient result of 5 had the best mechanical advantage.
4. Efficiency is achieved when a given amount of work can be accomplished with the least amount of effort. This means the amount of time and energy required to accomplish a specific task, or produce something can be reduced. This in turn lowers the cost of production and results in financial savings. This benefits both businesses and individuals.
5. Examples of careers: farmer, engineer, custodian.

ACTIVITY 3 - DISCUSSION ANSWERS

1. A machine can never be 100% efficient because some of its energy is lost or converted to other forms of energy such as heat, sound, etc.
2. Mechanical Efficiency is the relationship between the OUTPUT (Load) WORK and the INPUT (Effort) WORK expressed as a percentage. Work is always measured in Joules and this calculation is the quotient of output work divided by input work multiplied by 100 to get a percent.
3. The closer the calculated percentage is to 100, the less energy is wasted in running the machine. Because its output is maximized, the machine has a higher level of mechanical efficiency.
4. The escalator is the most efficient with a percentage of 93.75%.
5. Mechanical Efficiency is a measure of a machine's ability to do a maximum amount of work with the least possible energy. When this is accomplished, the machine is running at full capacity.
6. Mechanical Efficiency measures WORK and is expressed as a percent. Mechanical Advantage measures FORCE and is expressed as a ratio.
7. Answers may be similar to mechanical advantage, except students must use the word **WORK**. For example, the work the farmer has to do to crank up the elevator compared to the work done by the elevator.

SubTask 2 - Inclined Plane (BLM 2.1-Page 1)

Diagram 1

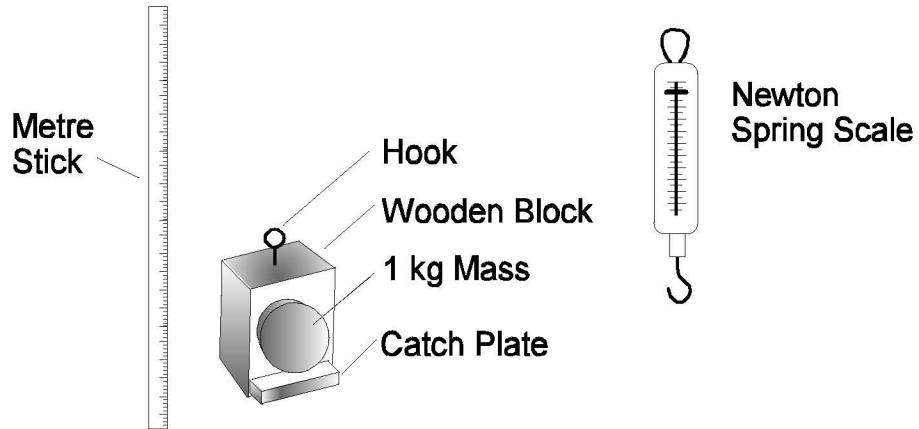


Diagram 2

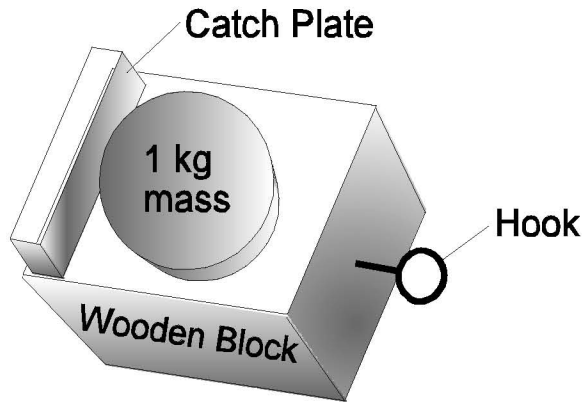
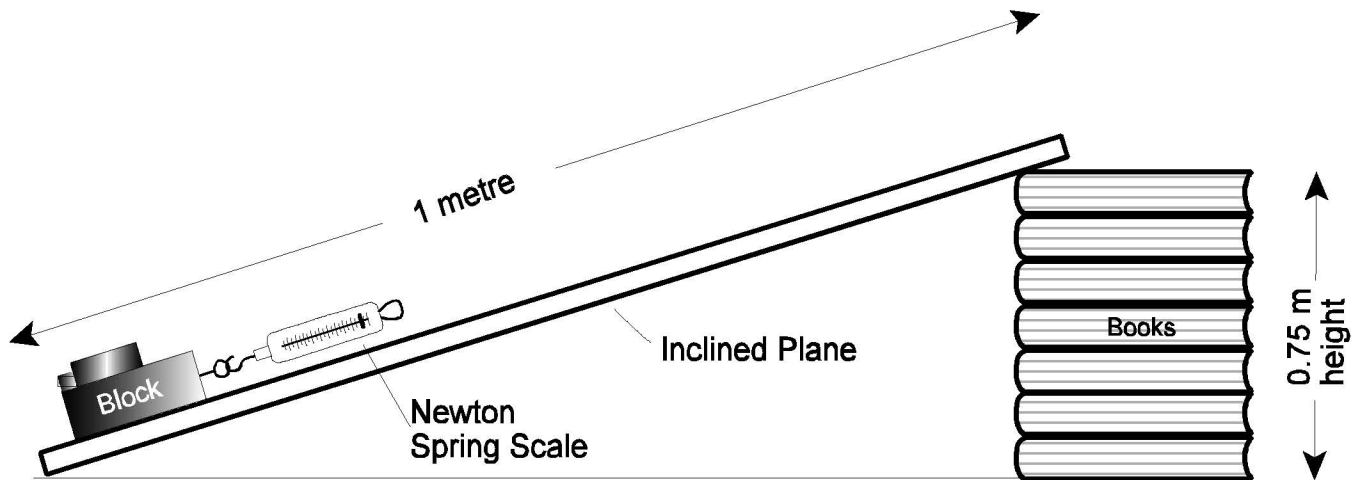


Diagram 3



SubTask 2 - Inclined Plane (BLM 2.1 - Page 2)

Diagram 3

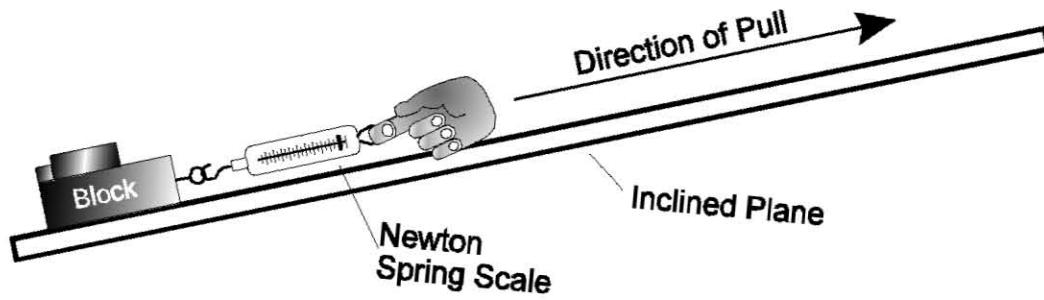


Diagram 4

Forces Acting on Block on Ramp

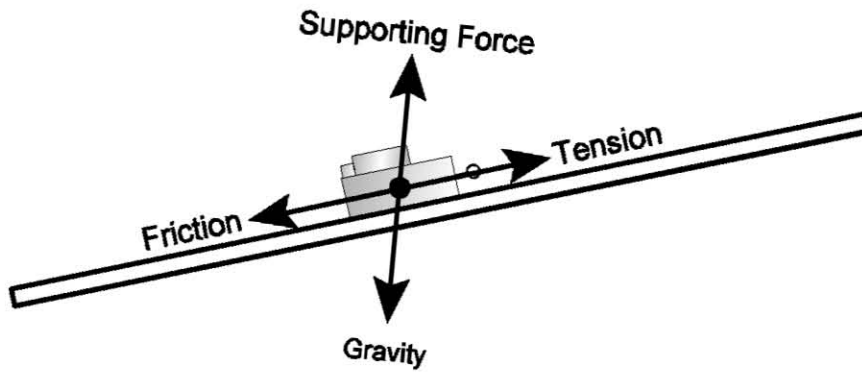
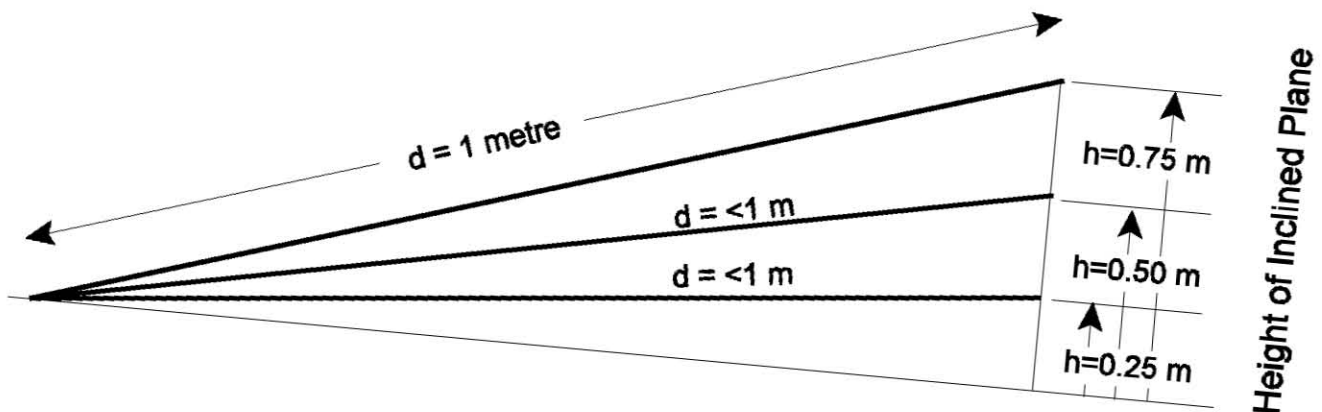


Diagram 5



BLM 2.3-Inclined Plane tables

INCLINED PLANE

The formula for calculating work is _____

Table 1: WITHOUT RAMP

FORCE (Newtons)	DISTANCE LIFTED (metres)	WORK ACCOMPLISHED (J) W=force (N) x distance (m)
	0.75 m	
	0.5 m	
	0.25 m	

Table 2: WITH RAMP

HEIGHT OF RAMP	FORCE (Newtons)	DISTANCE ALONG RAMP (metres)	WORK ACCOMPLISHED (J) W=force (N) x distance (m)
0.75 m			
0.5 m			
0.25 m			

Graph the results found in both tables above. Remember to label, use appropriate scales and be accurate and neat when completing graphs.

DISCUSSION QUESTIONS:

- As the height of the ramp was decreased, what happened to the amount of force that was necessary to drag the wooden block to the top of the books? _____

- Compare the amount of work accomplished to move the wooden block vertically a specific distance with the amount of work required by dragging the same wooden block up a ramp with the same vertical height. _____

- What forces are being exerted on the block of wood and the kilogram weight while being dragged up the ramp? _____

- List possible suggestions on how you could modify the ramp in order to reduce the amount of force needed to drag the wooden block. _____

BLM 2.4-Friction & Mechanical Advantage

FRICITION

MATERIAL USED	AMOUNT OF MATERIAL	INPUT FORCE [WORK ACCOMPLISHED $W = \text{force (N)} \times \text{distance (m)}$]
1. No material (See results from Table 2 on BLM 2.2-Inclined Plane)		
2. Material #1		
3. Material #2		
4. Material #3		

DISCUSSION QUESTIONS:

1. What is friction? _____
2. Why is it important to consider friction when creating a machine? _____
3. How can you reduce friction? _____

MECHANICAL ADVANTAGE

MACHINE	OUTPUT FORCE (load force in Newtons)	INPUT FORCE (effort force in Newtons)	MECHANICAL ADVANTAGE RATIO
1. Tow motor	5000 N	1000 N	
2. Pencil sharpener	100 N	50 N	
3. Remote control car	240 N	60 N	
4. Slow malfunctioning conveyor belt	450 N	500 N	
5. Block on ramp	10 N		
6. Block on ramp with Material #1	10 N		
7. Block on ramp with Material #2	10 N		
8. Block on ramp with Material #3	10 N		

BLM 2.5-Mechanical Advantage Discussion Questions

MECHANICAL ADVANTAGE

DISCUSSION QUESTIONS:

1. What is mechanical advantage and how is it measured?

2. If the ratio of the load force and the effort force increases, what happens to the mechanical advantage? _____

If the ratio of the load to effort force decreases, what happens to the mechanical advantage?

3. Which of the examples in the table for mechanical advantage in BLM 2.4, has the best mechanical advantage? _____

4. Why is mechanical advantage important? _____

5. In what types of situations might one calculate or at least consider mechanical advantage?

BLM 2.6-Mechanical Efficiency

MECHANICAL EFFICIENCY

Complete the following table:

MACHINE	OUTPUT WORK (work done by the machine) in JOULES	INPUT WORK (work put into the machine) in JOULES	MECHANICAL EFFICIENCY output/input X 100%
conveyor belt at grocery store checkout	150 J	175 J	
conveyor belt which sends up bales from the ground to the hay loft	1600 J	2000 J	
roller coaster full of passengers	3.0×10^5 J	4.0×10^5 J	
doughnut store conveyor belt for doughnuts that get sprayed with sprinkles	80 J	100 J	
circulating airport luggage conveyor belt	1000 J	1.1×10^3 J	
escalator	3.75×10^3 J	4.0×10^3 J	
ski slope tow rope	2.0×10^4 J	2.2×10^4 J	
track that carries cars in a car wash	7.5×10^3 J	8.3×10^3 J	
wheel chair lift up stairs	6.0×10^3 J	6.7×10^3 J	
luggage conveyor belt from out of the airplane's cargo hold	1.2×10^3 J	1.5×10^3 J	

BLM 2.7-Mechanical Efficiency Discussion Questions

MECHANICAL EFFICIENCY

DISCUSSION QUESTIONS:

1. Can you ever have a machine that is 100% efficient? Explain.

2. What is mechanical efficiency and how is it measured?

3. What is the relationship between mechanical efficiency and the percentage that is calculated?

4. Which of the examples in the table for mechanical advantage in BLM 2.4, has the best mechanical advantage? _____

5. Why is mechanical advantage important? _____

6. What is the difference between mechanical efficiency and mechanical advantage?

7. In what types of situations might you calculate or at least consider mechanical efficiency?

The Perpetual Motion Machine (BLM 2.8)

