# 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 x m = 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 x d
   100N x 1.5m = 150 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 = $\frac{\text{work}}{\text{time}}$ = $\frac{\text{Joules}}{\text{seconds}}$ = 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?

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

$\frac{15\text{N x } 2\text{m}}{2\text{ sec}} \rightarrow \frac{30\text{Nxm}}{2\text{ sec}} = \frac{15\text{ J}}{\text{sec}} = 15$ 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. **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?**

$$\frac{3\text{m}}{0.5\text{m}} = 6$$

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**J. Efficiency**

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

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

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

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

   **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


   b. 2nd Class


   c. 3rd Class


R = resistance (output) E = effort force (input) F = 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.**