

Chapter 14 – Work, Power, and Simple Machines

A. What is work?

1. Work requires motion.

- a. In order for a force to do work on an object, some of the force must act in the same direction in which the object moves.
- b. no movement = no work

2. Work depends on direction.

- a. Any part of the force that does not act in the direction of motion does no work on an object.
e.g. Carrying a bag of groceries. The vertical upward force on the bag does not act in the direction of movement. This vertical force does not perform any work on the groceries.

B. Calculating Work

1. Work = Force x Distance

force → constant force acting in the direction of movement

distance → the distance the object moves

2. Work = Newtons x meters

$N \times m = \text{Joule (SI unit of work)}$

2. 1 Joule = the force of 1 Newton that moves an object 1 meter

3. How much work does a weight lifter perform when he lifts a 100 N barbell a distance of 1.5m?
work = force x distance $W = f \times d$
 $100\text{N} \times 1.5\text{m} = 150 \text{ J}$

C. What is power?

1. Power is the rate (speed) at which work is done.
2. To increase power you can:
 - a. increase the amount of work in a given time
 - b. do a given amount of work in less time
(p. 414, figure 3)

D. Calculating Power

1. Power = $\frac{\text{work}}{\text{time}} = \frac{\text{Joules}}{\text{seconds}} = \text{watt (SI unit)}$

e.g. You exert a vertical force of 15 newtons to lift a box 2 meters in 2 seconds. How much power did you use?

$$\text{Power} = \frac{\text{work}}{\text{time}} \quad (\text{work} = \text{force} \times \text{distance})$$

$$\frac{15\text{N} \times 2\text{m}}{2 \text{ sec}} \rightarrow \frac{30\text{Nxm}}{2 \text{ sec}} = \frac{15 \text{ J}}{\text{sec}} = 15 \text{ watts}$$

E. Try math practice – page 415

1. James Watt was a Scottish scientist who defined horsepower.

- a. 1 HP = 1 strong horse which was used to compare steam engines to horses**
- b. 1 HP = 746 watts**

F. Machines do work

- 1. A machine is a device that changes a force.**
- 2. There are 3 different changes (not at once) a machine can do to a force.**

a. Change the size

- A small force exerted over a large distance becomes a large force exerted over a small distance.

b. Change the distance over which a force acts

- Some machines decrease the applied force, but increase the distance over which a force is exerted.

e.g. Oar of a boat

- Some machines decrease the amount of distance through which you exert a force. However, it increases the amount of force needed.

e.g. A single pulley vs. ramp

c. Change the direction of the applied force

e.g. Pulling back on an oar causes the other end to move in the opposite direction

G. Work input, Work output

- 1. Because of friction, the work done BY a machine is always less than the work done ON a machine.**
- 2. Input Force - force you exert on a machine**
- 3. Input Distance - the distance through which the input force acts**
- 4. Work Input = input force x input distance**
- 5. Output force - force that comes out of a machine**
- 6. Output Distance - the distance through which the output force is exerted**
- 7. Work Output = output force x output distance**
- 8. Work input is always greater than work output because of friction.**
- 9. The only way to increase work output is to increase work input.**

H. Mechanical Advantage (M.A.)

1. The M.A. of a machine is the number of times that the machine increases an input force.
2. Actual M.A. (AMA) equals the ratio of the output force to the input force.

$$\text{AMA} = \frac{\text{Output force}}{\text{Input force}}$$

3. Ideal MA (IMA) is the MA in the absence of friction
 - a. Because of friction, the actual MA (AMA) is always LESS than the ideal MA (IMA).

- b. $\text{IMA} = \frac{\text{Input distance}}{\text{Output distance}}$

e.g. A boy pushes a box up a ramp that is 3 meters long and raises the box 0.5 m.

What is the IMA of the ramp?

$$\frac{3\text{m}}{0.5\text{m}} = 6 \quad \text{Try math practice p. 425}$$

J. Efficiency

1. Because of friction, work input is always greater than work output. Therefore, the efficiency is always less than 100%.

2. $\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} \times 100\%$

3. $\text{Work Input} = \frac{\text{Work output} \times 100\%}{\text{Efficiency}}$

4. Work output = $\frac{\text{Work input} \times \text{efficiency}}{100\%}$

e.g. The efficiency of a machine is 50%. The machine requires 100J of work input to operate. What is the work output?

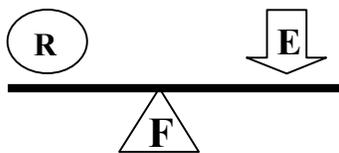
$$\frac{100\text{J} \times 50\%}{100\%} = \frac{5000\text{J}}{100} = 50\text{J}$$

4. Reduce friction to increase efficiency: ball bearings and grease are examples of friction reducers

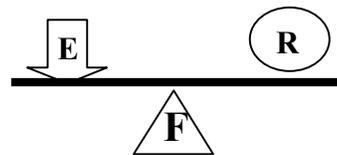
K. Levers

1. Lever is a rigid bar that is free to move around a fixed point.
2. Parts of a lever
 - a. Fulcrum - fixed point the bar rotates on
 - b. Input arm - distance between input force and fulcrum
 - c. Output arm - distance between the output and the fulcrum
3. IMA of Levers = $\frac{\text{Input arm}}{\text{Output arm}}$
4. 3 classes of levers

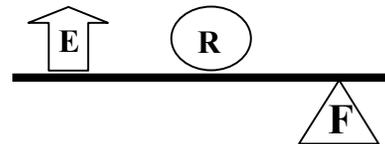
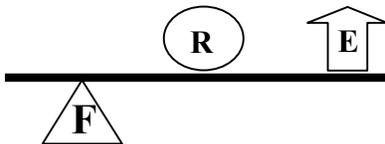
a. 1st Class



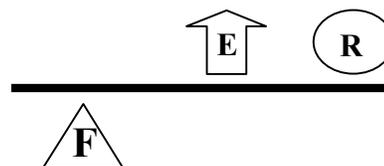
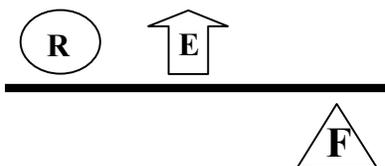
or



b. 2nd Class



c. 3rd Class



 = resistance (output)  = effort force (input)  = fulcrum

L. Wheel and Axle

1. Simple machine that consists of 2 disks or cylinders with different radii

e.g. Screwdriver

2. IMA of Wheel and Axle = $\frac{\text{Radius of Input}}{\text{Radius of Output}}$

M. Incline Planes

1. Incline plane is a slanted surface along which a force moves an object

2. IMA Incline Planes = $\frac{\text{Plane Length}}{\text{Plane Height}}$

N. Wedges and Screws - Similar to incline planes in that they have sloping surfaces. However, their sloping surfaces move.

- 1. Wedge - V shaped object consisting of 2 inclined planes**
 - a. a thin wedge of a given length has a greater IMA than a thick wedge of the same length
e.g. - knife, blades, zippers**
- 2. Screws - incline plane wrapped around a cylinder**
 - a. A screw with threads close together has a greater IMA.**

O. Pulleys

- 1. A pulley is a simple machine with a rope that fits into a groove on a wheel.**
 - a. IMA of pulley system is equal to the number of ropes that support the load. p. 432**
- 2. Fixed pulleys only change the direction of the force that is being exerted. The IMA of a fixed pulley is always 1.**
- 3. Moveable pulleys are used to increase the force by 2. However, you must pull more rope.**
- 4. A pulley system combines fixed and moveable pulleys in order to achieve a large MA.
(Fig 19 P. 432)**

**P. Compound Machines: combination of 2 or more simple machines that operate together
p. 434 Fig 20 - The watch gears act together. Each gear is a continuous lever.**