Physics 200 (Stapleton) Name: Answers

Work and Energy, Part 1

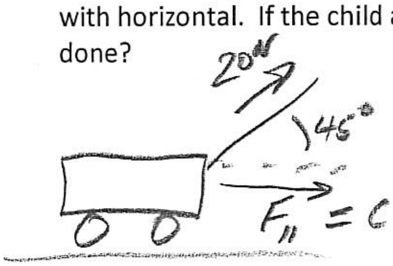
Work is the application of a force over a distance. **W=Fd**. The "distance" is the distance through which the force acts. Technically, the "force" in the equation is only the component of force in the direction of movement.

Work units = N•m = Joules (J). The common unit is Joules.

1. A child pulls a wagon 4m to the right, applying a constant rightward force of 10N. How much work is done?

$W = Fd = 10N(4m) = 40J$

2. Another child pulls a wagon using a rope. The tension in the rope is 20N, and the rope makes a 45° angle with horizontal. If the child applies this force constantly as the wagon travels 6m, how much work is done?



$F_{\parallel} = \cos 45°(20N)$

$W = F_{\parallel} d = (14.1N)(6m)$

$W = 84.9J$

Power is the rate of work. $P = \frac{W}{t}$. The units for power that we will use are Watts. **1 Watt = 1J/s.**

1horsepower = 746W

3. A 60kg student climbs 12m up a vertical rock wall in 50 seconds. The student's speed is constant.

a. Approximately how much work did the student do?

$W = Fd \quad F = mg = 60kg(9.8m/s^2) = 588N$

$W = 588N(12m) = 7{,}056J$

b. What was the student's average power output, in Watts?

$P = \frac{W}{t} = \frac{7{,}056J}{50s} = 141W$

c. How long would the climb have taken if the student's power output had been 1 horsepower?

$P = \frac{W}{t} \quad 746W = \frac{7{,}056J}{t} \quad t = 9.46s$

__Energy:__ Work can be thought of as equivalent to energy. When work is done ***on*** an object, the object gains energy. When work is done ***by*** an object, the object loses energy.

The **Work-Energy Theorem** states that $\mathbf{W_{net} = \Delta KE}$.

The abbreviation **KE** stands for ***Kinetic Energy***, which is energy of motion. The formula for Kinetic Energy is...

$KE = \frac{1}{2}mv^2$, where m = mass and v = velocity.

Energy units are the same as Work units. 1 Joule is derived from the amount of energy required to raise 1kg of water by 1°C. **1J = ~~4,184 calories = 4.184 food "calories."~~** The "calories" used in nutrition are actually kilocalories. $1cal = 4.184J$ $\quad 1kcal = 4{,}184J$

4. When a 0.5kg water rocket is launching, it experiences an average net force of 400N for a distance of 1m. By how much does the rocket's KE change during this time period?

$$W = \Delta KE$$
$$W = 400N(1m) = 400J = \Delta KE$$

5. Assuming that the rocket started from rest, use the KE formula to find the rocket's velocity after accelerating for that one meter.

$$\Delta KE = 400J = KE_{Final} - KE_{initial}$$
$$400J = KE_{Final} - 0. \quad KE_{Final} = 400J = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.5kg)v^2$$

$V = 40m$

6. A 2kg package is sliding across a surface with a velocity of 3m/s. The force of friction acting on the package is 1N. How far will the package slide before it stops?

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(2kg)(3m/s)^2 = 9J$$
$$W_{Friction} = \Delta KE = -9J = F_F d \qquad -9J = -1N(d)$$
$$d = 9m$$

<u>Potential Energy:</u> Potential energy is stored energy. PE can have many forms, including gravitational energy, spring energy, and chemical energy.

PE$_{gravitational}$: Work done against gravity results in a change in an object's gravitational potential energy. The minimum possible** work done in the process of lifting an object to a certain height equals the force of gravity multiplied by that height. For objects that are being lifted, this means **ΔPE = mgh**, where h is the height through which something is lifted. Any object which is already situated at some height can be thought of as having stored gravitational potential energy equal to mgh.

PE$_{gravitational}$ = mgh

<u>Energy Conservation:</u> Unless there is friction, or an external input of energy, the total amount of mechanical energy in a closed system remains constant. $KE_{initial} + PE_{initial} = KE_{final} + PE_{final}$. The total mechanical energy remains constant, so energy is said to be *conserved*. This is one form of the **Law of Conservation of Energy**.

7. A 3kg watermelon is dropped from a height of 100m. What is its potential energy at its release point (100m)? $PE = mgh = 3kg(9.8m/s^2)(100m) = 2940J$

8. What is the watermelon's potential energy when it has fallen to an altitude of 25m?

$$PE = 3kg(9.8m/s^2)(25m) = 735J$$

9. What is the watermelon's KE when its altitude is 25m?

$$0J + 2940J = KE_{Final} + 735J \qquad KE_{Final} = 2{,}205J$$

10. What is the watermelon's velocity when its altitude is 25m?

$$KE = \tfrac{1}{2}mv^2 \qquad 2{,}205J = \tfrac{1}{2}(3kg)v^2$$
$$v = 38.3m/s$$

Friction "Steals" Energy: When there is friction in a closed system, $KE_{initial} + PE_{initial} + W_{nc} = KE_{final} + PE_{final}$. In this case, the work done by friction is called "work by a non-conservative force," (W_{nc}). Since friction opposes motion, this W_{nc} is a negative number, and the work done by friction gets "lost." It's not really lost, but rather it gets turned into thermal energy. Still, the equation above apples to mechanical energy, not thermal energy.

11. A 20kg child sits at rest at the top of a slide which is 5m long and 3m high. As the child slides down the slide, the child experiences a constant 5N force of friction.

a. What is the child's total energy at the top of the slide? What form of energy does the child have?

All PE. $PE = mgh = 20kg(3m)(9.8m/s^2) = 588\,J$

b. How much work is done by friction?

$W_{Fric} = F_F d = 5m(-5N) = -25\,J$

c. How much PE and KE does the child have at the bottom of the slide?

$0J + 588J - 25J = KE_{Final} + 0J$

$KE_{final} = 563J$

d. What is the child's speed upon reaching the bottom of the slide?

$KE = \frac{1}{2}mv^2 \qquad 563J = \frac{1}{2}(20kg)v^2$

$v = 7.5m/s$

Energy Practice Problems: 38.

1.. A stick pushes a 170g hockey puck with a constant force of 100N over a distance of 0.4m and a time of 0.1 seconds. 78,0

a. How much work is done on the puck? 40J

b. How much power does the stick use while it is pushing the puck? 400W

c. Assuming that the puck starts from rest, what is its speed after being pushed by the stick? 21.7m/s

2. A dad pulls his daughter in a sled. He drags the sled using a rope, maintaining a constant tension of 100N.

a. How much work does the dad do if he pulls his daughter for one mile? 161,040J — 38,489 Cal

b. A Snicker's Bar contains about 260,000 calories of energy. Assuming that the dad's body is 30% efficient (makes use of only 30% of its energy intake), how many snickers bars must he eat to replace the energy lost by dragging his daughter around? 0.49 ~~2.06~~ snickers

3. A 5kg bowling ball is hanging by a cable from the ceiling of a train. The cable makes a 70° angle with the ceiling. During a certain time interval, the train travels 30m.

Net

a. How much work is done on the ball during this time interval? ~~535J~~ 17.8N

b. If the velocity of the train and ball were both 10m/s at the beginning of this time interval, what are their velocities at the end of the time interval? 17.7m/s

c. What if their velocities at the beginning of the interval were 20m/s?

4. Suppose it takes 10J of energy to smash an apple. What horsepower is required to smash 5 apples in ~~10~~ seconds?

0

$P = \frac{50J}{10s} = 5W = 0.67\,hp$

5. According to Wikipedia, a Ferrari 458 has a mass of 1,565kg, and the car's maximum acceleration takes it from 0-100km/h in 3.0 seconds. The tires, which are racing slicks, have a $\mu_s = 0.9$ and $\mu_k = 0.6$.

27.8 m/s   W = 15337

a. How much work does the car's motor do as the car accelerates from 0-100km/h? 604,747 J

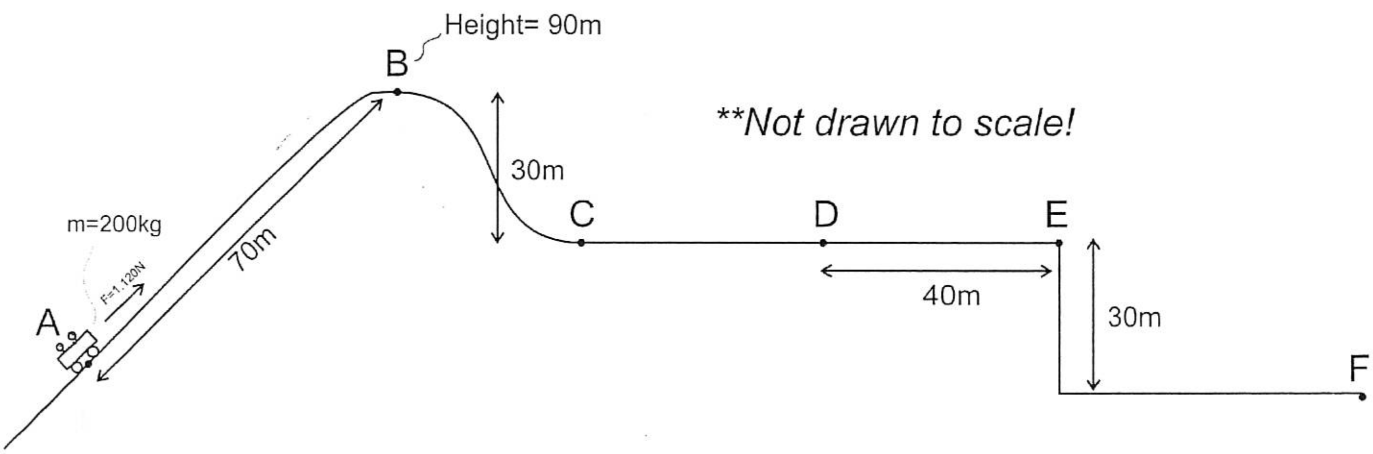
b. How much power, in Watts, is required in order to achieve this acceleration? 201,582 W

c. Convert that power to horsepower. 270 hp

d. If, after reaching 100km/h, the driver stops accelerating and applies the maximum braking force without skidding, how far will the car travel before coming to a stop? 43.8 m

f. How far will the car travel before stopping if the driver brakes too hard, the tires lock, and the car skids to stop? 65.7m

6. The diagram below shows the path followed by a 200kg car on a roller coaster. Between points A and B, the car is pulled up a slope in the absence of friction. The car is pulled very slowly by a 1,120N force along 70m of track. The ascent is so slow that, upon reaching point B, the cart's speed is virtually 0m/s. At point B, the cart begins to accelerate frictionlessly down the slope to C and then travels on a horizontal section to point D. At point D, a 50N braking force is applied, but this is not enough to keep the cart from flying off the precipice at point E. Complete the table, below.



mgh = 19600

10 m

Location	Height (m)	Velocity (m/s)	Potential Energy (J)	Kinetic Energy (J)	Total Energy (J)
A	50m	0	98,000	0	98,000
B	90m	0	176,400	0	176,400
C	60m	24.2	117,600	58,800	176,400
D	"	"	"	"	"
E	"	19.7 m/s	"	38,800	156,400
F	30m	31.2 m/s	58,800	97,600	156,400

Energy Practice Problems

1) a. $W = Fd = 100N(0.4m) = 40J$

b. $P = \frac{W}{\Delta t} = \frac{40J}{0.1s} = 400W$

c. $W_{Net} = \Delta KE = \frac{1}{2}mv^2$

$40J = \frac{1}{2}(0.170kg)v^2$

$v = 21.7 m/s$

2) a. $W = Fd = 100N\left[(5280ft)\left(\frac{0.305m}{1ft}\right)\right]$

$W = 161{,}000J$

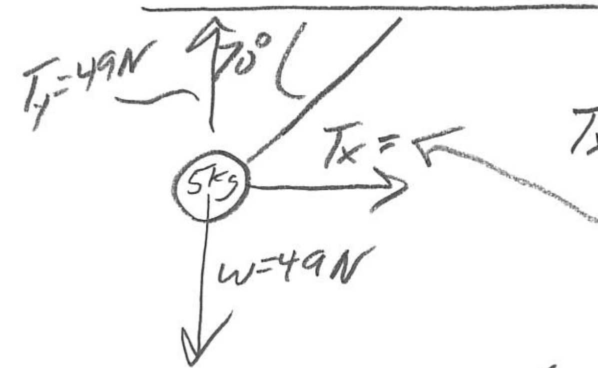
b. $30\%\left(260{,}000\frac{cal}{bar}\right) = 78{,}000$ useful cal/bar

$W = 161{,}000J\left(\frac{1cal}{4.184J}\right) = 38{,}500$ cal of work

$38{,}500 \text{ cal of work}\left(\frac{1 \text{ bar}}{78{,}000 \text{ useful calories}}\right) = 0.49$ snickers bars

3)

3)



$$T_x = \frac{T_y}{\tan 70^\circ} = \frac{49N}{2.75} = 17.8N$$

a) $W_{Net} = F_{Net}d = 17.8N(30m) = 535J$

b) $W_{Net} = \Delta KE = KE_{Final} - KE_{initial}$

$$535J = \tfrac{1}{2}(5kg)V_F^2 - \tfrac{1}{2}(5kg)(10m/s)^2$$

$$785J = \tfrac{1}{2}(5kg)V_F^2$$

$$V_F = 17.7m/s$$

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4) $P = \frac{W}{s} = \frac{5(100J)}{1s} = 500W$

$$(500W)\left(\frac{1Hp}{746W}\right) = 0.67Hp$$

5) $\Delta KE = W_{Net}$

$KE_F - KE_i = W_{Net}$

a) $\frac{1}{2}(1{,}565kg)(27.8 m/s)^2 - 0 = W_{Net} = 605{,}000 J$

b) $P = \frac{W}{\Delta t} = \frac{605{,}000 J}{3s} = 201{,}582 W$

c) $201{,}582 W \left(\frac{1 Hp}{746 W}\right) = 270 Hp$

d) $\Delta KE = W_{Net} = Fd$

brakes = neg

$\mu_s mg$

KE @ top speed

$KE_F - KE_i = W_{Net} = -Fd$

$0 - 605{,}000 J = -(0.9)(1{,}565kg)(9.8 m/s^2)\, d$

$d = 43.8 m$

e) $\Delta KE = W_{Net} = Fd = -(\mu_K mg)d$

$-605{,}000 J = -(0.6)(1565 kg)(9.8 m/s^2)\, d$

$d = 65.7 m$