Ch 8 – Energy & Work

Work, Energy, Power

"Work," "energy," and "power" are words that have certain meanings in everyday language. These words have very *specific* meanings in physics; you'll need to be careful not to mix up the two ways of speaking.

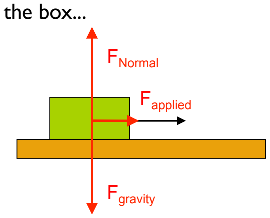
Definition of Work

$$Work_{done\ by\ a\ Force} = Force \times displacement$$

Note that the **Force** and the **displacement** have to be in the *same direction*.

Example 1

A 100-N horizontal force is used to drag a 20kg box 2.0-m across a frictionless table. How much Work is done on the box...



a) By the horizontal Force?

$$W = Fx$$
$$W = (100)(2.0) = 200 N \bullet m$$
$$W = 200\ Joules$$

b) By the table?

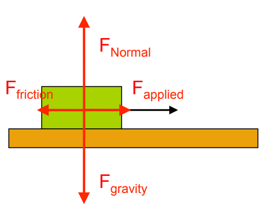
$$0 J$$

c) By gravity?

$$0 J$$

Example 2

The same 100-N horizontal force is used to drag a 20kg box 2.0-m across a rough surface at constant velocity.

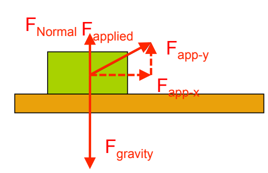


How much Work is done by Friction?

$$W = Fx\cos\theta$$
$$W = (-100N)(2.0m)$$
$$W = -200J$$

Example 3

A 100-N is applied at 37° above the horizontal, and used to drag the 20-kg box 2.0-m across a frictionless surface.

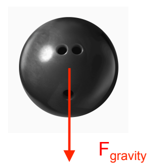


How much Work is done by the applied Force?

$$W = Fx$$
$$W = (80N)(2.0m)$$
$$W = 160J$$

More Examples

1. I lift a 8-kg bowling ball up 50 cm into the air at constant velocity--how much Work did I do?
2. How much Work did Earth's gravity do in the preceding problem?
3. How much Work do I do lowering an 8-kg bowling ball 50 cm down?
4. How much Work do I do holding an 8-kg bowling ball motionless in the air?
5. How much Work do I do carrying an 8-kg bowling ball sideways 50cm at constant velocity?



Work - Energy

Work is a means by which energy is *transferred.*

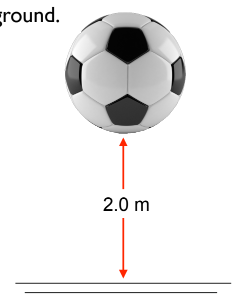
Mechanical Energy-2 types

Mechanical Energy is a term that refers to two specific types of energy that we're going to be focusing on.

$$GPE = U_g = mgh$$

Example

A 1.50-kg soccer ball is held 2.0 meters above the ground.



a) What is the GPE of the soccer ball, relative to the ground?

b) How much work was done to lift the soccer ball into the air?

Work done against gravity

$$Work = F \bullet d$$

$$GPE = mgh$$

$$Work = F_g \bullet d = mgd$$

$$Work = GPE\,?$$

$$mgd = mgh!$$

When I do Work on the ball, I transfer energy to the ball.

Mechanical Energy-2 types

Mechanical Energy is a term that refers to two specific types of energy that we're going to be focusing on.

$$GPE = U_g = mgh$$

$$KE = K = \frac{1}{2}mv^2$$

Conservation of Energy

"Energy is neither created nor destroyed – energy is always conserved."

$$\sum \Delta E = 0$$

$$GPE_i + KE_i = GPE_f + KE_f$$

Cons. of Energy - Non-isolated system

Isolated system = unaffected by outside influence

Non-isolated system = Work added to the system, or thermal energy (TE) "lost" (converted) as heat.

Power

Power = "the rate at which Work is done."

$$Power \;\; P_{avg} = \frac{\Delta Work}{\Delta time}$$

Example 15

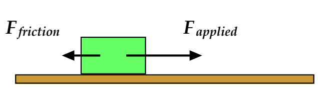
A student in class is lifted in a chair.

a) How much Work was required to lift the student?

b) How much Power was used to lift the student?

Energy & Friction?

Friction forces convert KE into *internal* energy.



$$W = Fd$$

$$TE = F_{friction} \bullet displacement$$

Conservation of Energy

"Energy is neither created nor destroyed – energy is always conserved."

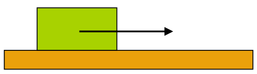
$$\sum E_i = \sum E_f$$

$$U_i + K_i = U_f + K_f$$

$$E_{system-initial} - \Delta E_{internal} + \Sigma W_{otherforces} = E_{system-final}$$

Example 12

A 6.0-kg mass is pulled with a constant horizontal Force of 12.0-N for a distance of 3.0-m on a rough surface with μ=0.15.



Find the final speed of the block using work-energy.

$$W + K_i - \Delta E_{int} = K_f$$

$$Fx + 0 - fd = \frac{1}{2} m v_f^2$$

$$f = \mu N = \mu m g$$

$$v_f = \sqrt{\frac{2(Fx - \mu m g d)}{m}}$$

$$v_f = \sqrt{\frac{2(12 \bullet 3 - 0.15 \bullet 6 \bullet 9.8 \bullet 3)}{6}}$$

$$v_f = 1.78 m/s$$

Example 13

A car traveling at a speed *v* skids a distance *d* after the brakes lock up.

a) How far will it skid if its initial velocity is 2*v*?

$$K_i - \Delta E_{int} = K_f$$

$$\frac{1}{2} m v^2 - fd = 0$$

$$d = \frac{m v^2}{2f} \to d \propto v^2$$

$$d' = \frac{m(2v)^2}{2f} = 4\left(\frac{m v^2}{2f}\right) = 4d$$

b) What happens to the car's *K* as it skids to a stop?

It's converted to random K of molecules in tire & road.

Example 14

A 1.6 kg block is attached to a spring with k = 1.0×10^3 N/m. The spring is compressed 2.0 cm and released.

a) What is the speed of the block as it passes through the equilibrium position? (Assume frictionless.)

$$W_{spring} + K_i = K_f$$

$$\frac{1}{2} k x^2 + 0 = \frac{1}{2} m v^2$$

$$v = \sqrt{\frac{k}{m}} x = \sqrt{\frac{1000}{1.6}} (0.02) = 0.5 m/s$$

b) What is the speed of the block as it passes the equilibrium position if there is a constant friction force of 4.0 N retarding its motion?

$$W_{spring} + K_i - \Delta E_{int} = K_f$$

$$\frac{1}{2} k x^2 + 0 - fd = \frac{1}{2} m v^2$$

$$\frac{1}{2} 1000 (0.02)^2 + 0 - (4)(0.02) = \frac{1}{2} 1.6 v^2$$

$$v = 0.39 m/s$$

Example 16

An elevator with a mass of 1000 kg carries a load of 800 kg. 4000 N of friction retards the elevator's upward motion.

a) Find minimum power necessary to lift the elevator at a speed of 3.00 m/s.

6.48e4 W

b) If the motor needs to have a 3:1 safety factor, what should the horsepower rating on the motor be? (746 W = 1 hp)

3*86.9=261 hp

c) What Power must the motor deliver at any instant (as a function of *v*) if it's designed to provide an acceleration of 1.00 m/s^2?

P=F•v=7.03e4v W

Example 17

A hiker carries a 15.0 kg backpack up a 20m long slope, inclined at 30° above the horizontal.

a) How much Work was done on the backpack by the hiker?

b) How much Work was done on the backpack by gravity?

c) What was the net Work done on the backpack?