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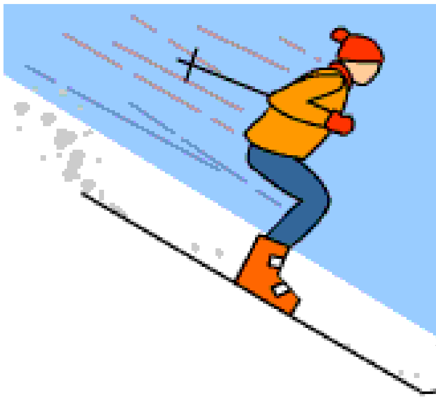
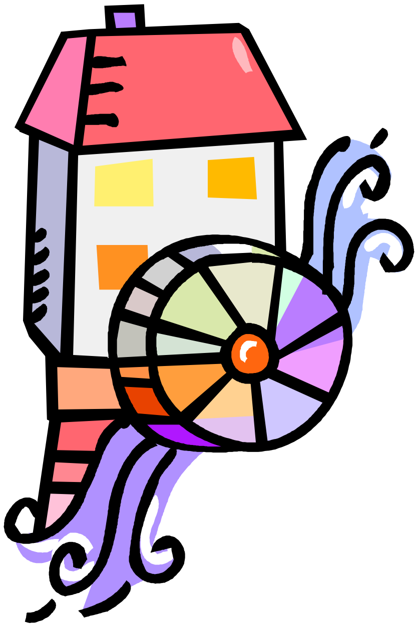
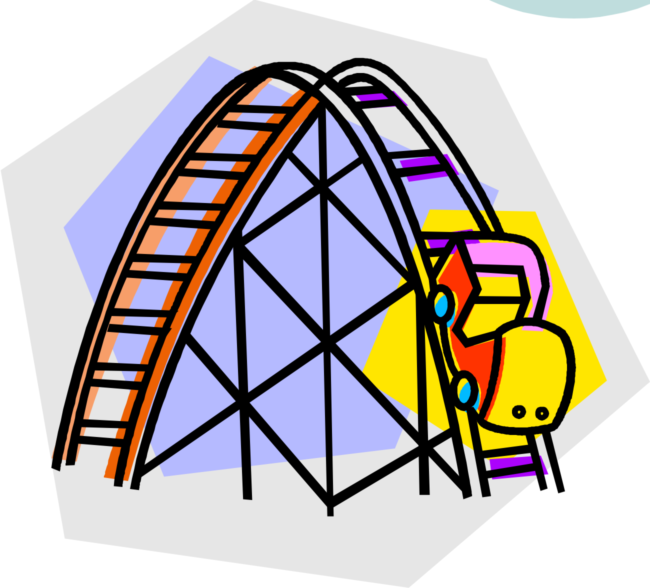
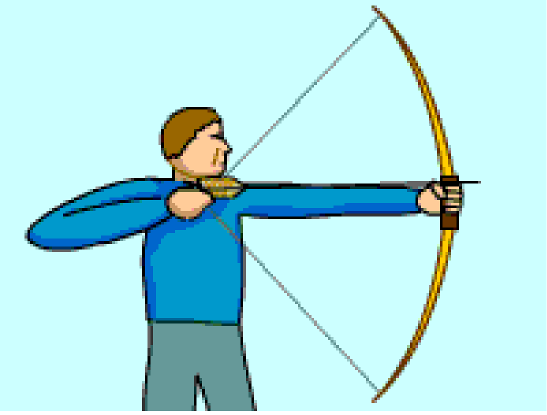
Unit 7

Energy

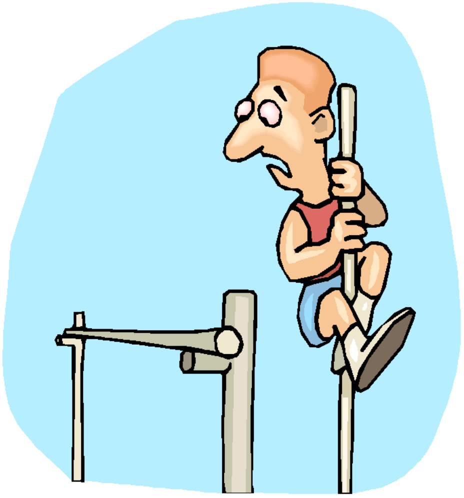


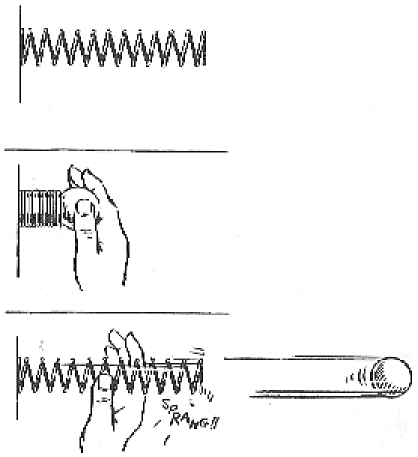


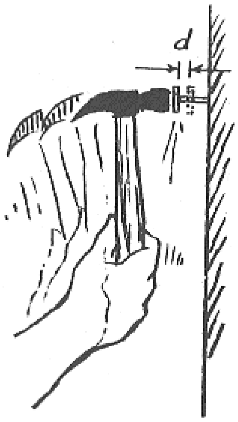


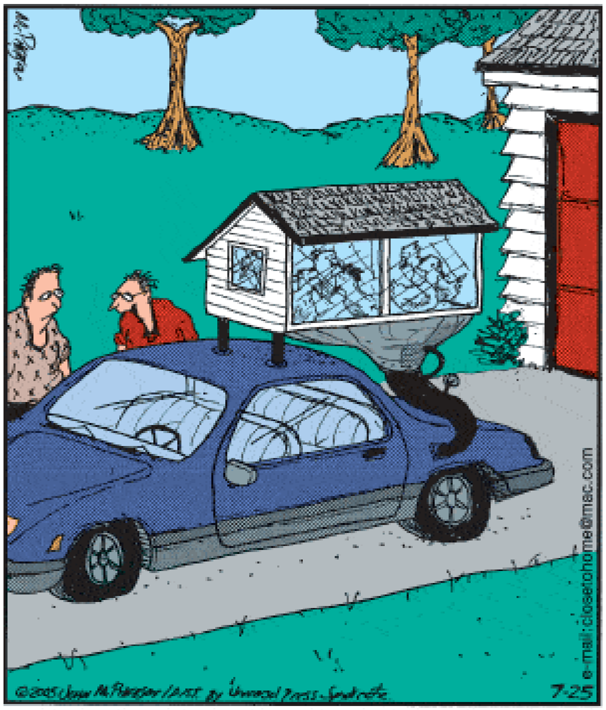


Unit Packet Contents









"It's a kit I found online. I converted the car so it runs entirely on chicken manure."

Why science teachers should not be given playground duty.

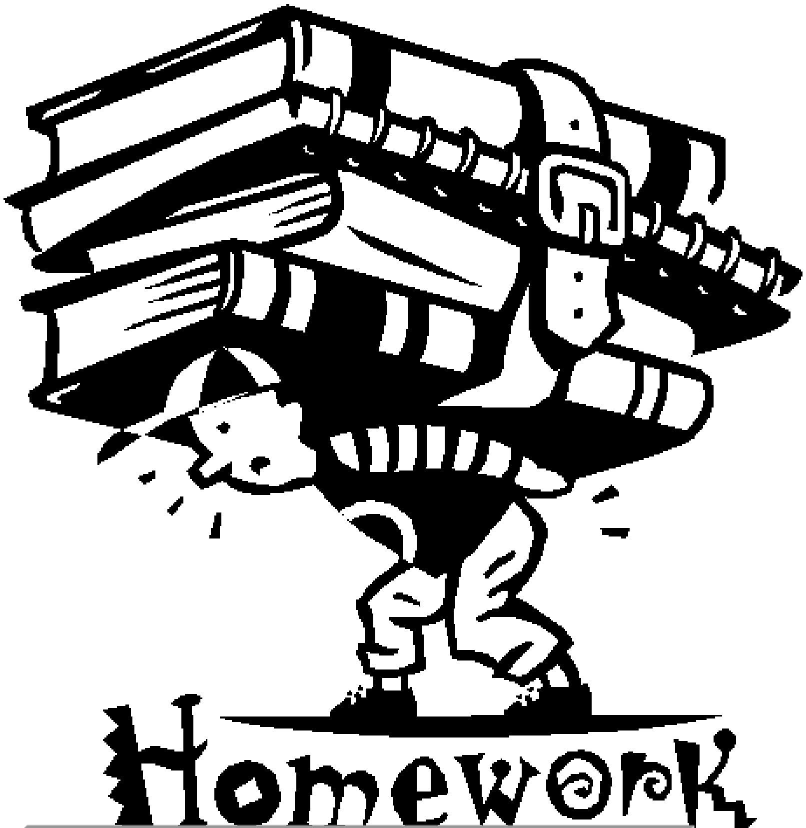
Name___________________________ Regents Physics
Date______________________ Unit Objectives: Energy / Work

1. Define work and state its SI unit.
2. Solve problems finding work done by various forces.
3. Define power and state its SI unit.
4. Solve problems relating power to work and energy.
5. Define energy and name 5 forms of energy.
6. Explain what is meant by gravitational potential energy and give examples of objects that possess it.
7. Use the gravitational potential energy equation to solve problems.
8. Explain what is meant by Kinetic Energy and use the kinetic energy equation to solve problems.
9. State the law of conservation of energy and solve problems that apply this law.
10. Relate potential energy to kinetic energy.
11. Discuss simple harmonic motion and how it is related to changes in energy.
12. Use the equations for gravitational potential energy and kinetic energy to solve problems involving them.
13. Use the equations for elastic potential energy and kinetic energy and solve problems involving them.
14. Use the equations for elastic potential energy to find the spring constant for a spring.

What really happened on that hill...

In Boston, lived Jack, as did Jill,
Who gained *mgh* on a hill.
In their liquid pursuit,
Jill exclaimed with a hoot,
" I think we've just climbed a landfill!"

While noting, "Oh, this is just grand,"
Jack tripped on some trash in the sand.
He changed his potential
To kinetic, torrential,
But not before grabbing Jill's hand.



Assignment Due Monday March 2, 2015:
Read pages 103 – 111
Do Questions page 119 # 1-13, 21, 23, 25, 31, 33

Name____________________________ Regents Physics
Date______________________

Notes: Potential/Kinetic Energy

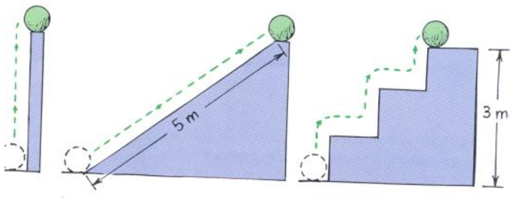
Objectives:
1. Define gravitational potential energy and kinetic energy
2. Use the energy equations to calculate a gravitational potential energy and kinetic energy.
3. Design an experiment that tests variables that affect the period of a pendulum.
4. Use graphical analysis of experimental data to develop an equation for the period of a pendulum.

Gravitational potential Energy

- A form of energy that is related to the *Vertical Position* of an object relative to some lower, reference position.
- The object has the potential to *convert* that energy to a different form of energy.
- Can be quantified using the formula:

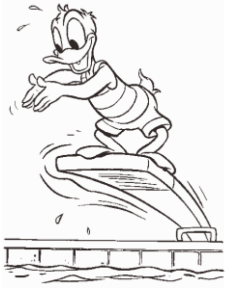
PE = mgh

m = Mass (kilograms)
g = 9.8 m/s^2
h = vertical height



- Note that the potential energy of the ball *is equal* in the three diagrams above because the height is equal.
- Potential energy only depends on height above the *reference position* and not on the path the object took to achieve that height.

Example 1: A diver with a mass of 65 kg is on a 10 m diving board. Find his potential energy on the



m=65 kg
g= 9.8 m/s^2
h= 10 m

P.E.= mgh
= (65kg)(9.8 m/s^2)(10m)
= 6370 kgm^2/s^2
= 6370 Joules

Example 2: A boy holds a stone with a mass of 2.5 kg over the edge of a cliff immediately before dropping it. The distance to the ground below is 75 meters. What is the potential energy of the stone.

$PE = mgh$

$= (2.5 kg)(9.8 m/s^2)(75 m)$

$PE = 1838 J$

Kinetic energy

- A form of energy that is related to the ***velocity*** and the ***mass*** of an object
- Anything that has ***mass*** and is ***in motion*** has kinetic energy
- Can be quantified using the formula:

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

m = mass (kg)

v = velocity (m/s)

Law of Conservation of Eenrgy

- Energy may be classified into various forms which include

Mechanical --→ ***Kinetic*** Energy

Gravitational Potential Energy

Elastic Potential Energy

Electromagnetic → ***Visible light***

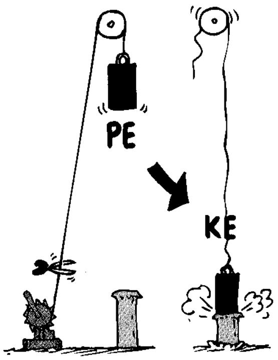
x-rays

Thermal

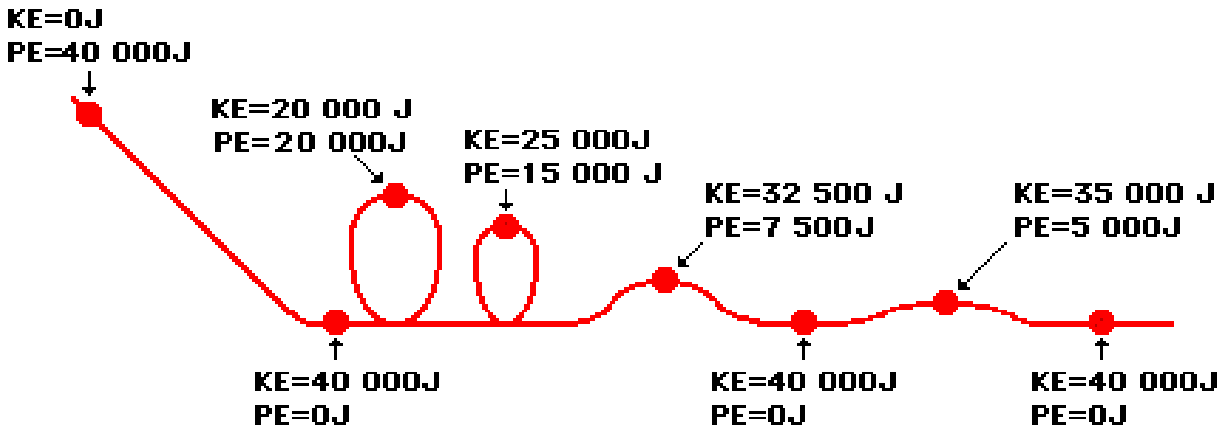
Nuclear

- According to the law of conservation of energy, Energy may be transformed into different ***forms*** but it cannot be ***created*** nor ***destroyed***

- If an object with potential begins ***free fall*** that object's potential energy is being converted to ***Kinetic Energy***



- At the end of the fall the object will have all of its original ***potential energy*** converted to ***kinetic energy***
- So at the end of the fall its potential energy will be ***zero*** and its kinetic energy will be equal to the amount of potential energy it possessed ***before the fall***



Example 2: A car with a mass of 575 kg has a velocity of 25.5 m/s. Find its kinetic energy.

$M = 575 kg$

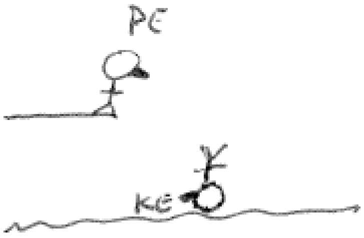
$v = 25.5 m/s$

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

$KE = \frac{1}{2}(575 kg)(25.5 m/s)^2$

$KE = 187,000 J$

Example 3: The diver in example 1 above had all of his potential energy converted to kinetic energy. What was his velocity when he hit the water?



$PE = KE$

$6370 J = \frac{1}{2} m v^2$

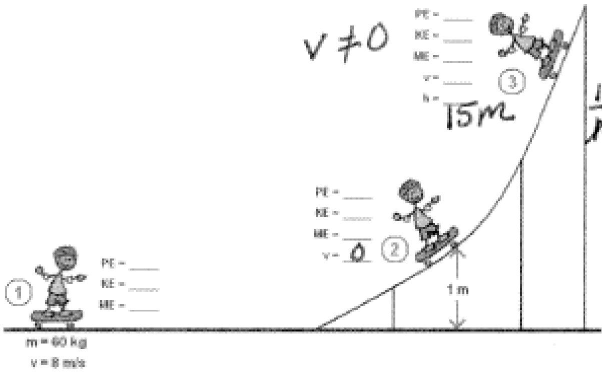
$6370 J = \frac{1}{2}(65 kg) v^2$

$6370 J = 32.5 kg\ v^2$

$$v = \sqrt{\frac{6370 J}{32.5 kg}}$$

$v = 14 m/s$

Example 3: Sammy was riding his skateboard at a speed of 8.0 m/s on a flat level ground. He approaches a 15 meter high ramp and realizes part of the way up the ramp that he did not have enough speed to make it to the top. What vertical height did Sammy make before he came to rest on the ramp?



$$KE_1 = PE_2$$

$$\frac{1}{\cancel{m}}\left[\frac{1}{2}\cancel{m}v_1^2 = \cancel{m}gh_2\right]$$

$$\frac{1}{2}v_1^2 = gh_2$$

$$h_2 = \frac{v_1^2}{2g}$$

$$= \frac{(8.0\ m/s)^2}{2(9.8\ m/s)}$$

$$h_2 = 3.26\ m$$

Example 4: Sammy took a second approach on the ramp this time at a speed of 19.5 m/s. He did make it to the top this time. How fast was Sammy going when he got to the top of the ramp?

$$KE_1 = PE_2 + KE_2$$

$$\frac{1}{\cancel{m}}\left[\frac{1}{2}\cancel{m}v_1^2 = \cancel{m}gh_2 + \frac{1}{2}\cancel{m}v_2^2\right]$$

$$\frac{1}{2}v_1^2 = gh_2 + \frac{1}{2}v_2^2$$

$$\frac{1}{2}(19.5\ m/s)^2 = (9.8\ m/s^2)(15\ m) + \frac{1}{2}v_2^2$$

$$190.125 J = 147 J + \frac{1}{2}v_2^2$$

$$\frac{1}{2}v_2^2 = 43.125$$

$$\boxed{v_2 = 9.3\ m/s}$$

Name_________________________________ Regents Physics

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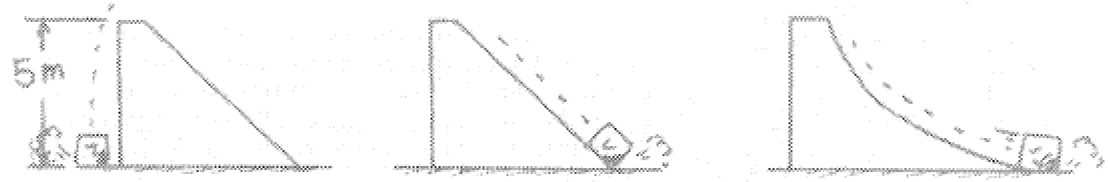
Guided Practice: Potential and Kinetic Energy

1.

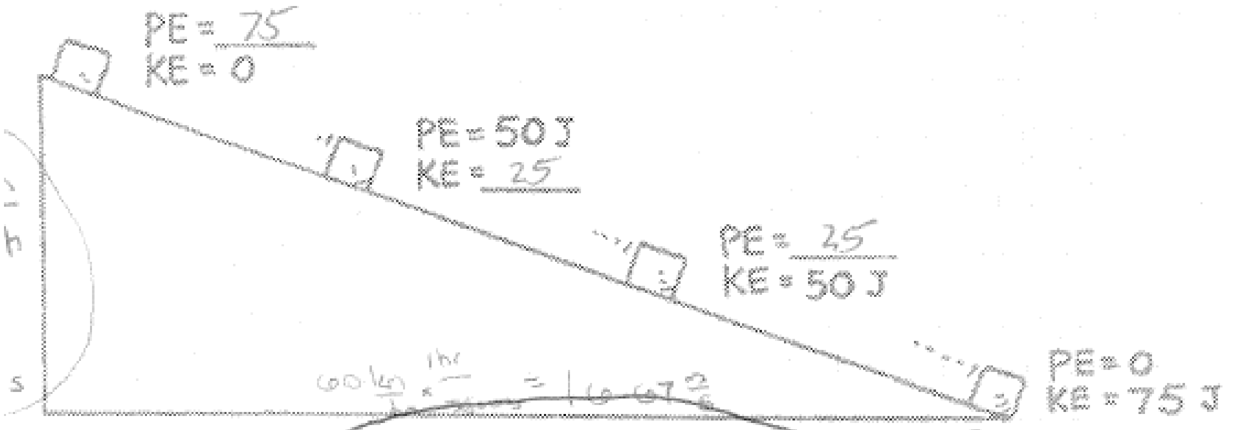
All the ramps are 5 m high. We know that the KE of the block at the bottom of the ramp will be equal to the loss of PE (conservation of energy). Find the speed of the block at ground level in each case. [Hint: Do you recall from earlier chapters how long it takes something to fall a vertical distance of 5 m from a positon of rest (assume g = 10 m/s²)? And how much speed a falling object acquires in this time? This gives you the answer to Case 1. Discuss with your classmates how energy conservation gives you the answers to Cases 2 and 3.]



Case 1: Speed = __10__ m/s Case 2: Speed = __10__ m/s Case 3: Speed = __10__ m/s

2.

The KE and PE of a block freely sliding down a ramp are shown in only one place in the sketch. Fill in the missing values.



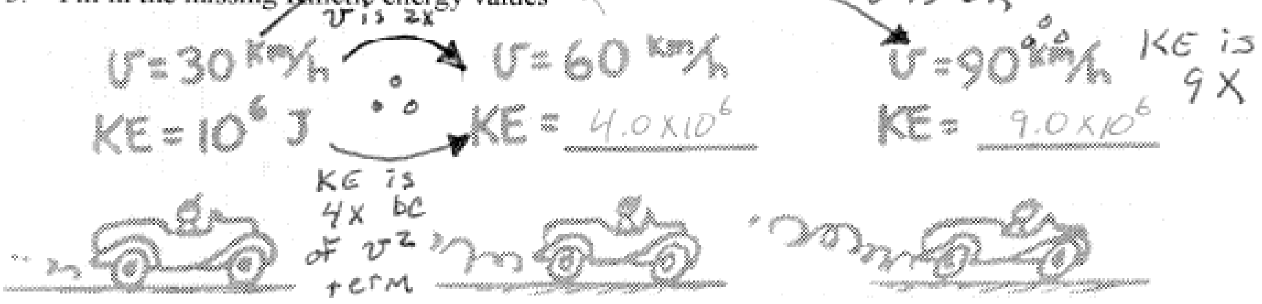
PE = __75__
KE = 0

PE = 50 J
KE = __25__

PE = __25__
KE = 50 J

PE = 0
KE = 75 J

3. Fill in the missing Kinetic energy values



v is 2x

v is 3x

v = 30 km/h
KE = 10^6 J

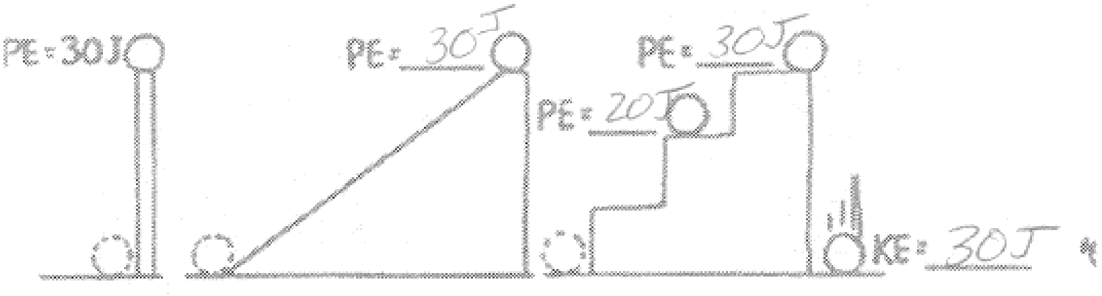
v = 60 km/h
KE = __4.0×10^6__

v = 90 km/h
KE = __9.0×10^6__

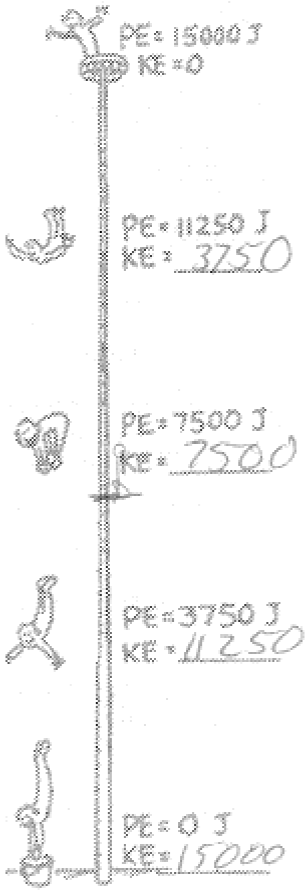
KE is 4x bc of v^2 term

KE is 9 X

4. Fill in the missing PE and KE values:



5. Fill in the missing PE and KE values in the diagram at the right



6. A 200.0 kg hammer of a pile driver is lifted 10.0 m. Find the gravitational potential energy of the system when the hammer is at this height.

$PE = mgh$

$= (200.0 kg)(9.8 m/s^2)(10.0 m)$

$= 19,600 J$

7. A person has a mass of 45 kg and is moving with a velocity of 10.0 m/s.
   a. Find the person's kinetic energy.
   b. The person's velocity becomes 5.0 m/s. What is the kinetic energy of the person?
   c. What is the ratio of the kinetic energy in part a to part b? Explain why this comes about.

8.

a) $KE = \frac{1}{2} m v^2$

$= \frac{1}{2} (45 kg)(10.0 m/s)^2$

$= 2250 J$

b) $KE = 563 J$

c) 4:1

b/c of v^2

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

a. Find the initial kinetic energy of the bike and rider.
b. The rider coasts up the hill.
   Assuming that there is not friction, at what height will the bike come to rest?
c. Does the answer in b depend on the mass of the bike and rider?

c. Does the answer in b depend on the mass of the bike and rider?

a) $KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}(85\,kg)(8.5\,m/s)^2$

$KE = 3070\,J$

b) $KE_1 = PE_2$

$\frac{1}{\cancel{m}}\left[\frac{1}{2}\cancel{m}v_1^2 = \cancel{m}gh_2\right]$

$h_2 = \frac{v_1^2}{2g} = \frac{(8.5\,m/s)^2}{2(9.8\,m/s^2} = 3.69\,m$

c) No...
mass divides out

9. 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 40.0 m high hill. Both hill heights are measured from the valley floor. Assume that you can neglect friction and the effect of ski poles.
   a. How fast is the skier moving at the bottom of the valley?
   b. What is the skier's speed at the top of the next hill?

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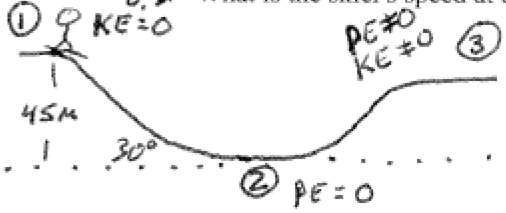
b. What is the skier's speed at the top of the next hill?



a) $PE_1 = KE_2$

$\frac{1}{\cancel{m}}\left[\cancel{m}gh_1 = \frac{1}{2}\cancel{m}v_2^2\right]$

$v_2 = \sqrt{2gh}$

$v_2 = \sqrt{2(9.8\,m/s^2)(45\,m)}$

$v_2 = 29.7\,m/s$

b) $PE_1 = PE_3 + KE_3$

$\frac{1}{\cancel{m}}\left[\cancel{m}gh_1 = \cancel{m}gh_3 + \frac{1}{2}\cancel{m}v_3^2\right]$

$(9.8\,m/s^2)(45\,m) = (9.8\,m/s^2)(40\,m) + \frac{1}{2}v_3^2$

$441\,\frac{m^2}{s^2} = 392\,m^2/s^2 + \frac{1}{2}v_3^2$

$\frac{1}{2}v_3^2 = 49\,m^2/s^2$

$v_3^2 = 98\,m^2/s^2$

$\boxed{v_3 = 9.9\,m/s}$

Name________________________ ***Regents Physics***

Date__________________

TTQ's: PE and KE

Documented Thinking

1) A joule is equivalent to a

A) N/s
B) N • s
C) N/m
D) N • m

2) A car with mass *m* possesses momentum of magnitude *p*. Which expression correctly represents the kinetic energy, *KE*, of the car in terms of *m* and *p*?

A) $KE = \frac{1}{2}mp^2$
B) $KE = \frac{1}{2}\left(\frac{p}{m}\right)$
C) $KE = \frac{1}{2}\left(\frac{p^2}{m}\right)$
D) $KE = \frac{1}{2}mp$

3) If the speed of a moving object is doubled, the kinetic energy of the object is

A) halved
B) quadrupled
C) doubled
D) unchanged

4) The table below lists the mass and speed of each of four objects.

Data Table

Objects	Mass (kg)	Speed (m/s)
A	1.0	4.0
B	2.0	2.0
C	0.5	4.0
D	4.0	1.0

Which two objects have the same kinetic energy?

A) *B* and *C*
B) *B* and *D*
C) *A* and *D*
D) *A* and *C*

5) The gravitational potential energy, with respect to Earth, that is possessed by an object is dependent on the object's

A) speed
B) acceleration
C) momentum
D) position

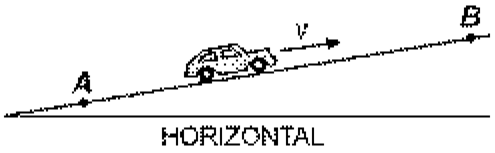
6) A 1.00-kilogram ball is dropped from the top of a building. Just before striking the ground, the ball's speed is 12.0 meters per second. What was the ball's gravitational potential energy, relative to the ground, at the instant it was dropped? [*Neglect friction.*]

A) 24.0 J
B) 72.0 J
C) 6.00 J
D) 144 J

7) While riding a chairlift, a 55-kilogram skier is raised a vertical distance of 370 meters. What is the total change in the skier's gravitational potential energy?

A) 5.4×10^2 J
B) 5.4×10^1 J
C) 2.0×10^5 J
D) 2.0×10^4 J

8) A car travels at constant speed *v* up a hill from point *A* to point *B*, as shown in the diagram below.



As the car travels from *A* to *B*, its gravitational potential energy

A) remains the same and its kinetic energy decreases

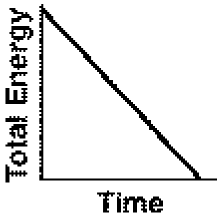
B) remains the same and its kinetic energy remains the same

C) increases and its kinetic energy remains the same

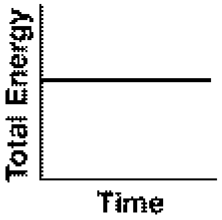
D) increases and its kinetic energy decreases

9) A ball is dropped from the top of a cliff. Which graph *best* represents the relationship between the ball's total energy and elapsed time as the ball falls to the ground? [*Neglect friction.*]

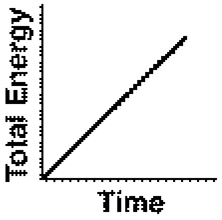
A)



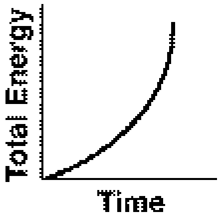
B)



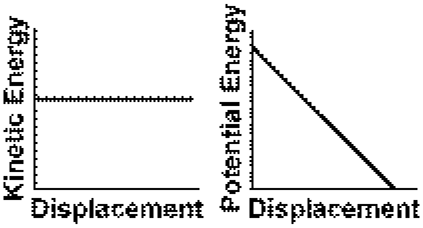
C)

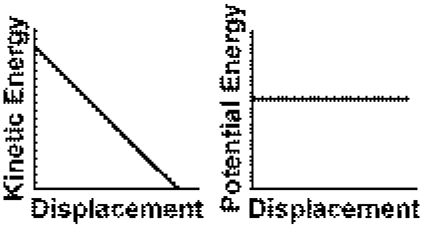


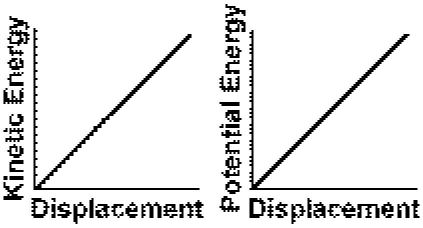
D)

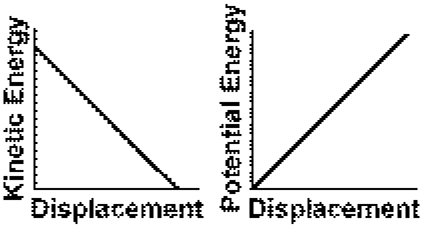


10) An object is thrown vertically upward. Which pair of graphs *best* represents the object's kinetic energy and gravitational potential energy as functions of its displacement while it rises?

A) 

B) 

C) 

D) 

Name________________________________ Regents Physics

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Independent Practice: Potential and Kinetic Energy

1. A person weighing 630 N climbs up a ladder to a height of 5.0 m. What is the increase in the gravitational potential energy of the person at this height?

$PE = mgh \qquad F_g = 630N = mg$

$PE = (630N)(5.0m)$

$PE_g = 3150J$

2. A 60.0 kg shell is shot from a cannon to a height of 4.0 x 10^2 m.
   a. What is the gravitational potential energy of the shell when it is at this height?
   b. What is the change in potential energy of the system when the shell falls to a height of 2.00 x 10^2 m.

2.00 x 10^2 m.

$PE_g = mgh$

$= (60.0kg)(9.8 m/s^2)(4.0 \times 10^2 m)$

$PE_g = 235,200 J$

ⓑ $\Delta PE = mg\Delta h$

$= (60.0kg)(9.8 m/s^2)(4.0 \times 10^2 m - 2.0 \times 10$

$= 117,600 J$

3. An 8.0 kg mass moves at 30.0 m/s. What is its kinetic energy?

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

$KE = \frac{1}{2}(8.0kg)(30.0 m/s)^2$

$KE = 3600 J$

4. A child and bicycle together have a mass of 45 kg. The child rides the bicycle 1.80 km in 10.0 minutes at a constant velocity. What is the kinetic energy of the system?

$m = 45 kg$

$d = 1.80 km$

$t = 10.0 min$

$KE = ?$

$v_{AV} = \frac{d}{t}$

$= \frac{1800m}{600s}$

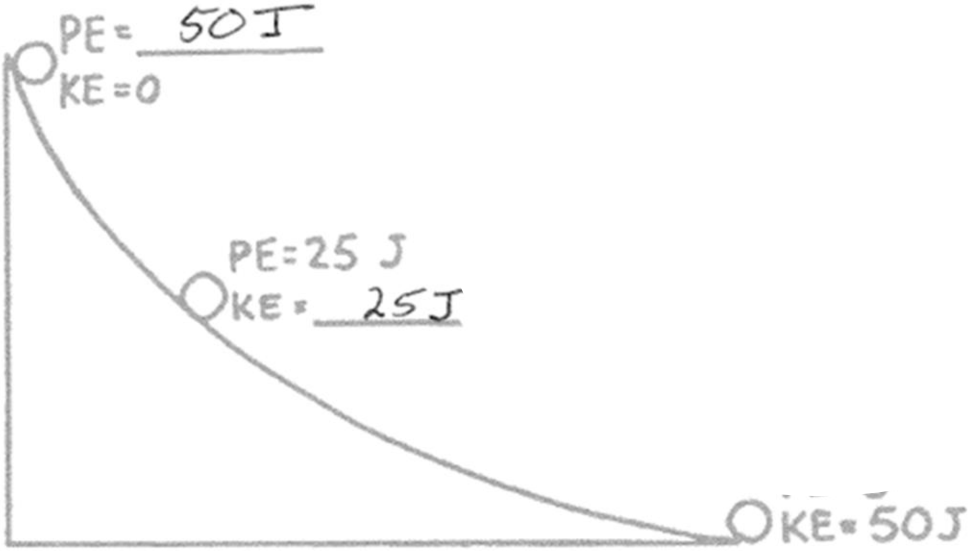
$v_{AV} = 0.30 m/s$

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

$KE = \frac{1}{2}(45kg)(0.30 m/s)^2$

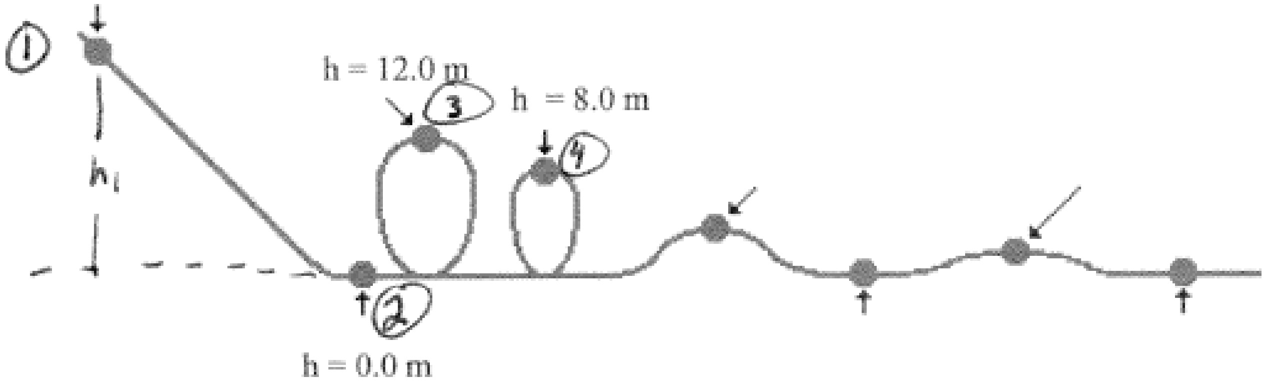
$KE = 2.025 J$

5.



6. Fill in the unknown PE and KE values for the pendulum below.

7. A roller coaster followed a track, a portion of which is shown in the diagram below. The train has a mass of 250. Kg.



a. What is the height of the first hill?

$PE_1 = mgh_1$

$125,000\text{ J} = (250\text{ kg})(9.8\text{ m/s}^2)\,h_1$

$h_1 = 51.0\text{ m}$

b. Find the speed of the train at the bottom of the first hill.

$PE_1 = KE_2$

$\frac{1}{m}\left[\cancel{m}gh_1 = \frac{1}{2}\cancel{m}v_2^2\right]$

$v_2 = \sqrt{2gh} \quad = \sqrt{2(9.8\text{ m/s}^2)(51.0\text{ m})} \quad = 31.6\text{ m/s}$

c. Find the speed of the car at the top of the first loop.

$PE_1 = PE_3 + KE_3 = mgh_3 + \frac{1}{2}mv_3^2$

$125,000\text{ J} = (250\text{ kg})(9.8\text{ m/s}^2)(12.0\text{ m}) + \frac{1}{2}(250\text{ kg})\,v_3^2$

$125,000\text{ J} = 29400\text{ J} + \frac{1}{2}(250\text{ kg})\,v_3^2$

$95,600\text{ J} = 125\text{ kg}\,v_3^2$

$\boxed{v_3 = 27.7\text{ m/s}}$

d. Find the speed of the car at the top of the second loop.

$PE_1 = PE_4 + KE_4 = mgh_4 + \frac{1}{2}mv_4^2$

$125,000\text{ J} = (250\text{ kg})(9.8\text{ m/s}^2)(8.0\text{ m}) + \frac{1}{2}(250\text{ kg})\,v_4^2$

$v_4 = 29.0\text{ m/s}$

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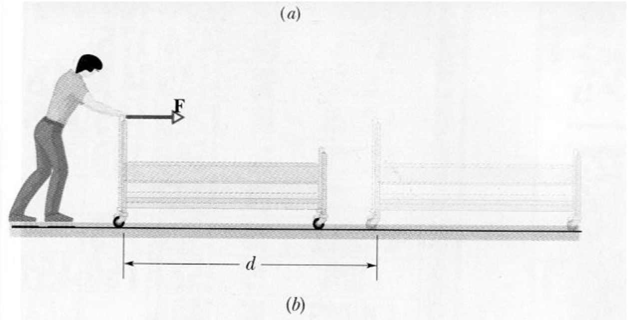
Notes: Work / Energy

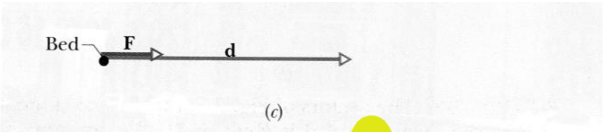
A Walk Around Newtonian Mechanics

- In this unit we will explore a new ***point of view*** of Newton's Laws
- We will apply the concepts of ***kinetic energy*** and ***work*** to address some of the same types of problems that we have been doing.

Work: Motion in one Dimension with a Constant Force

- In the following diagram a college student is pushing a wheeled bed with a constant ***horizontal force*** causing the bed to move through a ***horizontal displacement***





- The work being done by the student can be described as:

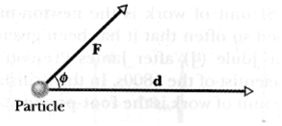
$$\boxed{W = F\cdot d}$$

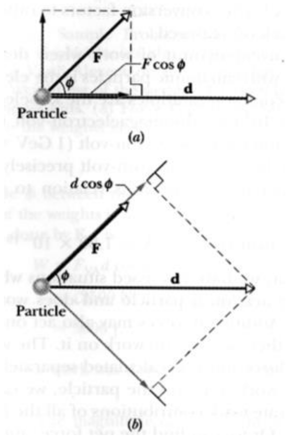
Reference Tables

- We always describe work as being done by a specific ***force*** in this case it is the force that the student exerts on the bed
- It is important to note that the angle φ between the ***force*** and the ***displacement*** is zero degrees.
- The above equation is actually a generalization which applies only when the angle φ is ***0°***
- The more general description of work is that it is the product of the displacement with the ***component*** of the force that is in the same direction as the displacement.
- This can be summarized in equation form as:

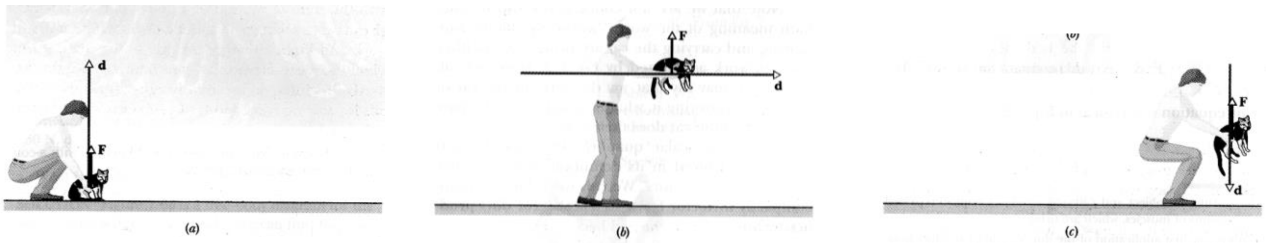
$$\boxed{W = F\cdot d\cos\varphi}$$

- Where the angle φ is the angle between the displacement vector and the *force vector* that is causing the displacement.





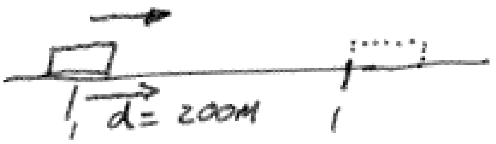
- If the force and the displacement are in the same direction then the angle between them is *0°* and the calculated work will be a *positive value*.
- If the force and the displacement are at a *90° angle* then the calculated work will be *zero* because the cos φ will be zero.
- If the force and displacement are in opposite directions then the angle between them is *180°* and the calculated work will be a *negative value*



(a) (b) (c)

- Work is a *scalar* quantity .
- The SI unit of work is the *newton-meter* which may also be written as a *Joule*
- Another unit of work that is commonly used when describing work done by or on atoms and molecules is the *electron-volt*

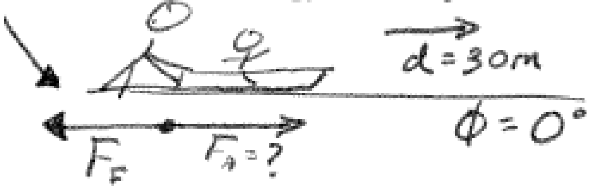
Example 1: How much work is done on an object if a force of 30 newtons (south) displaces the object 200 meters south?



$\phi = 0°$

$$W = Fd \cos\phi$$
$$= (30N)(200M)(\cos 0) = \boxed{6000\ N \cdot M}$$

Example 2: A girl pushes her brother in a sled a total distance of 30 meters. The wagon and the brother together have a mass of 50 kg. The coefficient of friction between the sled and the snow is 0.05. How much work does the girl do?



$F_f = F_A$ b/c const. speed

$F_f = \mu F_N$ $\quad F_N = F_g = mg$

$F_f = \mu mg$

$F_f = (0.05)(50kg)(9.8 m/s^2)$

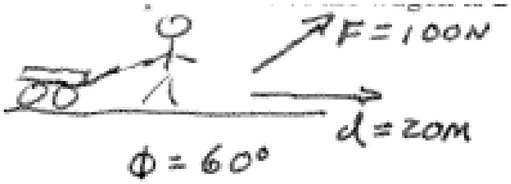
$F_f = 24.5N$

$W = Fd\cos\phi$

$W = (24.5N)(30m)(\cos 0)$

$W = 735 J$

Example 3: As Alex pulls his red wagon down the sidewalk, the handle of the wagon makes an angle of 60º with the pavement. If Alex exerts a force of 100 newton along the direction of the handle, how much work is done when the displacement of the wagon is 20 meters along the ground?



$W = Fd\cos\phi$

$= (100N)(20m)(\cos 60°)$

$= 1000 N\cdot M$

Work / Total energy theorem

- Energy is defined as the ability to do work
- The law of conservation of energy can be expanded to include work
- By the law of conservation of energy discussed this far

$$E_{Ti} = E_{Tf}$$

$$E_{Ti} = \text{Total Energy Initial}$$
$$E_{Tf} = \text{Total Energy Final}$$

$$E_T = PE + KE + Q$$

Reference Tables

$$Q = \text{Internal Energy / Thermal Energy}$$

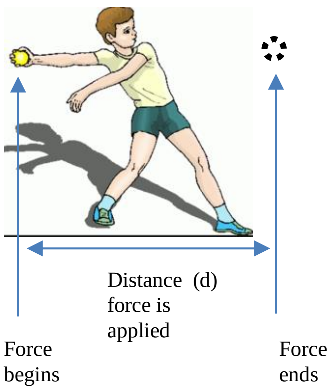
- When including work we would say

$$W = Fd = \Delta E_T$$

Reference Tables

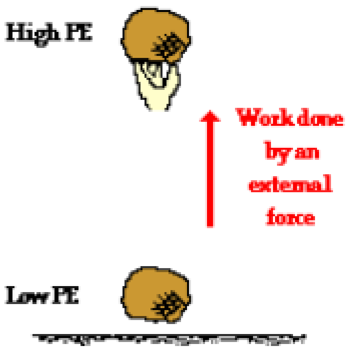
Conceptual Examples

1. Work is done in the process of throwing a ball



- The applied force begins at the windup and ends at the ball's release position.
- The amount of work done is the average force applied times the distance - d.
- The work done results in a ΔE_T, Specifically an increase in kinetic energy as the ball gains velocity.

2. Work is done in the process of lifting a stone



- An upward force equal to the stone's ***weight*** (Fg) is necessary to lift the stone at constant speed
- The force is applied over a ***distance (h)*** so work is done.
- The work done has caused an increase in the stone's ***gravitational potential energy***.

Example 1: A 25 kg trunk is sliding across the floor with an initial velocity of 2.3 m/s. Friction brings the trunk to rest over a distance of 3.5 meters.

a. How much kinetic energy did the trunk possess initially?
b. How much work was done by friction on the trunk?
c. What was the magnitude of the friction force?

a) $m = 25 kg$

$v = 2.3 m/s$

$d = 3.5 m$

$KE = ?$

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

$= \frac{1}{2}(25 kg)(2.3 m/s)^2$

$= 66.125 J$

b) $W = \Delta E_T = \Delta KE$

$W = (KE_f - KE_i) = (0 - 66.125 J)$

$= -66.125 J$

c) $W = Fd \cos \theta$

$-66.125 J = F(3.5 m)\cos 180°$

$F = \frac{-66.125 J}{(3.5 m)(\cos 180)}$

$F = 18.89 N$

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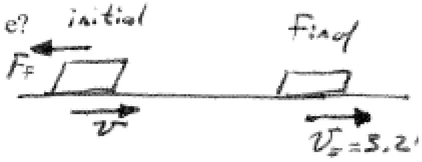
Guided Practice: Work / Energy

1. Lee pushes a 20.0 kg mass 10 m across a floor with a horizontal force of 80 N. Calculate the amount of work Lee does.

$W = F \cdot d = (80N)(10.\ m)$

$= 800 N \cdot m$

2. A 15.0 kg cart is moving with a velocity of 7.50 m/s down a level hallway. A constant friction force of -10.0 N acts on the cart, which results in its velocity being decreased to 3.20 m/s.
   a. What is the change in kinetic energy of the cart?
   b. How much work was done on the cart by the friction force?
   c. How far did the cart move while the force acted?



a) $\Delta KE = (\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2) = -345 J$

b) $-345 J$

c) $W = F d$

$-345 J = (-10 N)(d)$

$d = 34.5 m$

3. Mike pulls a 4.5 kg sled across level snow with a force of 225 N along a rope that is 35.0 ° above the horizontal. If the sled moves a distance of 65.3 m, how much work does Mike do?

$W = F d \cos\phi$

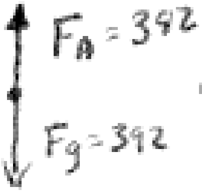
$= (225N)(65.3m)(\cos 35°)$

$= 12\,035 J$

4. Hans picks up a 40.0 kg dumbbell over his head from the floor to a height of 1.65 meters.
    a. What is the gravitational force acting on the dumbbell?
    b. What upward force must Hans exert in order to lift the dumbbell at **constant speed**?
    c. How much work does Hans do lifting the weight?

a) $F_g = mg = (40.0\,kg)(9.8\,m/s^2)$

$= 392\,N$

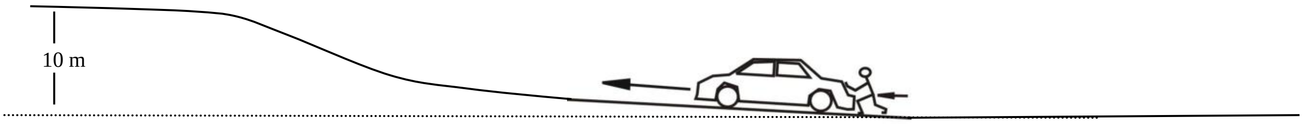


b) 392N Balanced forces required for constant speed.

c) $W = Fd = \Delta E_t = \Delta PE_g$

W = 646 J

5. Howser pushes his 1500 kg car a total distance of 20 m up to the top of a hill. He applies a constant, 9700 N force up the hill. The top of the hill is 10.0 meters higher than the bottom.
    a. Calculate the gravitational potential energy of the car at the top of the hill.
    b. Calculate the work that Howser does pushing the car up the hill.
    c. How much work does Howser do to overcome friction?



a) $PE_g = mgh$

$PE_g = (1500\,kg)(9.8\,m/s^2)(10.0\,m)$

$PE_g = 147{,}000\,J$

b) $W = Fd$

$= (9700\,N)(20\,m)$

$= 194{,}000\,J$

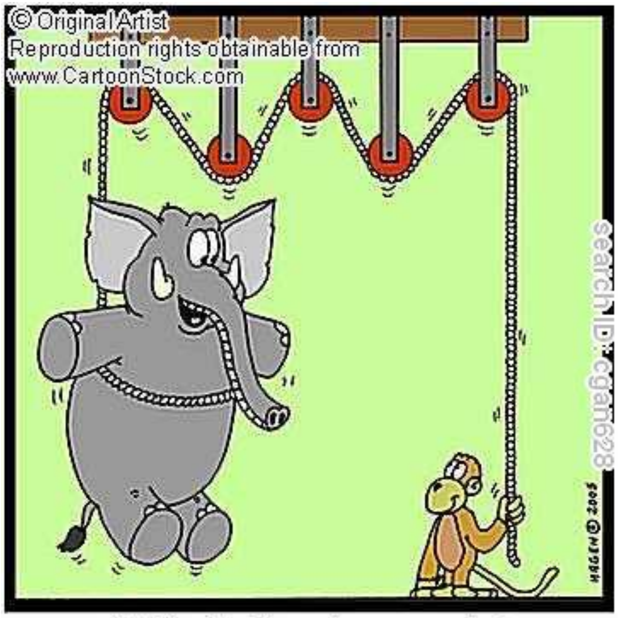
Work done Friction becomes internal energy (Q

c) $W = Fd = \Delta E_t = \Delta PE + \overset{0}{\cancel{\Delta KE}} + \Delta Q$

$194{,}000\,J = 147{,}000\,J + \Delta Q$

$\Delta Q = 47{,}000\,J$

6. Maurice the monkey lifts Elliot the Elephant by exerting a force of 500 N on the rope. He pulls the rope over a distance of 30 m. The 1000 kg elephant is elevated a distance of 1 meters.
    a. Find the gravitational potential energy of Elliot in the elevated position
    b. How much work does Maurice do on the rope?
    c. How much of Maurice's work was lost to friction in the pullies?



Alright, alright, you've won your bet:
You can lift me with one hand...

a) $PE_g = mgh$

$= (1000\,kg)(9.8\,m/s^2)(1.0\,m)$

$PE_g = 9800\,J$

b) $W = F \cdot d$

$= 500N)(30m)$

$= 15{,}000\,J$

c) $W = Fd = \Delta Et = \Delta PE + \cancelto{0}{\Delta KE} + \Delta G$

$15000\,J = 9800\,J + \Delta Q$

$\Delta Q = 5200\,J$

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TTQ's: PE and KE

Documented Thinking

1) Which of the following is an SI unit for work done on an object?

A) $\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$ C) $\frac{\text{kg} \cdot \text{m}}{\text{s}^2}$

B) $\frac{\text{kg} \cdot \text{m}}{\text{s}}$ D) $\frac{\text{kg} \cdot \text{m}^2}{\text{s}}$

2) The work done in lifting an apple one meter near Earth's surface is approximately

A) 0.01 J C) 1 J

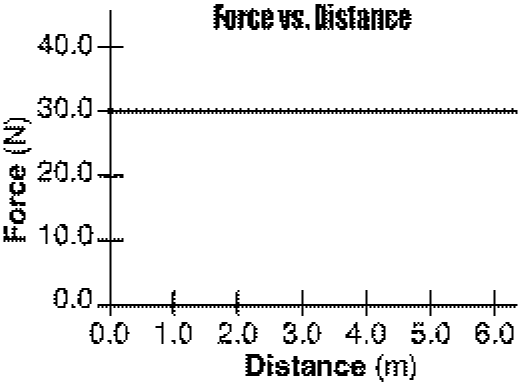
B) 100 J D) 1,000 J

3) How much work is required to lift a 10.-newton weight from 4.0 meters to 40. meters above the surface of Earth?

A) 3.6 J C) 2.5 J

B) 4.0×10^2 J D) 3.6×10^2 J

4) A boy pushes his wagon at constant speed along a level sidewalk. The graph below represents the relationship between the horizontal force exerted by the boy and the distance the wagon moves.



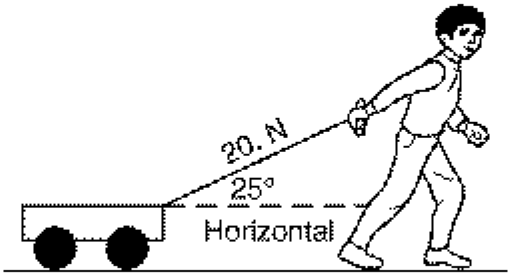
In the given situation, what is the total work done by the boy in pushing the wagon 4.0 meters?

A) 5.0 J C) 7.5 J

B) 120 J D) 180 J

Documented Thinking

5) As shown in the diagram below, a child applies a constant 20.-newton force along the handle of a wagon which makes a 25° angle with the horizontal.



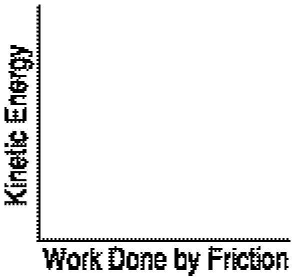
How much work does the child do in moving the wagon a horizontal distance of 4.0 meters?

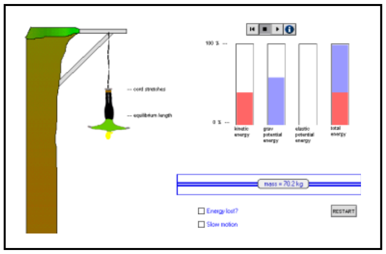
A) 73 J
B) 5.0 J
C) 80. J
D) 34 J

6) A 15.0-kilogram mass is moving at 7.50 meters per second on a horizontal, frictionless surface. What is the total work that must be done on the mass to increase its speed to 11.5 meters per second?

A) 992 J
B) 422 J
C) 120. J
D) 570. J

9) A car, initially traveling at30. meters per second, slows uniformly as it skids to a stop after the brakes are applied. On the axes provided below, sketch a graph showing the relationship between the kinetic energy of the car as it is being brought to a stop and the work done by friction in stopping the car.





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Notes: Elastic PE and Power

Elastic potential energy

Recall that every spring has a *force constant* that describes its elasticity

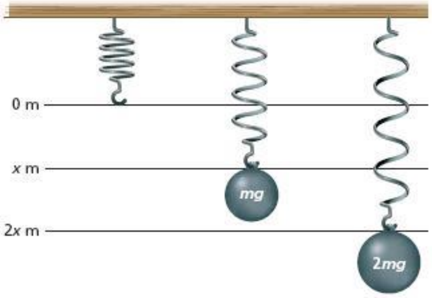
$$F = kx$$

Reference Tables

Where F=force(newtons) ,

k= spring const N / m ;

x = displacement from equilibrium

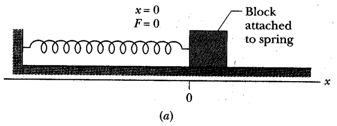


- A spring system, not at equilibrium possesses *elastic potential energy* described by the equation:

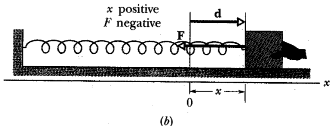
$$PE = \frac{1}{2}kx^2$$

Reference Tables

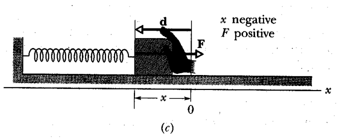
- By the law of conservation of energy a spring system with *elastic potential energy* can have that energy converted to *other forms*:



- *Spring is in equilibrium position*
- *No force acts on the block*
- *The block and spring remain at rest.*

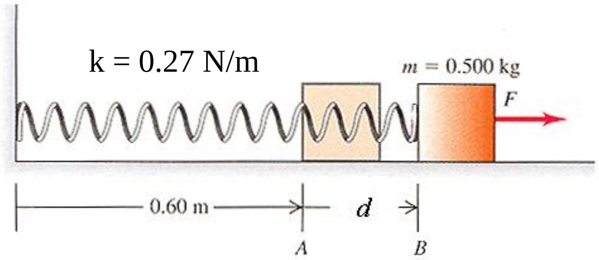


- *The block is pulled to the right stretching the spring*
- *The spring exerts a force on the block to the left*
- *When released, the block will accelerate to the left*



- *The block is pushed to the left compressing the spring*
- *The spring exerts a force on the block to the right*
- *When released, the block will accelerate to the right*

Example 1: A 0.50 kg block is on the end of a spring which is being stretched on a horizontal frictionless surface. The spring is stretched a distance of 0.15 meters from its equilibrium position and the spring constant for the spring is 0.27 N/m.



$M = 0.50 \text{kg}$

$K = 0.27 \text{N/m}$

a. Find the potential of the block in the stretched position.

$PE_s = \frac{1}{2} k x^2$

$PE_s = \frac{1}{2}(0.27 \text{N/m})(0.15 \text{m})^2$

$PE_s = 0.0030 \text{J}$

b. If the block is released, at what point will all of this potential energy be converted to kinetic energy?

At the equilibrium position

c. Find the velocity of the block at this point.

$PE_{s1} = KE_2 = \frac{1}{2} m v_2^2$

$0.0030 \text{J} = \frac{1}{2}(0.50 \text{kg}) v_2^2$

$\boxed{v_2 = 0.110 \text{m/s}}$

Power

- Power is the ***rate*** at which ***work*** is being done.
- Power is a ***scalar*** quantity with units of ***J / s*** or ***Watts***
- Power can be calculated by the formula:

$$P = \frac{W}{t} = \frac{Fd}{t} = F\overline{v}$$

Reference Tables

P = Power
W = Work
Δt = time interval
$\overline{v}$ = average speed

Example 6: If 3000 joules of work is performed on an object in 1.0 minute, what is the power expended on the object?

$W = 3000 J$

$t = 1.0 min = 60 sec$

$P = ?$

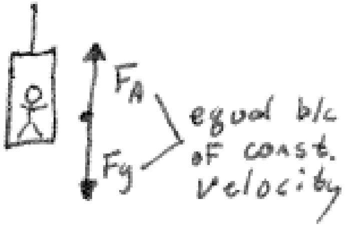
$$P = \frac{W}{t} = \frac{3000 J}{60 s} = \boxed{50 J/s}$$

Example 7: An electric motor hoists an elevator weighing 12, 000 Newtons, 9.00 meters in 15.0 seconds. What is the power of the motor in watts? . . . in kilowatts?

$F_g = 12,000 N$

$d = 9.0 M$

$t = 15.0 S$



$$P = \frac{Fd}{t} = \frac{(12000 N)(9.0 M)}{15.0 s}$$

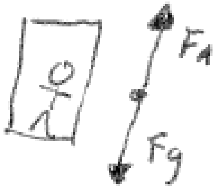
$$\boxed{P = 7200 Watts}$$

Example 8: A loaded elevator with a mass of 2300 kg is moving upward at a constant speed of 3.5 m/s. At what rate is power being used by the elevator?

$M = 2300 kg$

$v = 3.5 m/s$

$P = ?$



$$P = Fv = mgv$$

$$= (2300 kg)(9.8 m/s^2)(3.5 m/s$$

$$\boxed{P = 78\ 890 Watts}$$

$F_A = F_g = mg$

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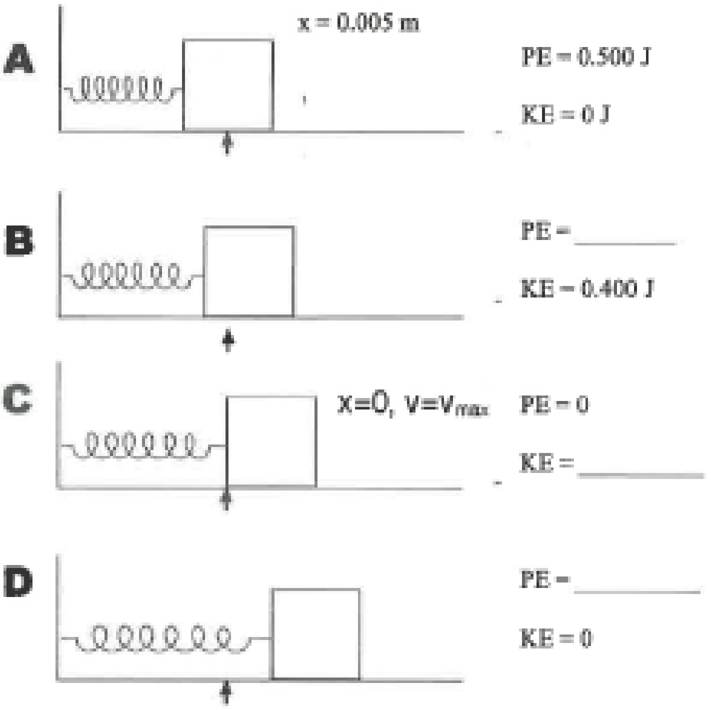
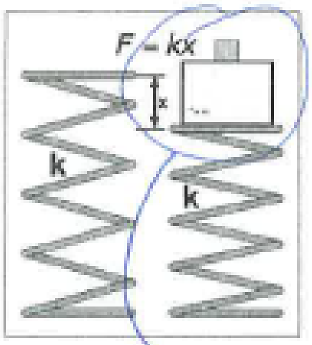
Guided Practice: Elastic Potential Energy

1. The diagram at the right shows a block connected to a spring with snapshots taken at consecutive time intervals labeled A - D. The block is resting on a frictionless surface. The block oscillates from an initial push. The arrow marks the location of equilibrium for the spring.
   a. Complete the PE and KE blanks.
   b. Which snap shot(s) show(s) the block momentarily at rest?
   c. The mass of the block is 5 kg. What is its velocity in snapshot C where the KE is maximum.



When a 13.2-kg mass is placed on top of a **vertical** spring, the spring compresses x = 5.93 cm. Find the force constant of the spring.



G $m_s = 13.2\,Kg$

$\Delta x = 5.93cm$

$= 0.0593m$

U $k = ?$

E $F = kx$

$F_g = mg$

S ① $F_g = mg$

$F_g = (13.2kg)(9.8\,m/s^2)$

$F_g = 129.36N$

$F = kx$

$129.36N = k(0.0593m)$

S $k = 2181\,N/m$

3. If a spring has a spring constant of 400 N/m, how much work is required to compress the spring 25.0 cm from its undisturbed position?

G $k = 400\,N/m$

$\Delta x = 25cm$

$= 0.25m$

U $W = ?$

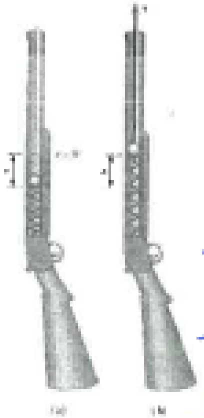
E $W = \Delta E_t = \Delta PE_s$

$W = \frac{1}{2}k\Delta x^2$

S $W = \frac{1}{2}(400\,N/m)(0.25m)^2$

S $W = 12.5\,J$

4. A spring operated dart gun fires 0.010 kg darts. Arming the gun requires 185 N of force and results in the shortening of the spring by 10 cm.
   a. Find the spring constant.
   b. Find the energy stored in the spring
   c. Find the muzzle velocity of the dart.
   d. If the dart is launched vertically, how high will it rise?



G $m = 0.010\text{ kg}$
$F = 185\text{ N}$
$\Delta x = 10\text{ cm} = 0.10\text{ m}$

U a) $k = ?$

E $F = k\Delta x$

S $k = \frac{F}{\Delta x} = \frac{185\text{N}}{0.10\text{m}}$

S $k = 1850\text{ N/m}$

ⓑ

U $PE_s = ?$

E $PE_s = \frac{1}{2}kx^2$

S $PE_s = \frac{1}{2}(1850\text{ N/m})(0.10\text{m})^2$

S $PE_s = 9.25\text{ J}$

ⓒ

U $v_f = ?$

E $PE_s = KE = \frac{1}{2}mv^2$

S $9.25\text{J} = \frac{1}{2}(0.010\text{kg})v^2$

S $v = 43\text{ m/s}$

ⓓ

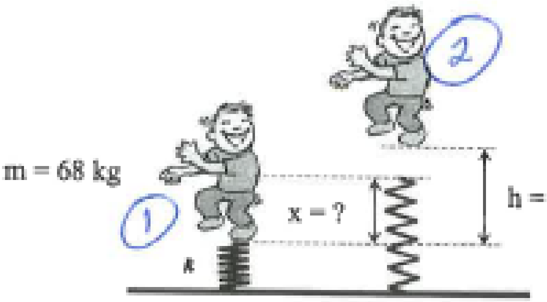
U $h = ?$

E $PE_s = PE_g = mgh$

S $9.25\text{J} = (0.01\text{kg})(9.8\text{ m/s}^2)h$

S $h = 94.4\text{ m}$

5. A 68 kg acrobat stands on a spring loaded platform as a part of a stunt. If the spring under the platform has spring constant of 1.6×10^3 N/m, how far should the spring be compressed to vault the acrobat to a height o 5.0 m?



G $k = 1.60\times10^3\text{ N/m}$
$h = 5.0\text{ m}$
$m = 68\text{ kg}$

U $x = ?$

E $PE_{s1} = PE_{g2}$

S $\frac{1}{2}kx_1^2 = mgh_2$

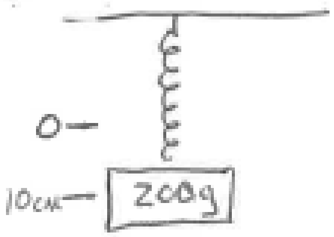
S $\frac{1}{2}(1.60\times10^3\text{ N/m})x^2 = (68\text{kg})(9.8\text{ m/s}^2)(5.0\text{m})$

$x^2 = \frac{(68\text{kg})(9.8\text{m/s}^2)(5.0\text{m})(2)}{(1.6\times10^3\text{ N/m})}$

$x^2 = 4.165$

$x = 2.04\text{ m}$

6. A spring stretches 10 cm under a load of 200 g.
   a. Determine the spring constant.
   b. How much work is required to stretch the first 5 cm.
   c. How much work is required to stretch the last 5 cm.



ⓐ

E $F_g = mg = Kx$

$K = \frac{mg}{x}$

S $K = \frac{(.200kg)(9.8m/s^2)}{.10m}$

S $K = 19.6 N/m$

G $m = 200g$
$= .200kg$
$\Delta x = 10cm$
$= .10m$

U $K = ?$

ⓑ

U $W = ?$
$[\Delta x = 0\text{-}5cm]$

E $W = \frac{1}{2}Kx^2$

S $W = \frac{1}{2}(19.6 N/m)(.05m)^2$

S $W = 0.0245J$

ⓒ

U $W = ?$
$[\Delta x = 5\text{-}10cm]$

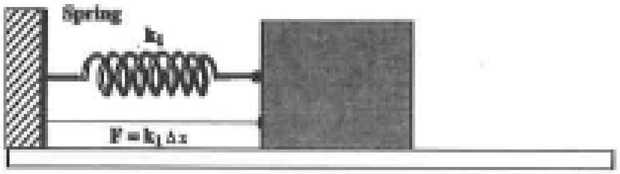
E $W_{0\text{-}10} = \frac{1}{2}kx^2$

S $W = \frac{1}{2}(19.6 N/m)(.10m)^2$

S $W = 0.098J$

$W_{5\text{-}10} = W_{0\text{-}10} - W_{0\text{-}5}$
$= 0.098J - 0.0245J$
$W_{5\text{-}10} = 0.0735J$

7. A mass sitting on a horizontal frictionless surface is attached to one end of spring; the other end is fixed to a wall. 3.0 J of work is required to compress the spring by 0.12 m. If the mass is released from rest with the spring compressed, it experiences a maximum acceleration of 15 m/s/s. Find the value of the spring constant.



G $W = 3.0J$
$\Delta x = 0.12m$
$a = 15 m/s^2$

U $K = ?$

E $W = \Delta PE_s = \frac{1}{2}kx^2$

S $2[3.0J] = [\cancel{\frac{1}{2}}(k)(0.12m)^2]\cancel{2}$

$\frac{1}{(0.12m)^2}[2(3.0J)] = [k\cancel{(0.12m)^2}]\frac{1}{\cancel{(0.12m)^2}}$

S

$K = \frac{2(3.0J)}{(0.12m)^2}$

$K = 417 N/m$

Name ______________________ Regents / Honors Physics

Date ____________

Guided Practice: Power

7. Robin pushes a wheelbarrow by exerting a 145 N force horizontally. Robin moves it 60.0 m at a constant speed for 25.0 s.
   a. What power does Robin develop?
   b. If Robin moves the wheelbarrow twice as fast, how much power is developed?

$F_A = 145N$

$d = 60m$

$t = 25.0s$

a) $P = 348\ W$ $\quad P = \frac{Fd}{t} = \frac{(145N)(60m)}{25.0s}$

b) $P = 696W$ $\quad$ 2x faster $\therefore t = \frac{25s}{2}$ $\quad P = \frac{Fd}{t} = \frac{(145N)(60m)}{12.5s}$

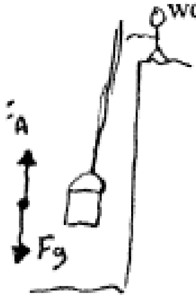
8. A force of 300.0 N is used to push a 145 kg mass 30.0 m horizontally in 3.00 s.
   a. Calculate the work done on the mass. 9000 J
   b. Calculate the power developed. 3000 W

a) $W = Fd = (300.0N)(30.0m)$

b) $P = \frac{W}{t} = \frac{9000J}{3.0s}$

9. Two construction workers, standing on the roof of a building, hoist identical buckets of tools to the top by puling upward on long ropes. The weight of the tools and buckets are the same for each worker, as is the distance each bucket is hoisted. However, one worker hoists their bucket from the ground to the roof in one-third the time that it takes the other worker. compare the efforts of the two workers in terms of energy and power.

workers in terms of energy and powe



$\Delta E_{t1} = \Delta E_{t2}$

$P_1 = 3P_2$

$F_A = F_g$ b/c of const. velocity

10. A 2000 newton force is applied to an object that moves in the direction of the force. If the object travels with a constant velocity of 10 m/s, calculate the power expended on the object.

$\boxed{P = 20{,}000\ \text{W}}$

$P = F \cdot v$

$P = (2000\text{N})(10.\ \text{m/s})$

11. A motor having a power rating of 475. watts is used to lift an object with a mass of 125 kg. How much time does the motor take to lift the object a vertical distance of 10.0 meters?

$P = 475\ \text{W}$

$m = 125\ \text{kg}$

$d = 10\ \text{m}$

$F = mg = 1225\ \text{N}$

$t = ?$

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

$t = \frac{Fd}{P} = 25.8\ \text{s}$

$\boxed{t = 25.8\ \text{s}}$

12. At what constant speed can a 3200 watt motor working at full capacity vertically lift a 55 kg weight?

$P = 3200\ \text{W}$

$m = 55\ \text{kg}$

$F = 539\ \text{N}$

$P = Fv$

$v = \frac{P}{F} = \boxed{5.94\ \text{m/s}}$

Name________________________ **Regents Physics**

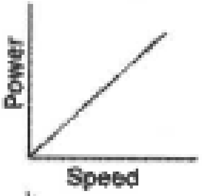
Date__________________

TTQ's: PE and KE

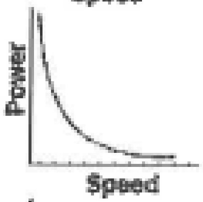
Documented Thinking

1) Which of the following graphs *best* represents the relationship between the power required to raise an elevator and the speed at which the elevator rises?

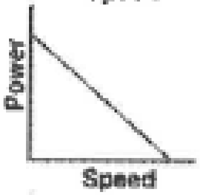
A)



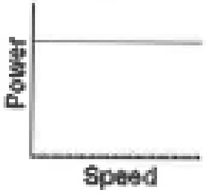
B)



C)



D)



A

$p = F\bar{v}$

What is the slope of the graph.

2) Student *A* lifts a 50.-newton box from the floor to a height of 0.40 meter in 2.0 seconds. Student *B* lifts a 40.-newton box from the floor to a height of 0.50 meter in 1.0 second. Compared to student *A*, student *B* does

A) less work but develops more power
B) more work but develops less power
C) the same work but develops less power
D) the same work but develops more power

D

$w = F \cdot d$

Ⓐ $w = (50N)(.4m) = 20\,N{\cdot}M$

$P = \frac{W}{t} = \frac{20N{\cdot}M}{2.0s} = 10W$

Ⓑ $w = (40N)(.5m) = 20N{\cdot}M$

$P = \frac{W}{t} = \frac{20N{\cdot}M}{1.0s} = 20W$

3) What is the average power required to raise a 1.81×10^4-newton elevator 12.0 meters in 22.5 seconds?

A) 2.17×10^5 W
B) 8.04×10^2 W
C) 9.65×10^3 W
D) 4.89×10^6 W

C

$P = \frac{Fd}{t} = \frac{(1.81 \times 10^4 N)(12.0m)}{22.5s} = 9.65 \times 10^3 W$

4) What is the power output of an electric motor that lifts a 2.0-kilogram block 15 meters vertically in 6.0 seconds?

A) 49 W
B) 5.0 W
C) 5.0 J
D) 49 J

A

G $m = 2.0Kg$
$d = 15m$
$t = 6.0s$

$F_g = mg$

$F_g = (2.0Kg)(9.8 m/s^2) = 19.6N$

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

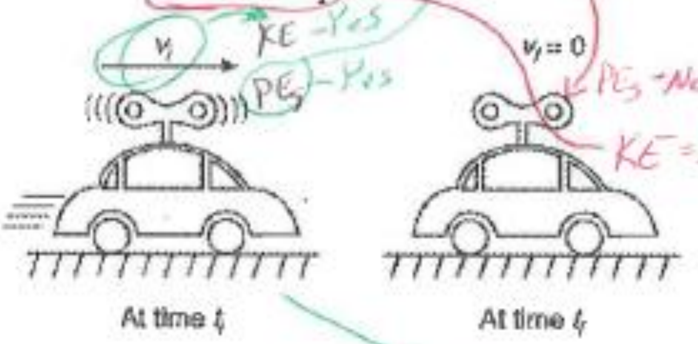
$P = \frac{(19.6N)(15m)}{6.0s}$

Documented Thinking

PEg – No change

5) A wound spring provides the energy to propel a toy car across a level floor. At time t_i, the car is moving at speed v_i across the floor and the spring is unwinding, as shown below. At time t_f, the spring has fully unwound and the car has coasted to a stop.

B



Forms of Energy

PEs, PEg, KE, Q (Internal Thermal)

Which one of the following statements *best* describes the transformation of energy that occurs between times t_i and t_f?

A) Both kinetic energy and internal energy at t_i are converted to elastic potential energy at t_f

B) Both elastic potential energy and kinetic energy at t_i are converted to internal energy at t_f

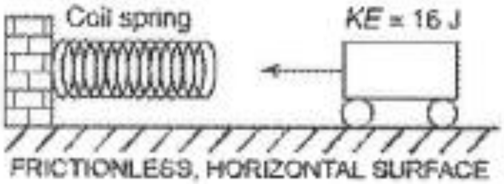
C) Gravitational potential energy at t_i is converted to internal energy at t_f

D) Elastic potential energy at t_i is converted to kinetic energy at t_f

PEs & KE $\Longrightarrow$ Internal Energy

6) The diagram below shows a toy cart possessing 16 joules of kinetic energy traveling on a frictionless, horizontal surface toward a horizontal spring.

A



If the cart comes to rest after compressing the spring a distance of 1.0 meter, what is the spring constant of the spring?

– K

A) 32 N/m
B) 16 N/m
C) 4.0 N/m
D) 8.0 N/m

Conservation of Energy

G

$PE_s = KE_i = 16J$

$\Delta x = 1M$

U

$K = ?$

E

$PE_s = \frac{1}{2}Kx^2$

$16J = \frac{1}{2}K(1M)^2$

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Documented Thinking

7) A student makes a simple pendulum by attaching a mass to the free end of a 1.50-meter length of string suspended from the ceiling of her physics classroom. She pulls the mass up to her chin and releases it from rest, allowing the pendulum to swing in its curved path. Her classmates are surprised that the mass doesn't reach her chin on the return swing, even though she does not move. Explain why the mass does *not* have enough energy to return to its starting position and hit the girl on the chin.

Friction - it loses energy
- internal energy

8) A vertically hung spring has a spring constant of 150. newtons per meter. A 2.00-kilogram mass is suspended from the spring and allowed to come to rest.

(a) Calculate the elongation of the spring produced by the suspended 2.00-kilogram mass. [*Show all work, including the equation and substitution with units.*]

(b) Calculate the total elastic potential energy stored in the spring due to the suspended 2.00-kilogram mass. [*Show all work, including the equation and substitution with units.*]

a) 0.131 m.

$F = kx$

$mg = kx$

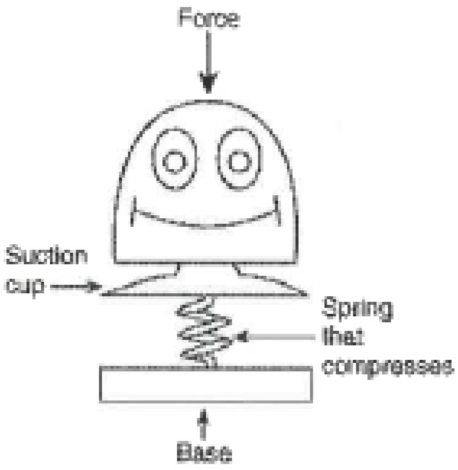
$x = \frac{mg}{k} = \frac{(2 kg)(9.8 m/s^2)}{150 N/m} = 0.131 m.$

b) $PE = \frac{1}{2}kx^2$

$PE = \frac{1}{2}(150 N/m)(0.131 m)^2$

$PE = 1.29 J$

9) A pop-up toy has a mass of 0.020 kilogram and a spring constant of 150 newtons per meter. A force is applied to the toy to compress the spring 0.050 meter.



(a) Calculate the potential energy stored in the compressed spring described. [*Show all work, including the equation and substitution with units.*]

(b) The toy is activated and all the compressed spring's potential energy is converted to gravitational potential energy. Calculate the maximum vertical height to which the toy is propelled. [*Show all work, including the equation and substitution with units.*]

$PE_s = \frac{1}{2}kx^2$

$= \frac{1}{2}(150 N/m)(0.05 m)^2$

$= 0.19 J$

$PE_g = mgh$

$h = \frac{PE_g}{mg} = \frac{0.19 J}{(.02 kg)(9.81 m/s^2)}$

$h = 0.97 m$