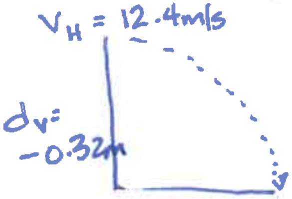
5. How would the three answers to Question #4 change if:
   a. The stone was thrown with twice the horizontal speed
      - The time wouldn't change
      - The distance horizontally travelled would double
      - The final vertical v will stay the same
      - Final horizontal velocity doubles (does not change from initial, though)
   b. The stone was thrown with the same speed but the cliff was twice as high?
      - The time would increase
      - distance horizontally will increase.
      - The final vertical velocity will increase
      - Final horizontal velocity stays the same

6. A dart player throws a dart horizontally at a speed of 12.4 m/s. The dart hits the board 0.32 m below the height from which it was thrown. How far away is the player from the board?



Vertically

$v_i = 0\,m/s$

$d_v = -0.32\,m$

$a = -9.81\,m/s^2$

$t = ?$

$$d_v = \cancel{v_{iv}t} + \tfrac{1}{2}a_v t^2$$

$$t = \sqrt{\frac{2d}{a}}$$

$$= \sqrt{\frac{(2)(-0.32\,m)}{-9.81\,m/s^2}} = 0.2554\,s$$

Horizontally:

$v_H = 12.4\,m/s$

$t_v = 0.2554\,s$

$d_H = ?$

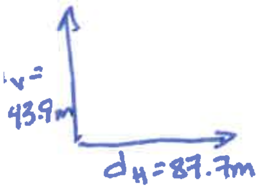
$$d_H = v_H t$$

$$= (12.4\,m/s)(0.2554\,s)$$

$$= 3.17\,m$$

$$= \boxed{3.2\,m}$$

7. An automobile, moving too fast on a horizontal stretch of mountain road, slides off the road, falling into deep snow 43.9 m below the road and 87.7 m beyond the edge of the road.
   a. How long did the auto take to fall?



vertically: $v_i = 0\,m/s$

$d = -43.9\,m$

$a = -9.81\,m/s^2$

$$d = \cancel{v_i t} + \tfrac{1}{2}at^2$$

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{(2)(-43.9\,m)}{-9.81\,m/s^2}} = 2.992\,s$$

$$= \boxed{2.99\,s}$$

   b. How fast was it going when it left the road?

$t = 2.992\,s$

$d_H = 87.7\,m$

$v_H = ?$

$$v_H = \frac{d_H}{t} = \frac{87.7\,m}{2.992\,s}$$

$$= 29.31\,m/s \text{ or } \boxed{29.3\,m/s}$$

   c. What was the acceleration 10 m below the edge of the road?

$-9.81\,m/s^2$ (in freefall)

1. a) At the end; b) at the top of the trajectory; c) same throughout 2. Directly overhead 3. Yes 4.a) 4.00 s; b) 20 m; c) v_x = 5.0 m/s; v_y= -39.2 m/s 5a) no change to time or vertical component of v_f; horizontal distance and horizontal v_f doubles, b) time, vertical v_f and horizontal distance increase; 6. 3.2m 7. a) 2.99 s; b) 29.3 m/s; c) -9.81 m/s²

Chapter 6: Work and Mechanical Energy

Energy is the capacity to do work

Work

- the product of force exerted on an object and the distance the object moves in the direction of the force.

$$\boxed{W = Fd}$$

W = Work (Joules, J)
F = force applied (N)
d = distance (m)

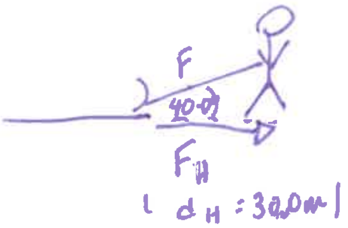
- If a large force is applied with no movement, then no work is done.
- If a force is exerted perpendicular to the motion, then no work is done.
- If a force is exerted at an angle to the motion, then the force can be replaced by its components. Only the component in the direction of motion does work.

Ex#1: How much work do you do when you climb a 3.0 m high staircase? (Assume your weight is 600 N)

$d = 3.0\text{m}$
$F_A = 600\text{N}$
$W = ?$

$W = F \cdot d$
$= (600\text{N})(3.0\text{m})$
$= 1800\text{J} = \boxed{2000\text{J}}$ (1 sf)

Ex 2: A man pulls a toboggan along the snow with the rope at an angle of 40.0° with the horizontal. How much work is done by the man if he exerts a force of 255 N on the rope and pulls the toboggan 30.0 m?



$\cos 40.0° = \frac{F_H}{F}$

$F_H = 255\text{N}(\cos 40.0°)$

$W = F_H \cdot d$
$= (255\text{N})(\cos 40.0°)(30.0\text{m})$
$= 5860.2\text{J}$
$= \boxed{5860\text{J}}$

Work

1. When a bowling ball rolls down a level alley, does Earth's gravity do any work on the ball? Explain.

   No - Force of gravity acts vertically while the ball's movement is solely horizontal.

2. A force of 825 N is needed to push a car across a lot. Two students push the car 35 m.

   a. How much work is done?

   $d = 35m$

   $F = 825N$

   $W = F \cdot d$

   $= (825N)(35m) = 28875J$ or $\boxed{2.9 \times 10^4 J}$

   b. After a rainstorm, the force needed to push the car doubled because the ground became soft. By what amount does the work done by the students change?

   Work doubles if force doubles.

   $2F \cdot d = 2W$

3. A delivery clerk carries a 34 N package from the ground to the fifth floor of an office building, a total of 15 m. How much work is done by the clerk?

   $F = 34N$

   $d = 15m$

   $w = ?$

   $W = F \cdot d$

   $= (34N)(15m)$

   $= \boxed{510J}$

4. What work is done by a forklift raising a 583 N box to a height of 1.2 m?

   $F = 583N$

   $d = 1.2m$

   $W = ?$

   $W = F \cdot d$

   $= (583N)(1.2m)$

   $= 699.6 J$ or $\boxed{7.0 \times 10^2 J}$

5. You and a friend each carry identical boxes to a room one floor above you and down the hall. You choose to carry it first up the stairs and then down the hall. Your friend carries it down the hall, and then up another stairwell. Who does more work?

   Neither. Both lift the boxes to the same height.

6. How much work does the force of gravity do when a 25N object falls a distance of 3.5 m?

   $F = 25N$

   $d = -3.5m$

   $W = ?$

   $W = F \cdot d$

   $= (25N)(-3.5m)$

   $= -87.5J$ or $\boxed{-88J}$

7. An airplane passenger carries a 215 N suitcase up stairs, a displacement of 4.20 m vertically and 4.60 m horizontally.

   a. How much work does the passenger do?

$d_v = 4.20m$ $\quad W = F \cdot d$

$F_v = 215N$ $\quad = (215N)(4.20m)$

$W = ?$ $\quad = \boxed{903J}$

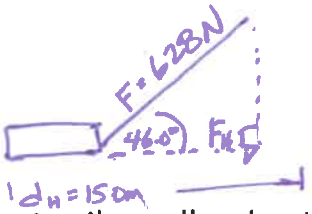
   b. The same passenger carried the same suitcase back down the same stairs. How much work does the passenger do now?

$d = -4.20m$

$F = 215N$ $\quad -903J$

$W = ?$

8. A rope is used to pull a metal box 15.0 m across the floor. The rope is held at an angle of 46.0° with the floor and a force of 628 N is used. How much work does the force on the rope do?



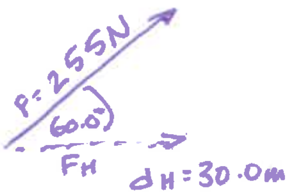
$F_H = F\cos 46.0°$ $\quad W = F_H \cdot d$

$d_H = 15.0m$ $\quad = (628N)(\cos 46.0°)(15.0m)$

$W = ?$ $\quad = 6544J$

$= \boxed{6.54 \times 10^3 J}$

9. A sailor pulls a boat along a dock using a rope at an angle of 60.0° with the horizontal. How much work is done by the sailor if he exerts a force of 255 N on the rope and pulls the boat 30.0 m?



$F_H = F\cos 60.0°$ $\quad W = (F\cos 60°)(d)$

$= (255N)(\cos 60.0°)$ $\quad = (255N)(\cos 60.0°)(30.0m)$

$d_H = 30.0m$ $\quad = 3825J$

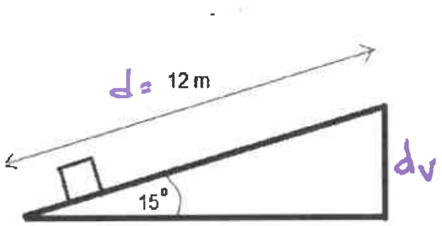
$W = ?$ $\quad = \boxed{3.83 \times 10^3 J}$

10. Ronan pushes a 5.0 kg box up a 12 m long ramp that is built at a 15° angle to the horizontal. How much work does Ronan do?

$\sin 15° = \frac{d_v}{d}$ $\therefore d_v = (12m)(\sin 15°)$

$F_v = mg = (5.0kg)(9.81N/kg)$

$= 49.05N$



$W = d_v F_v = (12m)(\sin 15°)(49.05N)$

$= 152.3J = \boxed{1.5 \times 10^2 J}$

Answers: 1) No - displacement is perpendicular to force 2a) 2,9x10^{4}J b) doubles 3) 510J 4) 7.0x10^{2}J 5) same 6) 88J
7a) 903J b) -903J 8) 6.54x10^{3}J 9) 3,83x10^{3}J 10) 1.5x10^{2}J

Mechanical Advantage

- Simple machines such as pulleys, ramps and levers can be used to help people do work.
- The amount of work done doesn't change, only the amount of effort (force) required to get it done!
- If the work doesn't change, but the effort force goes down, then that force MUST be applied over a greater distance
- Mechanical advantage is the amount of help you get by using the machine (rather than just doing that work directly).

$$\text{Mechanical Advantage} = \frac{\text{Load Force}}{\text{Effort Force}}$$

Ex#1: A set of pulleys is used to lift a 722 kg car engine. If a 295 N force is needed to lift the engine, what is the mechanical advantage of the set of pulleys?

Load force = $F_g = (722\text{kg})(9.81\text{N/kg})$

$= 7083\text{N}$

Effort force = 295N

$$\text{M.A.} = \frac{\text{Load force}}{\text{Effort force}} = \frac{7083\text{N}}{295\text{N}} = \boxed{24}$$

* FIX

Ex#2: Beth needs to bring a 52 kg box of books up a 3.0 m high flight of stairs. Instead of carrying them directly up, she sets up a 12 m ramp. If Beth needs to apply a force of 128 ~~150~~ N to push the box up the ramp, what is the mechanical advantage of the ramp?

Load force = $(52\text{kg})(9.81\text{N})$

$= 510.1\text{N}$

Effort force = 128N

$$\text{M.A.} = \frac{\text{Load force}}{\text{Effort force}} = \frac{510.1\text{N}}{128\text{N}} = \boxed{4.0}$$

Power

- Rate at which work is done.

$$\boxed{P = \frac{W}{t}}$$

P = power, watts (w)
W = work, Joules (J)
t = time, seconds (s)

Ex#1: How much power is developed by a 70.0 kg boy running up a flight of stairs, 4.5 m high in a time of 2.5 s?

$m = 70.0\,kg$
$d = 4.5\,m$
$t = 2.5\,s$

$F_g = mg$

$W = F \cdot d = mg \cdot d$

$$P = \frac{W}{t} = \frac{mg \cdot d}{t} = \frac{(70.0\,kg)(9.81\,N/kg)(4.5\,m)}{2.5\,s}$$

$$= 1236\,W \text{ or } \boxed{1.2 \times 10^3\,W}$$

Ex#2: How much energy (or work!) does a 1500 W toaster convert to heat in 2 minutes?

$P = 1500\,W$
$t = 2\,min \times \frac{60\,s}{1\,min} = 120\,s$
$W = ?$

$P = \frac{W}{t}$

$$W = P \cdot t$$
$$= (1500\,W)(120\,s)$$
$$= \boxed{1.8 \times 10^5\,J}$$

Power

1. A box that weighs 575 N is lifted a distance of 20.0 m straight up by a rope. The job is done in 10.0 s. What power is developed?

$F = 575N$

$d = 20.0m$

$t = 10.0s$

$$P = \frac{W}{t} = \frac{F \cdot d}{t} = \frac{(575N)(20.0m)}{10.0s} = \boxed{1150W}$$

2. A rock climber wears a 7.50 kg knapsack while scaling a cliff. After 30.0 min, the climber is 8.2 m above the starting point.

   a. How much work does the climber do on the knapsack?

   $m = 7.50Kg$

   $d = 8.2m$

   $$W = mg \cdot d = (7.50kg)(9.81N/kg)(8.2m) = 603J = \boxed{6.0 \times 10^2 J}$$

   b. If the climber weighs 645 N, how much work does she do lifting herself and the knapsack?

   $F_g = 645N + (7.50kg)(9.81N/kg) = 718.6N$

   $d = 8.2m$

   $$W = F \cdot d = (718.6N)(8.2m) = 5892J \text{ or } \boxed{5.9 \times 10^3 J}$$

   c. What is the power developed by the climber?

   $t = 30.0min \times 60.0s/min = 1800s$

   $W = 5892J$

   $$P = \frac{W}{t} = \frac{5892J}{1800s} = \boxed{3.3W}$$

3. Brutus, a champion weightlifter, raises 240 kg a distance of 2.35 m.

   a. How much work is done by Brutus lifting the weights?

   $m = 240Kg$

   $g = 9.81N/Kg$

   $d = 2.35m$

   $$W = F \cdot d = mg \cdot d = (240kg)(9.81N/kg)(2.35m) = 5533J \text{ or } \boxed{5.5 \times 10^3 J}$$

   b. How much work is done holding the weights above his head?

   No work $(d = 0m)$

   c. How much work is done lowering them back to the ground?

   $-5533J$ or $\boxed{-5.5 \times 10^3 J}$

   d. If Brutus completes the lift in 2.5 s, how much power is developed?

   $W = 5533J$

   $t = 2.5s$

   $$P = \frac{W}{t} = \frac{5533J}{2.5s} = 2213W \text{ or } \boxed{2.2 \times 10^3 W}$$

4. An electric motor develops 65 kW of power as it lifts a loaded elevator 17.5 m in 35.0 s. How much force does the motor exert?

$P = 65\,kW = 6.5\times10^4 W$

$d = 17.5 m$

$t = 35.0 s$

$F = ?$

$P = \frac{W}{t}$

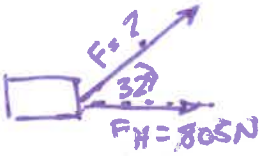
$P = \frac{F \cdot d}{t}$

$F = \frac{P \cdot t}{d}$

$= \frac{(6.5\times10^4 W)(35.0 s)}{17.5 m} = \boxed{1.3\times10^5 N}$

5. A horizontal force of 805 N is needed to drag a crate across a horizontal floor with a constant speed. Pete drags the crate using a rope held at an angle of 32°.

a. What force does Pete exert on the rope?



$\cos 32° = \frac{F_H}{F}$

$F = \frac{F_H}{\cos 32°} = \frac{805N}{\cos 32°} = 949.2 N$ or $\boxed{949N}$

b. How much work does Pete do on the crate when moving it 22 m?

$F_H = 805N$

$d_H = 22m$

$W = ?$

$W = F_H \cdot d$

$= (805N)(22m)$

$= 17710 J$ or $\boxed{1.8\times10^4 J}$

c. If Pete completes the job in 8.0 s, what power is developed?

$W = 17710J$

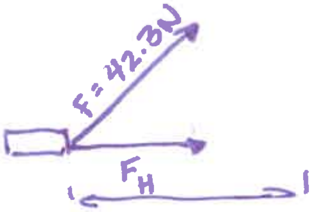
$t = 8.0s$

$P = ?$

$P = \frac{W}{t} = \frac{17710J}{8.0s}$

$= 2214 W$ or $\boxed{2.2\times10^3 W}$

6. Seth pulls a 305 N sled along a snowy path using a rope that makes a 45.0° angle with the ground. Seth pulls with a force of 42.3 N. The sled moves 16 m in 3.0 s. What is Seth's power?



$d = 16m$

$t = 3.0s$

$F_H = F\cos 45.0°$

$= (42.3N)(\cos 45.0°)$

$\therefore P = \frac{W}{t} = \frac{F_H \cdot d}{t} = \frac{(42.3N)(\cos 45.0°)(16m)}{3.0s}$

$= 159.5 W$ or $\boxed{1.6\times10^2 W}$

ANSWERS: 1) 1.15×10^3W 2a) 6.0×10^2J b) 5.9×10^3J c) 3.3W 3a) 5.5×10^3J b) no work c) -5.5×10^3J d) 2.2×10^3W 4) 1.3×10^5N
5a) 949N b) 1.8×10^4J c) 2.2×10^3W 6) 1.6×10^2W

Mechanical Energy

Energy: the ability to do Work

transfer of energy = work done on an object

$$\Delta E = W = E_f - E_i$$

Forms of Mechanical Energy

Gravitational Energy - as a result of an object's position.
ie. roller coaster at the top of a hill

Kinetic Energy - due to the motion of an object. ie. moving car

Gravitational Potential Energy

- dependent on the object's position above the Earth's surface.

$$W = F.d$$

since $F_g = mg$

and $d = h$

then, $\mathbf{E_p = mgh}$

E_p = Grav. Potential Energy (J)

m = mass (kg)

g = gravitational field strength (9.80 m/s²)

h = height above reference level (m)

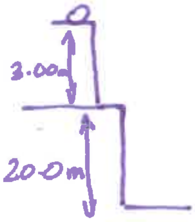
- formula is valid only where g is constant.
- select a position at which an object's potential energy is zero (lowest point)
- potential energy is measured relative to the reference level.

Ex#1: Each step of a ladder increases one's vertical height by 40cm. If a 90.0 kg painter climbs eight steps of the ladder, what is the increase in potential energy?

$h = 8 \times 0.4m$
$= 3.2m$
$m = 90.0kg$
$g = 9.81 N/kg$

$E_p = mgh$
$= (90.0kg)(9.81 N/kg)(3.2m)$
$= 2825 J$
or $\boxed{2.8 \times 10^3 J}$

Ex#2: A 10.0 kg rock is on top of a house 3.00 m high on the edge of a cliff that is 20.0 m high. What is the gravitational potential energy of the rock...



a) relative to the roof of the house? $E_p = mgh = (10.0kg)(9.81 N/kg)(0) = 0 J$

b) relative to the floor of the house? $(10.0kg)(9.81 N/kg)(3.00m) = 294 J$

c) relative to the bottom of the cliff? $(10.0kg)(9.81 N/kg)(23.0m) = 2260 J$

Kinetic Energy

- result of work being done on an object.
- depends on an object's mass and velocity.

Work done is $W = F.d$

Since $F = ma$

then, $W = mad$

If $v_f^2 = v_i^2 + 2ad$ then $ad = v_f^2 - v_i^2$

If an object starts at rest, $ad = v_f^2/2$

$W = m(v_f^2/2)$

THEREFORE : $E_K = \frac{1}{2}mv^2$

E_K = Kinetic energy (J)

m = mass (kg)

v = velocity (m/s)

Ex#1: What is the kinetic energy of a 25.0 g bullet travelling at 3600 km/h?

$m = 25.0 g \times \frac{1 Kg}{10^3 g} = 0.0250 Kg$

$V = 3600 \frac{Km}{h} \times \frac{1000 m}{1 Km} \times \frac{1 h}{3600 s} = 1000 m/s$

$E_K = \frac{1}{2} m v^2$

$= (0.5)(0.0250 Kg)(1000 m/s)^2$

$= 12500 J$

or $\boxed{1.3 \times 10^4 J}$

Work - Energy Theorem

$$W = E_{Kf} - E_{Ki} = \Delta E_K$$

$$\Delta E_K = \tfrac{1}{2} m v_f^2 - \tfrac{1}{2} m v_i^2 = \tfrac{1}{2} m (v_f^2 - v_i^2)$$

" The net work done on an object is equal to its change in Kinetic Energy."

Net work is positive if net force acts in the same direction as the motion, and kinetic energy increases.

Net work is negative if net force acts in the opposite direction of the motion, and kinetic energy decreases.

Ex#1. How much work does a pitcher do when he accelerates a 145g baseball from rest to 25 m/s?

$m = 0.145 Kg$

$v_i = 0 m/s$

$v_f = 25 m/s$

$W = \Delta E_K = E_{Kf} - E_{Ki}$

$= \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$

$= (0.5)(0.145 Kg)(25 m/s)^2 - (0.5)(0.145 Kg)(0 m/s)^2$

$= 45.31 J - 0 J = \boxed{45 J}$

Ex#2. A car gains 577 KJ of kinetic energy when it accelerates from 12 m/s to 25 m/s in 12 seconds. What is the mass of the car?

$\Delta E_K = 577 KJ$

$= 5.77 \times 10^5 J$

$v_i = 12 m/s$

$v_f = 25 m/s$

$m = ?$

$\Delta E_K = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$

$\Delta E_K = \frac{1}{2} m (v_f^2 - v_i^2)$

$m = \frac{2 \Delta E_K}{(v_f^2 - v_i^2)} = \frac{(2)(5.77 \times 10^5 J)}{(25 m/s)^2 - (12 m/s)^2}$

$= 2399 Kg$ or $\boxed{2400 Kg}$

Conservation of Energy

"Within a closed, isolated system, energy can change form, but the total amount of energy is conserved."

- Energy can be neither created nor destroyed.

Mathematically:

$$E_{Ki} + E_{Pi} = E_{Kf} + E_{Pf}$$

Total energy before **= Total energy** after

The decrease in potential energy is equal to the increase in its kinetic energy.

$$\Delta E_k = -\Delta E_p$$

The total energy, E, of an object is the sum of the kinetic energy and potential energy

$$E = E_k + E_p$$

Ex#1: A 20.0 kg rock falls 50.0 m from rest.

a) What is the rock's loss in gravitational energy?

$m = 20.0\,kg$

$h_i = 50\,m$

$h_f = 0\,m$

$$\Delta E_p = E_{p_f} - E_{p_i}$$
$$= mgh_f - mgh_i$$
$$= mg(h_f - h_i)$$
$$= (20.0\,kg)(9.81\,N/kg)(0 - 50\,m) = -9810\,J$$

b) What is its gain in kinetic energy? 9810 J

c) What is the final speed of the rock?

$E_{k_f} = 9810\,J$

$m = 20.0\,kg$

$v_f = ?$

$$E_k = \frac{1}{2}mv_f^2$$
$$v_f = \sqrt{\frac{2E_k}{m}}$$
$$= \sqrt{\frac{(2)(9810\,J)}{20.0\,kg}} = 31\,m/s \text{ down}$$

Ex#2: A girl on a bicycle is on the top of a 15 m high hill. How fast will she be moving at the bottom of the hill? (Ignore friction)

$$\Delta E_K = -\Delta E_P$$

$$E_{K_f} - E_{K_i} = E_{P_i} - E_{P_f}$$

$$E_{K_i} = 0 J$$
$$E_{P_f} = 0 J$$

$$\therefore \quad E_{K_f} = E_{P_i}$$
$$\frac{1}{2}\cancel{m}v_f^2 = \cancel{m}gh_i$$

$$\rightarrow \quad v_f = \sqrt{2gh_i}$$
$$= \sqrt{(2)(9.81 N/kg)(15 m)}$$
$$= 17.16 m/s$$

$$\text{or } \boxed{17 m/s}$$

Kinetic Energy

1. A compact car has a mass of 750 kg.
   a. Calculate the kinetic energy of the car moving at 50 km/h.

$m = 750 kg$
$V = 50 km/h \div 3.6$
$= 13.9 m/s$
$E_K = ?$

$$E_K = \frac{1}{2}mv^2$$
$$= (0.5)(750 kg)(13.9 m/s)^2$$
$$= 72454 J \text{ or } 7.2\times10^4 J$$

   b. How much work must be done on the car to slow it from 100 km/h to 50 km/h?

$m = 750 kg$
$v_i = 100 km/h = 27.8 m/s$
$v_f = 13.9 m/s$

$$\Delta E_K = E_{K_f} - E_{K_i}$$
$$= \frac{1}{2}m(v_f^2 - v_i^2$$
$$= (0.5)(750 kg)((13.9 m/s)^2 - (27.8 m/s)^2)$$
$$= -217361 J \text{ or } \boxed{-2.2\times10^5 J}$$

   c. How much work must be done on the car to bring it from 50 km/h to rest?

$$\Delta E_K = E_{K_f} - E_{K_i}$$
$$= 0 J - 72454 J$$
$$= \boxed{-7.2\times10^5 J}$$

   d. The force that does the work is constant. Find the ratio of the distance needed to slow the car from 100 km/h to 50 km/h to the distance needed to slow it from 50 km/h to rest.

$$\boxed{\begin{array}{c} F_{100-50} = F_{50-0} \\ \text{and } F = \frac{W}{d} \end{array}}$$

$$\therefore \frac{W_{100-50}}{d_{100-50}} = \frac{W_{50-0}}{d_{50-0}}$$

$$\frac{d_{100-50}}{d_{50-0}} = \frac{W_{100-50}}{W_{50-0}}$$

$$= \frac{-217361 J}{-72454 J} = \frac{3}{1}$$

$$\text{or } \boxed{3:1}$$

2. A rifle can shoot a 4.20 g bullet at a speed of 965 m/s.

   a. Find the kinetic energy of the bullet.

$m = 4.20\text{g}$
$= 4.20\times10^{-3}\text{Kg}$
$v = 965\text{m/s}$

$E_K = \frac{1}{2}mv^2$
$= (0.5)(4.20\times10^{-3}\text{Kg})(965\text{m/s})^2$
$= 1956\text{J}$ or $\boxed{1.96\times10^{3}\text{J}}$

   b. What work is done on the bullet if it starts from rest?

$W = \Delta E_K = E_{Kf} - E_{Ki}$
$= 1956\text{J} - 0\text{J} = \boxed{1.96\times10^{3}\text{J}}$

   c. If the work is done over a distance of 0.75 m, what is the average force on the bullet?

$W = 1956\text{J}$
$d = 0.75\text{m}$
$F = ?$

$W = F\cdot d$
$F = \frac{W}{d} = \frac{1956\text{J}}{0.75\text{m}} = 2607\text{N}$ or $\boxed{2.6\times10^{3}\text{N}}$

   d. If the bullet comes to rest by pushing 1.5 cm into metal, what is the average force it exerts?

$W = \Delta E_K = E_{Kf} - E_{Ki}$
$= 0\text{J} - 1956\text{J}$
$= -1956\text{J}$

$d = 0.15\text{m}$

$F = \frac{W}{d}$
$= \frac{-1956\text{J}}{0.15\text{m}}$
$= -13040\text{N}$ or $\boxed{-1.3\times10^{4}\text{N}}$

3. A comet with mass 7.85x10^{11} kg strikes Earth at a speed, relative to Earth, or 25 km/s. Find the kinetic energy of the comet in joules.

$m = 7.85\times10^{11}\text{kg}$
$v = 25000\text{m/s}$
$E_K = ?$

$E_K = \frac{1}{2}mv^2$
$= (0.5)(7.85\times10^{11}\text{kg})(25000\text{m/s})^2$
$= 2.453\times10^{20}\text{J}$ or $\boxed{2.5\times10^{20}\text{J}}$

4. A 5700 kg trailer truck needs 2.2x10^6 J of work to accelerate it to 100 km/h.

   a. How fast would it go if just half as much work is done on it?

$W = E_{Kf} - E_{Ki}$
$E_{Kf} = W + E_{Ki}$
$= 1.1\times10^{6}\text{J} + 0\text{J}$

$v_f = ?$
$m = 5700\text{Kg}$

$E_{Kf} = \frac{1}{2}mv_f^2$
$v_f = \sqrt{\frac{2E_{Kf}}{m}} = \sqrt{\frac{2(1.1\times10^{6}\text{J})}{5700\text{Kg}}} = 19.6\text{m/s} = \boxed{71\text{Km/h}}$

   b. How fast would it go if twice as much work is done on it?

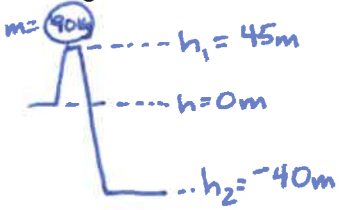
$E_{Kf} = 4.4\times10^{6}\text{J}$
$m = 5700\text{Kg}$
$v_f = ?$

$v_f = \sqrt{\frac{2E_{Kf}}{m}} = \sqrt{\frac{(2)(4.4\times10^{6}\text{J})}{5700\text{Kg}}} = 39.3\text{m/s} = \boxed{140\text{Km/h}}$

*Need 4x the work to double the speed!

Potential Energy

5. A 90 kg rock climber first climbs 45 m upward to the top edge of a quarry, then, from the top, descends 85 m to the bottom. Find the potential energy of the climber at the edge and at the bottom, using the initial height as the reference level.



E_p @ edge $= mgh_1$

$= (90kg)(9.81N/kg)(45m) = +39731J$ or $\boxed{4.0 \times 10^4 J}$

E_p @ bottom $= mgh_2$

$= (90kg)(9.81N/kg)(-40m) = -35316J$ or $-\boxed{3.5 \times 10^4 J}$

6. A 50.0 kg shell is shot from a cannon at Earth's surface to a height of 4.00x10^2 m.
   a. What is the gravitational potential energy with respect the Earth's surface of the Earth-shell system when the shell is at this height?

$h = 400m$
$m = 50.0kg$
$E_p = ?$

$E_p = mgh$
$= (50.0kg)(9.81N/kg)(400m)$
$= 196200J = \boxed{1.96 \times 10^5 J}$

   b. What is the change in potential energy of the system when the shell falls to a height of 2.00x10^2 m?

$E_{p_i} = 196200J$

$E_{p_f} = mgh = (50.0kg)(9.81N/kg)(200m) = 98100J$

$\therefore \Delta E_p = E_{p_f} - E_{p_i} = 98100J - 196200J$
$= -98100J$ or $\boxed{-9.81 \times 10^4 J}$

7. A person weighing 630 N climbs up a ladder to a height of 5.0 m.
   a. What work does the person do?

$F = 630N$
$d = 5.0m$
$W = F \cdot d$

$W = F \cdot d$
$= (630N)(5.0m)$
$= 3150J$ or $\boxed{3.2 \times 10^3 J}$

   b. What is the increase in the gravitational potential energy of the person from the ground to this height?

$E_{p_i} = 0J$

$E_{p_f} = mgh = 3150J$

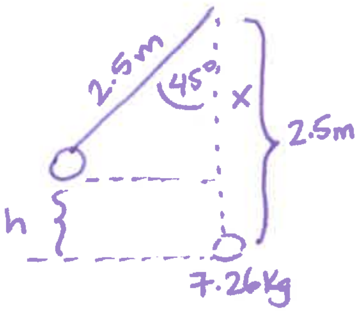
$\Delta E_p = E_{p_f} - E_{p_i}$
$= 3150J - 0J$
$= \boxed{3.2 \times 10^3 J}$

   c. Where does the energy come from to cause this increase in the gravitational potential energy?

Chemical energy stored in person's muscles.

8. A pendulum is constructed from a 7.26 kg bowling ball hanging on a 2.5 m long rope. The ball is pulled back until the rope makes a 45^0 angle with the vertical.

   a. What is the potential energy of the ball?



$h = 2.5\text{m} - x$

$x = (2.5\text{m})(\cos 45^\circ)$
$= 1.77\text{m}$

$h = 2.5 - 1.77\text{m}$
$= 0.73\text{m}$

$E_p = mgh$
$= (7.26\text{kg})(9.81\text{N/kg})(0.73\text{m})$
$= 52.15\text{ J}$
$= \boxed{52\text{ J}}$

   b. What reference level did you use in your calculations?

- When the ball is at its lowest point of the swing

Conservation of Energy

9. A bike rider approaches a hill at 8.5 m/s. The total mass of the bike and rider is 85 kg.

   a. Find the kinetic energy of the bike and rider.

$m = 85\text{ kg}$
$v = 8.5\text{ m/s}$
$E_k = ?$

$E_k = \frac{1}{2}mv^2$
$= (0.5)(85\text{ kg})(8.5\text{ m/s})^2$
$= 3071\text{ J}$ or $\boxed{3.1 \times 10^3\text{ J}}$

   b. The rider coasts up the hill. Assuming there is no friction, at what height will the bike come to a stop?

$E_{p_i} + E_{k_i} = E_{k_f} + E_{p_f}$

$E_{p_i} = 0\text{ J}$
$E_{k_f} = 0\text{ J}$

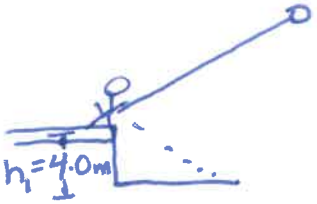
$\therefore E_{k_i} = E_{p_f}$

$\frac{1}{2}\cancel{m}v_i^2 = \cancel{m}gh_i$

$h_i = \frac{v_i^2}{2g} = \frac{(8.5\text{ m/s})^2}{(2)(9.81\text{ m/s}^2)} = 3.682\text{ m}$
$= \boxed{3.7\text{ m}}$

10. Tarzan, mass 85 kg, swings down from a tree limb on the end of a 20 m vine. His feet touch the ground 4.0 m below the limb.

a. How fast is Tarzan moving when he reaches the ground?



$$E_{p_i} + \cancel{E_{k_i}} = \cancel{E_{p_f}} + E_{k_f}$$

$$\cancel{m}gh_i = \tfrac{1}{2}\cancel{m}v_f^2$$

$$v_f = \sqrt{2gh} = \sqrt{(2)(9.81 m/s^2)(4.0 m)} = 8.859 m/s = \boxed{8.9 m/s}$$

b. Does your answer depend on Tarzan's mass?

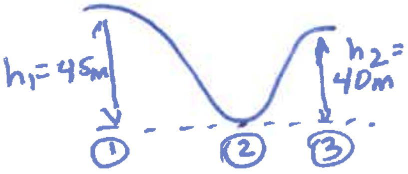
No! Cancels out.

c. Does your answer depend on the length of the vine?

No, just the height above the reference level (the ground).

11. A skier starts from rest at the top of a 45 m hill, skis down a 30° incline into a valley, and continues up a 40 m hill. Both hill heights are measured from the valley floor. Assume you can neglect friction and the effect of ski poles.

a. How fast is the skier moving at the bottom of the hill?



$$E_{p_i} + \cancel{E_{k_i}} = \cancel{E_{p_2}} + E_k$$

$$\cancel{m}gh_i = \tfrac{1}{2}\cancel{m}v_2^2$$

$$v_2 = \sqrt{2gh_1} = \sqrt{(2)(9.81 m/s^2)(45 m)} = 29.7 m/s = \boxed{30 m/s}$$

b. What is the skier's speed at the top of the next hill?

$$E_{p_1} + \cancel{E_{k_1}} = E_{p_3} + E_{k_3}$$

$$\cancel{m}gh_1 = \cancel{m}gh_2 + \tfrac{1}{2}\cancel{m}v_3^2$$

$$v_3^2 = \frac{gh_1 - gh_3}{2} \text{ or } v_3 = \sqrt{2g(h_1 - h_3)} = \sqrt{2(9.81 m/s^2)(45-40 m)}$$

$$= 9.90 m/s$$

$$= \boxed{10 m/s}$$

1.a) 7.4×10^4J; b) -2.20×10^5J; c) -7.4×10^4J; d) 3:1 2. a) 1.96×10^3 J; b) 1.96×10^3 J; c) 2.6×10^3 N; d) -1.3×10^5 N 3. 2.5×10^{20} J; 4. a) 71km/h; b) 140 km/h; 5. $+4.0 \times 10^4$J; -3.5×10^4J; 6. a) 1.96×10^5J; b) -9.80×10^4J; 7. a) 3200 J; b) 3200 J; c) work done on person; chemical energy stored in person's body; 8. a) 52J; b) height of ball when rope was vertical; 9. a) 3.1×10^3J; b) 3.7 m; 10. a) 8.9 m/s; b) no; c) no; 11. a) 30m/s; b) 10 m/s

Energy Concept Review

1. Describe the work done and the energy changes taking place when:
   a. You climb a rope.

      You do work against gravity + gain potential energy

   b. You throw a ball horizontally

      You do work on the ball and it gains kinetic energy

   c. A horizontally thrown ball is caught in a mitt

      The mitt does work against the ball and the ball loses kinetic energy).

   d. A horizontally thrown ball falls, gaining vertical velocity

      Gravity does work on the ball, and the ball gains kinetic energy.

2. A student is doing a problem involving a ball falling down a well. If the top of the well is chosen as the reference level for potential energy, then what is the sign of the potential energy at the bottom of the well?

   Negative (since h would be negative).

3. Explain how energy and work are related.

   Work is required to change the amount of energy an object has.

4. Explain how energy and force are related.

   When a force is applied over a distance, an object's energy will change.

5. Can the kinetic energy of a baseball ever have a negative value? Explain.

No - Kinetic energy is a scalar quantity, and as long as the object is in motion it has $E_K > 0J$.

↳ Mass can only be positive

↳ the square of the velocity is positive

* Note: ΔE_K can be negative

6. Sally and Lisa have identical compact cars. Sally is northbound on the freeway and Lisa is southbound with the same speed. Which car has more kinetic energy?

They have the same amount of energy.

7. If you drop a tennis ball onto a concrete floor, it will bounce back farther than if you drop it on a rug. Where does the lost energy go when it strikes the rug?

Sound, heat (friction)

8. If two identical bowling balls are raised to the same height, one on the Earth, and the other on the moon, which has the larger potential energy relative to the surface of the bodies?

$$\overset{\uparrow}{E_p} = m\overset{\uparrow}{g}h$$

- m and h are the same,
- "g" is larger on earth

$\therefore$ E_p is larger on earth (for equal m + h).

Chapter 7 Thermal Energy

Thermodynamics - the study of heat

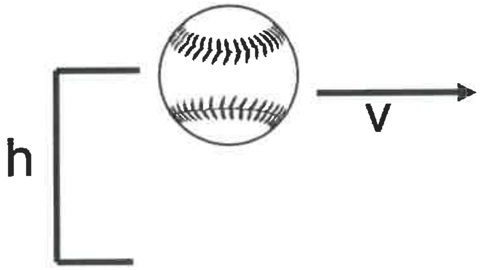
Kinetic Molecular Theory

- all matter is made up of particles in constant motion.
- a hotter body has faster moving particles than a cooler body, thus more energy.

External Energy of a Baseball

- result of position and speed of a baseball.

$$E_p = mgh$$



$$E_k = \frac{1}{2} mv^2$$

Internal Energy of a Baseball

- result of the E_p and E_k of the particles
- E_k of particles = particles moving back and forth.
- E_p of particles = attraction of particles due to electromagnetic forces.
- Thermal Energy - the sum of the E_k and E_p energy of the ____________ motion of particles that make up an object.

Thermal Energy vs. Temperature

Thermal Energy - the total kinetic energy of all particles of an object;
Temperature - the average kinetic energy of the particles of an object; measured with a thermometer.

- particles of an object have a range of energies, some high and some low.

- hotter objects have great average E_k of particles.

Heat

Heat - the amount of thermal energy transferred from one object to another due to differences in temperatures between the objects.

Equilibrium - occurs when the rate of energy transfer between two bodies is equal; objects at equilibrium are at the same temperature.

Thermal Energy Transfer

conduction - transfer of kinetic energy in Solids when particles of an object touch.

convection - heat transfer by the movement of fluids caused by different densities.

radiation - transfer of thermal energy through space in the ~~of~~ form of waves (i.e., infrared)

Temperature Scales

- **thermometer** - device used to measure temperature. It is placed in contact with an object and allowed to come to thermal equilibrium.

Celcius

- scale based on the properties of water.

Kelvin

- scale based on thermal energy no upper limit.
- used to accommodate wide range of temperatures in the universe.
- absolute zero - temperature at which all thermal energy is removed from objects. (-273.15°C)

Celsius	Kelvin
-273.15 °C	0
0.00 °C	273.15
22.00 °C	295.15
100.00 °C	373.15

5.4 Measuring Heat Energy

- energy transferred as a result of a difference in temperature.
- dependent on:

a) mass of the object,
b) difference in temperature,
c) heat capacity of material.

$$\boxed{Q = m \,.\, C.\, \Delta T}$$

Q = heat energy gained or lost (J) (sometimes E_h)
m = mass (kg)
C = specific heat (J/Kg°C or J/Kg.K)
ΔT = change in temperature (°C or K)

Ex#1: A 0.4 kg block of iron is heated from 295 K to 325 K. How much heat is absorbed by the iron? (See table on pg. 121 of workbook for values of C)

$m = 0.4\text{ kg}$
$T_i = 295\text{K}$
$T_f = 325\text{K}$
$C = 450 \frac{\text{J}}{\text{kgK}}$
$Q = ?$

$$\begin{aligned} Q &= mC\Delta T \\ &= mC(T_f - T_i) \\ &= (0.4\text{ kg})(450\text{ J/kg K})(325\text{K} - 295\text{K}) \\ &= 5400\text{ J} \quad \text{or} \quad \boxed{5\times10^3\text{ J}} \end{aligned}$$

Ex#2: After 250 kJ of heat is transferred to a container of water, the temperature rose to from 15°C to 25°C. What was the mass of the water in the container?

$Q = 250\times10^3\text{ J}$
$T_i = 15°\text{C}$
$T_f = 25°\text{C}$
$C = 4186\text{ J/kg°C}$
$m = ?$

$$Q = mC\Delta T$$

$$m = \frac{Q}{C(T_f - T_i)}$$

$$= \frac{250000\text{ J}}{(4186\text{ J/kg°C})(25°\text{C} - 15°\text{C})} = 5.972\text{ kg}$$

$$= \boxed{6.0\text{ kg}}$$

Thermal Energy

Concept Questions

1. Explain the difference between a ball's external energy and its thermal energy.

External energy refers to energy due to entire ball's position + motion while the internal energy refers to the energy of the particles within the baseball

2. Explain the difference between a ball's thermal energy and temperature.

Thermal energy is the total kinetic energy of all the particles in an object, while temperature is the average kinetic energy of the particles.

3. Can temperature be assigned to a vacuum? Explain.

No... if no particles, there's no way to assess their average kinetic energy

4. Do all of the molecules or atoms in a liquid have about the same speed?

No – some are much faster (allowing them to escape the liquid's surface – evaporate); some are slower as well.

5. Could the thermal energy of a bowl of hot water equal that of a bowl of cold water? Explain. Yes – if the bowl of cold water is much bigger than the bowl of hot water!

6. On cold winter nights before central heating, people often placed hot water bottles in their beds. Why would this be better than, say, warmed bricks?

Water has a high heat capacity + can therefore transfer a lot of heat energy to the surrounding environment.

7. If you take a spoon out of a cup of hot coffee and put it in your mouth, you won't burn your tongue. But, you could very easily burn your tongue if you put the liquid in your mouth. Why? Heat capacity of the metal spoon is much lower + therefore will cool off faster than the liquid.

Problems:

1. Convert these Celsius temperatures to Kelvin temperatures.
   - a. 0°C 0°C + 273 = 273 K
   - b. 273 °C 273 + 273 = 546K
   - c. 27°C 27 + 273 = 300K
   - d. 560°C 560 + 273 = 833K
   - e. -184°C -184 + 273 = 89K
   - f. -300 °C -300 + 273 = -~~27K~~ ∴ Impossible

2. Covert these Kelvin temperatures to Celsius temperatures.
   - a. 0K 0 - 273 = -273°C
   - b. 273K 273 - 273 = 0°C
   - c. 110K 110 - 273 = -163°C
   - d. 22K 22 - 273 = -251°C
   - e. 402K 402 - 273 = 129°C
   - f. 323 K 323 - 273 = 50°C

1: 273K; 546K; 300K; 833K; 89K; impossible; 2: -273°C; 0°C; -163°C; -251°C; 129°C; 50°C

3. How much heat is absorbed by 60.0 g of copper when it is heated from 20.0°C to 80.0°C? (1.39x10³J)

*$m = 0.0600$ kg

$T_i = 20.0°C$

$T_f = 80.0°C$

$C = 390$ J/kg°C

$Q = mC\Delta T$

$= (0.0600\text{kg})(390\text{ J/kg°C})(80.0°C - 20.0°C)$

$= 1404$ J

$= \boxed{1.4 \times 10^3 \text{ J}}$

4. A 38 kg block of lead is heated from -26 °C to 180 °C. How much heat does it absorb during the heating? (1.0x10⁶J)

$m = 38$ kg

$T_i = -26°C$

$T_f = 180°C$

$C = 130$ J/kg°C

$Q = mC\Delta T$

$= (38\text{kg})(130\text{ J/kg°C})(180°C - (-26°C))$

$= 1017{,}640$ J

$= \boxed{1.0 \times 10^6 \text{ J}}$

5. The cooling system of a car engine contains 20.0 L of water (1 L of water has a mass of 1kg). What is the change in the temperature of the water if the engine operates *until 836.0 kJ of heat are added? (10.0°C)

$Q = 836.0 \times 10^3$ J

$m = 20.0$ kg

$C = 4186$ J/kg°C

$\Delta T = ?$

$Q = mC\Delta T$

$\Delta T = \frac{Q}{mC} = \frac{836000\text{J}}{(20.0\text{kg})(4186\text{ J/kg°C})} = 9.9857°C$

$= \boxed{9.99°C}$

6. A 5.00x10² g block of metal absorbs 5016 J of heat when its temperature changes from 20.0°C to 30.0°C. Calculate the specific heat of the metal. (1.00x10³ J/kgK)

$m = 0.500$ kg

$Q = 5016$ J

$\Delta T = 30.°C - 20.0°C = 10.0°C$

$C = ?$

$Q = mC\Delta T$

$C = \frac{Q}{m\Delta T} = \frac{5016\text{J}}{(0.500\text{kg})(10.0°C)}$

$= 1003.2\text{J} = \boxed{1.00 \times 10^3 \text{ J}}$

7. A 565g cube of iron is cooled from the temperature of boiling water to room temperature (20°C).

   *a. How much heat must be ~~absorbed~~ released by the cube? -(2.0x10⁴ J)

$m = 0.565$ kg

$\Delta T = 20°C - 100°C = -80°C$

$C = 450$ J/kg°C

$Q = mC\Delta T$

$= (0.565\text{kg})(450\text{ J/kg°C})(-80.0°C)$

$= -20340$ J or $\boxed{-2.0 \times 10^4 \text{ J}}$

   b. If the iron is cooled by dunking it into water at 0°C that rises in temperature to 20°C, how much water is needed? (0.24kg)

$C = 4186$ J/kg°C

$T_i = 0°C$

$T_f = 20°C$

$Q = +20340$ J

$m = ?$

$m = \frac{Q}{C\Delta T}$

$= \frac{+20340\text{J}}{(4186\text{ J/kg°C})(20-0°C)} = 0.24295$ kg

$= \boxed{0.24 \text{ kg}}$