Unit 7: Work, Energy and Power

1 - Work

Energy:

Work and energy are:

_______________ values

Measured in _________________

Work can be defined as either:

A change in ________ or The product of...

In physics we talk about work being done...

Ex.

- If I hold a 30 kg weight at a height of 1.5 m, I'm using energy, therefore...
- However the work is **not** being done ___ ____ __________, it is being done on my muscles.
- *Think of it like this: though I am exerting a ______ on the weight, its ________________ is zero, therefore ______ work is done on it.*

Ex. If I were to lift the 30.0 kg weight up off the ground to a height of 1.5 m, how much work would be done on the weight?

When an object is lifted against gravity the formula:

$W = Fd$

Where: m =

g =

h =

Ex. A 10.0 kg pumpkin is moved horizontally 5.00 m at a constant velocity across a level floor using a horizontal force of 3.00 N. How much work is done in moving the pumpkin?

Note: Use ___________ force, not _________ force

Ex. A 3.0 kg pineapple is held 1.2 m above the floor for 15 s. How much work is done on the pineapple?

Note: No ____________________ means no ___________

Ex. A 50.0 kg banana box is pulled 11.0 m along a level surface by a rope. If the rope makes an angle with the floor of 35^o and the tension in the rope is 90.0 N, how much work is done on the box?

Note: Use on the __________________ of the force that is in the direction of displacement

Ex. A 1385 kg car traveling at 61 km/h is brought to a stop while skidding 42 m. What is the work done on the car by frictional forces?

Note: Work can be ______________ if the force doing the work acts in the direction.

2 – Potential Energy

Potential Energy:

Examples:

- In this class we will focus on…
- This is stored energy due to…
- Remember:

Gravitational Potential Energy:

Where:
m =
g =
h =

Gravitational energy is always measured…

Ex. A 15.0 kg textbook is sitting on a 1.20 m tall table. If the book is lifted 0.80 m above the table, how much gravitational potential energy does it have:

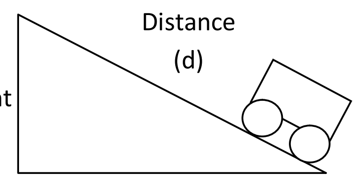
a. with respect to the table?

b. with respect to the floor?

Ex 2. An archer pulls on a bow string with an average force of 240 N while drawing the arrow back a distance of 0.200 m. Calculate the potential energy of the bow-arrow system.

HINT: The **work** done to the bow is all being stored as *potential energy*.

Ramp It Up!



Procedure: Measure the work done on a cart and its Ep at the top of the ramp.

$W = Fd$ $E_p = mgh$

Trial 1:
F = m =
d = g =
h =
W = Ep =

Trial 2:
F = m =
d = g =
h =
W = Ep =

Trial 3:
F = m =
d = g =
h =
W = Ep =

How does the work done on the cart compare to its gain in potential energy?

Using all the words ***work, height, force*** and ***distance*** explain why ramps can be useful machines.

Unit 7: Work, Energy and Power

3 – Kinetic Energy

Kinetic Energy:

- ____________ value
- Measured in ____________

Where:
m =
v =

Ex. A 60.0 kg student is running at a uniform speed of 5.70 m/s. What is the kinetic energy of the student?

Ex. The kinetic energy of a 2.1 kg rotten tomato is 1.00×10^3 J. How fast is it moving?

The Work Energy Theorem

· If a net force acts on an object it must be _______________

· This must be proportional its

__________ ___ __________

· Therefore

Ex. A sprinter exerts a net force of 260 N over a distance of 35 m. What is his change in kinetic energy?

Ex. A student pushes a 25 kg crate which is initially at rest with a force of 160 N over a distance of 15 m. If there is 75 N of friction, what is the final speed of the crate?

Left) Quicksilver, a mutant from the comic X-men, is said to have a top speed of 4091 m/s. What is his kinetic energy?

Right) In the spiderman comic, Gwen Stacy was pushed from the top of the George Washington Bridge by evil Green Goblin. What is Gwen's Kinetic Energy just before hitting the water 184 m below if her mass is 55 kg.

Unit 7: Work, Energy and Power

4 – The Law of Conservation of Energy

The Law of Conservation of Energy:

This is similar to a pendulum:

Imagine a ball being thrown up into the air:

As the ball travels upwards _____ is converted into _____

As the fall falls down _____ is converted into _____

- When only conservative forces (like gravity) work on an object…

- When forces like __________ are at work then energy is not conserved.

- Friction converts some energy into __________

The Law of Conservation of Energy:

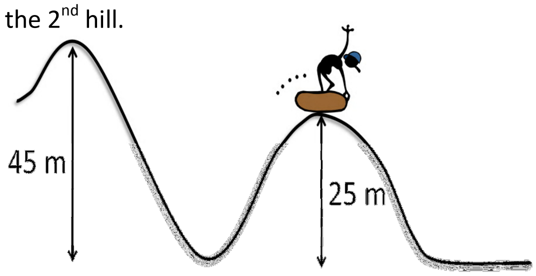
Ex: While jumping over The Great Wall of China an 82 kg skateboarder is needs to leave the ramp traveling at 78 km/h.

a) How much potential energy does he need to start with?

b) What minimum height of ramp should he use?

Ex: A trampoline dunk artist is bounces to a maximum vertical height of 4.8 m before launching himself towards the hoop. At the top of his arc he is 3.2 m above the ground. How fast is he traveling at this point?

Ex: A 65 kg snowboarder starts at rest, travels down a hill into a gulley and back up the other side as shown. Find his speed at top of the 2nd hill.



Unit 7: Work, Energy and Power

5 – Power

Power is the _______________ of doing _____________

Power is measured in ________ or ___________ (   )

Ex. Lover's Leap is a 122 m vertical climb. The record time of 4 min 25 s was achieved by Dan Osman (65 kg). What was his average power output during the climb?

Ex. A $1.00x10^3$ kg car accelerates from rest to a velocity of 15.0 m/s in 4.00 s. Calculate the power output of the car. Ignore friction.

Another useful formula:
Since,

and,

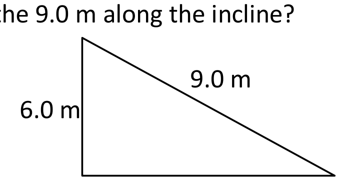
Therefore:

Ex. A student uses 140 N to push a block up a ramp at a constant velocity of 2.2 m/s. What is their power output?

Note that this formula is only useful when...

Worksheet 7.5: Power

1) A 45.0 kg student runs at a constant velocity up the incline shown. If the power output of the student is 1.50×10^3 W, how long does it take the student to run the 9.0 m along the incline?



2) A 20.0 kg object is lifted vertically 2.50 m in 2.00 s at a constant velocity. Calculate the power output of the student.

3) A 2.00 kg object is accelerated uniformly from rest to 3.00 m/s while moving 1.5 m across a level frictionless surface. Calculate the power output.

4) An 8.5×10^2 kg elevator is pulled up 32.0 m at a constant velocity of 1.40 m/s. Calculate the power output of the motor.

1) 1.8 s 2) 245 W 3) 9.0 W 4) 12000 W

Unit 7: Work, Energy and Power

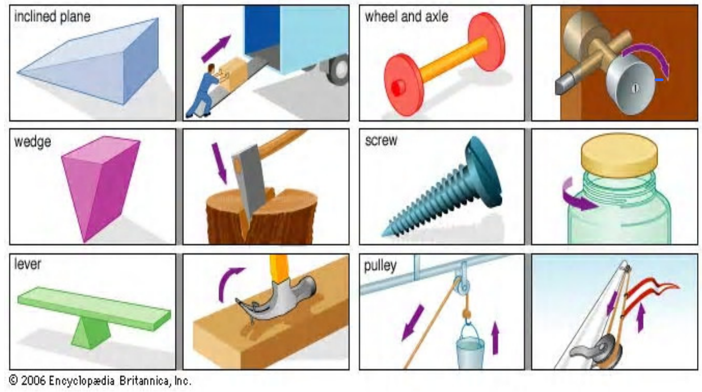
6 – Efficiency

Efficiency is a measure of how much…

Machines are useful because they allow us to use _________ force over a distance to do the work.

The 2nd Law of Thermodynamics states that whenever work is done, some energy is converted to heat.
Therefore:

Work in:
Work out:



The Efficiency of a machine is:

There are no units for efficiency, it is expressed as…

Ex: A lever is used to lift a 50.0 kg object 10.0 cm. To do this we must apply a force of 75 N to the end of the lever which displaces 1.00 m. Find the efficiency of the lever.

Worksheet 7.6: Efficiency

1) A 5.00×10^2 W electric motor lifts a 20.0 kg object 5.00 m in 3.50 s. What is the efficiency of the motor?

2) If a 1.00×10^2 W motor has an efficiency of 82%, how long will it take to lift a 50.0 kg object to a height of 8.00 m?

3) A 955.0 kg car is accelerates uniformly from rest to 16.0 m/s while moving 18.0 m across a level surface. If the car uses 125 000 W of power, what is the efficiency of the car?

An 8.5×10^2 kg elevator is pulled up at a constant velocity of 1.00 m/s by a 10.0 kW motor. Calculate the efficiency of the motor.

1) 56%. 2) 48 sec. 3) 43%. 4) 83.35

7 – Thermal Energy

Thermal Energy vs. Temperature

Thermal energy (

Temperature:

Example: which contains more heat – a pot of boiling water or an iceberg?

Why?

Atoms and molecules are in constant motion:

Solids	Liquids	Gases

When a material is heated the molecules __________ __________ and as a result it will _______________

If an object is heated it will either

1) 2)

Take for example the heating curve for H_2O

Heat will always flow from ________ to __________ concentration by either

1)

2)

3)

Until __________ ________________ is achieved.

The amount of heat transferred to an object is found with:

Where:

Q =

m =

c =

ΔT =

Specific Heat Capacity	
Water	
Carbon	
Iron	
Copper	
Lead	

Example:
Mr. Trask makes a cup of coffee by boiling 250 g of water that is initially at 15° C. How much heat is needed?

Example:
A 35 kg child goes down a 3.2 m high slide. The child is initially at rest and moving at 1.8 m/s at the bottom of the slide. If the slide is made of 12 kg of iron and all the heat is transferred into the slide, by how much does the temperature of the slide increase?

8 – Conservation of Heat and Latent Heat

Conservation of Heat

When heat is transferred from one substance to another, all of the energy transferred is conserved. In an ideal situation, we can write that the ______________________ by one substance is equal to the ____________________ by the other

$$\Delta Q_{gain} = \Delta Q_{loss}$$

a) A 0.5 kg block of lead, at 300°C, is placed in 2 kg of water at a temperature of 20°C. What is the final temperature of the mixture when equilibrium has been achieved?	b) 0.5 kg of a mysterious metal "Cheungmeium" at 100°C is placed in 0.2 kg of water at 20°C. The final temperature of the system is 25°C. Find the specific heat of "Cheungmeium"

Change of State and Latent Heat

Latent heat: the amount of heat (energy) required to change the phase of a unit mass of a substance.

$$Q = mL_f \quad or \quad Q = mL_v$$

"**L**" Latent Heat, measure in Energy/Mass, [J/kg].

Heat (energy) is required to melt a substance (solid to liquid phase transition). The corresponding latent heat is called the ***latent heat of fusion***. ________ When a substance solidifies, it releases heat.

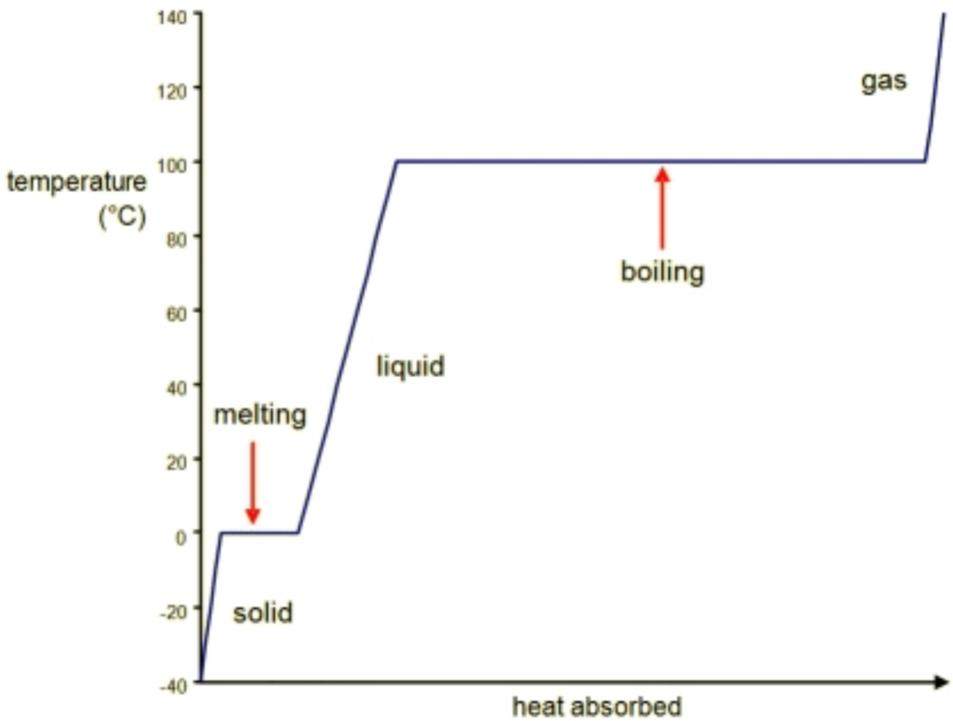
Heat (energy) is required to vaporize a substance (liquid to gas phase transition). The corresponding latent heat is called the ***latent heat of vaporization***. ____________A substance releases heat when it condenses into liquid.

Latent Heat

Substances	Melting Point (°C)	L_f (kJ/kg) $\times 10^3$	Boiling Point (°C)	L_v (kJ/kg) $\times 10^3$
Hydrogen	-259.3	58.6	-252.9	452
Nitrogen	-210.0	25.5	-195.8	201
Oxygen	-218.8	13.8	-183.0	213
Ethanol	-114	104	78.3	854
Ammonia	-77.7	332	-33.4	1370
Mercury	-38.9	11.8	357	272
Water	0.00	334	100.0	2256
Sulphur	119	38.1	444.6	326
Lead	327	24.5	1750	871
Antimony	631	165	1440	561
Aluminum	660	380	2450	11400
Silver	961	88.3	2193	2336
Gold	1063	64.5	2660	1578
Copper	1083	134	2595	5069
Uranium	1133	84	3900	1900
Tungsten	3410	184	5900	4810

Heating curve of water

As we heat a block of ice, the temperature rises ($Q = mc\Delta T$) until it reaches its melting point. At certain fixed point on the temperature scale (melting point, boiling point) the additional heat energy des not increase the temperature; instead, a change of state occurs. The temperature remains constant during the state change because the energy is being used to weaken or breaks the intermolecular bonds



Example: A block of ice at -40°C is heated to liquid water at 80° in the following steps

Step 1: -40°C Ice to 0°C Ice

Step 2: 0°C Ice to 0°C Water

Step 3: 0°C Water to 80°C Water

Ex 1) How much heat energy is required to melt 2.0 kg of solid gold at 500°C to liquid gold at 1645°C? liquid gold c = 150 J/kgC	Ex 2) How much heat energy is needed to boil 3 kg of water at 25°C to steam.
Ex 3) How much heat does a refrigerator freezer have to remove from 1.5 kg of water at 20°C to make ice at -10°C	

Unit 7: Work, Energy and Power

9 - Elastic Energy and Hooke's Law

Elastic Potential Energy –.

Elastic medium –

The force in the medium is governed by how far it is stretched, compressed, or bent. This is known as ….

Hooke's Law: [ ]

The negative in the equation above indicates that the force is a restoring force.

Energy stored in an elastic medium is given by:

[ ] Where **k** is
x is

A force of 200 N stretches a spring 30 cm. What is the spring constant of the spring? How far would this spring stretch with a force of 100 N applied to it?	A trampoline has a spring constant of 3430 N/m, how far will the trampoline sink when a 70 kg person land on it from a height of 2m?

Worksheet 7.9: Elastic Energy

1. A spring is stretched 2 cm when a mass of 40 grams is hung from it. What is the spring constant of the spring? (20 N/m)

2. A 20 kg box is attached to a compressed spring that has a spring constant of 300 N/m. The box is resting on a frictionless surface and the spring is compressed 30 cm.
   a. What is the EPE of the spring? (13.5 J)
   b. What will be the KE of the box when the spring expands back to its natural length? (13.5 J)
   c. How fast will the box be moving after the spring releases the box? (1.2 m/s)

3. A spring has a spring constant of 256 N/m. How far must it be stretched to give it an elastic potential energy of 48 J? (0.61 m)

4. A toy rocket-launcher contains a spring with a spring constant of 35 N/m. How much must the spring be compressed to store 1.5 J of energy? (0.29 m)

5. Each of the coil springs of a car has a spring constant of 25,000 N/m. How much is each spring compressed if it supports one-forth of the car's 12,000 N weight? (0.12 m)

Worksheet 7.1: **Work**

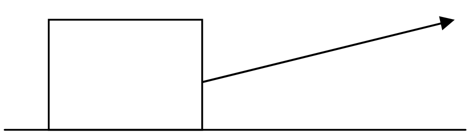
1. A 20.0 N pomegranate is lifted at a constant velocity from the floor to a height of 1.50 m. How much work is done on the object?

2. A 15.0 N potato is moved horizontally 3.00 m across a level floor using a horizontal force of 6.00 N. How much work is done on the potato?

3. A 2.20 N pear is held 2.20 m above the floor for 10.0 s. How much work is done on the pear?

4. A 10.0 kg pink grapefruit is accelerated horizontally from rest to a velocity of 11.0 m/s in 5.00 s by a horizontal force. How much work is done on the pink grapefruit assuming no friction?

5.

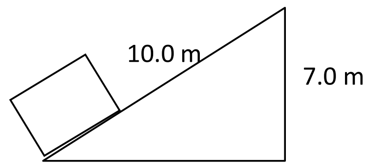


A 90.0 N box of papayas is pulled 10.0 m along a level surface by a rope. If the rope makes an angle of 20.0° with the surface, and the force in the rope is 75.0 N, how much work is done on the box?

6. A 60.0 kg student runs at a constant velocity up a flight of stairs. If the height of the stairs is 3.2 m, what is the work done against gravity?

7. A 20.0 kg passionfruit is pulled horizontally 9.0 m along a level frictionless surface at a constant velocity. How much work is done on the passionfruit?

8.



An 80.0 kg pumpkin is pushed up at a constant velocity along a frictionless incline as shown in the diagram. How much work is done on the pumpkin in moving it up the incline?

9. A 25.0 kg pickle is accelerated from rest through a distance of 6.0 m in 4.0 s across a level floor. If the friction force between the pickle and the floor is 3.8 N, what is the work done to move the object?

10. A 1165 kg car traveling at 55 km/h is brought to a stop while skidding 38 m. Calculate the work done on the car by the friction forces.

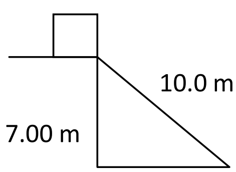
1) 30.0 J 2) 18.0 J 3) 0 J 4) 605 J 5) 705 J 6) 1900 J 7) 0 J 8) 5500 J 9) 135 J 10) 1.4×10^5 J

Worksheet 7.2 - Potential Energy

1. A 25.0 N object is held 2.10 m above the ground. What is the potential energy with respect to the ground?

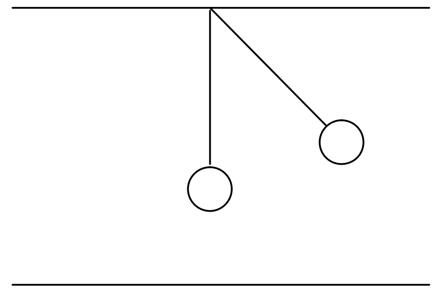
2. An uncompressed spring is 20.0 cm in length. What is the potential energy of the spring when an average force of 65.0 N compresses it to a length of 13.5 cm?

3.



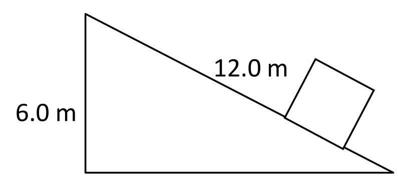
A 2.75 kg box is at the top of a frictionless incline as shown in the diagram. What is the potential energy with respect to the bottom of the incline?

4.



The bob of a pendulum has a mass of 2.0 kg and hangs 0.50 m above the floor. The bob is pulled sideways so that it is 0.75 m above the floor. What is its potential energy with respect to its equilibrium position?

5.



A 2.00 $\times 10^3$ kg crate is pushed to the top of an incline as shown. If the force applied along the incline is 12000 N, what is the potential energy of the object when it is at the top of the incline with respect to the bottom?
(Ok smartypants how much energy was wasted as heat?)

1) 52.5 J 2) 4.23 J 3) 189 J 4) 4.9 J 5) 1.18×10^5 J (26000 J)

Worksheet 7.3 - Kinetic Energy

1. A 3.0 kg ewok is traveling at a constant speed of 7.5 m/s. What is its kinetic energy?

2. The kinetic energy of a 20.0 N droid is 5.00×10^2 J. What is the speed of the droid?

3. A 10.0 N lightsaber is accelerated from rest at a rate of 2.5 m/s^2. What is the kinetic energy of the lightsaber after it has accelerated over a distance of 15.0 m.

4. A 1200.0 N Wookie jumps off a cliff on Earth. What is its kinetic energy after it falls for 4.50 s?

5. An 8.0 kg bantha poodoo is dropped from a height of 7.0 m. What is the kinetic energy of the poodoo just before it hits the ground? (No kinematics!)

6. A 9.00 kg object falls off of a 1.2 m high table. If all of the objects potential energy is converted into kinetic energy just before it hits the floor, how fast is it moving? (Solve without using kinematics)

7. Solve #6 using kinematics this time. Is there any difference?

8. A golfer wishes to improve his driving distance. Which would have more effect:
(a) *doubling the mass* of his golf club or
(b) *doubling the speed* with which the clubhead strikes the ball?
Explain your answer.

1) 84 J 2) 22.1 m/s 3) 38 J 4) 119 000 J 5) 550 J 6) 4.8 m/s 7) 4.8 m/s (down) 8) b

Worksheet 7.4 - Law of Conservation of Energy

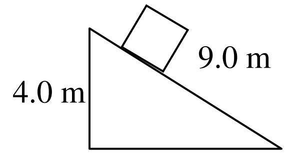
1. Physics student is dropped (don't ask why or you're next). If they reach the floor at a speed of 3.2 m/s, from what height did they fall?

2. A heavy object is dropped from a vertical height of 8.0 m. What is its speed when it hits the ground?

3. A bowling ball is dropped from the top of a building. If it hits the ground with a speed of 37.0 m/s, how tall was the building?

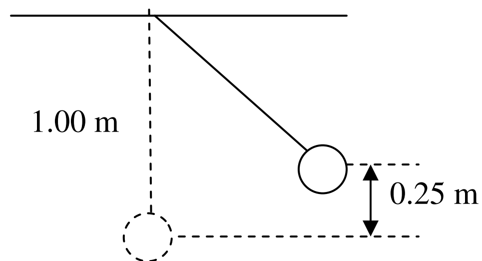
4. A safe is hurled down from the top of a 1.3×10^2 m building at a speed of 11.0 m/s. What is its velocity as it hits the ground?

5.



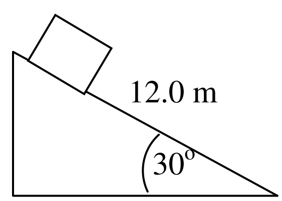
A box slides down a frictionless ramp. If it starts at rest, what is its speed at the bottom?

6.



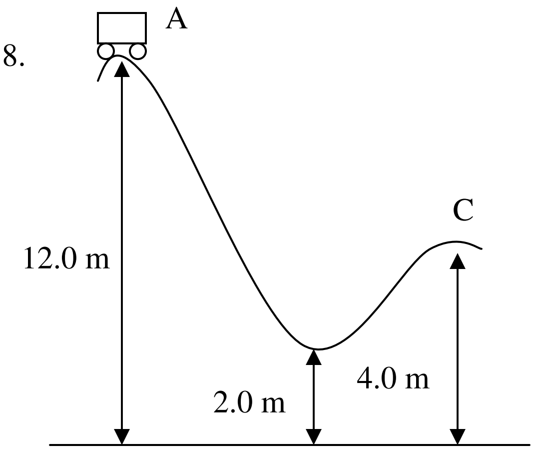
A pendulum is dropped from the position shown, 0.25 m above its equilibrium position. What is the speed of the pendulum bob as it passes through its equilibrium position? B

7.



A box slides down a frictionless incline as shown. If the box starts from rest, what is its speed at the bottom?

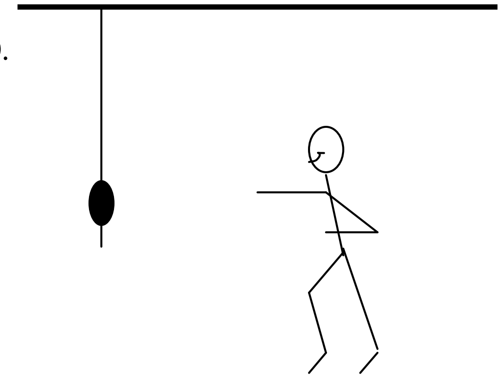
8.



A roller coaster car starts from rest at point A. What is its speed at point C if the track is frictionless?

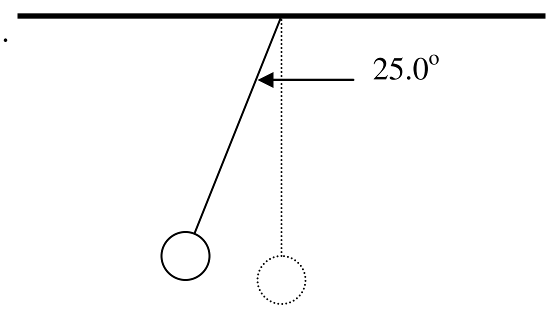
9. A 2.5 kg object is dropped from a height of 10.0 m above the ground. Calculate the speed of the object as it hits the ground.

10.



An 80.0 kg student running at 3.5 m/s grabs a rope that is hanging vertically. How high will the student swing?

11.



A pendulum is 1.20 m long. If the pendulum is pulled until it makes a 25.0° angle to the vertical, what is the speed of the pendulum bob when it passes through its equilibrium position? HINT: Determine the vertical drop of the pendulum bob first.

1) 0.52 m 2) 13 m/s 3) 69.8 m 4) 52 m/s 5) 8.9 m/s 6) 2.2 m/s 7) 10.8 m/s 8) 13 m/s 9) 14 m/s 10) 0.63 m 11) 1.49 m/s

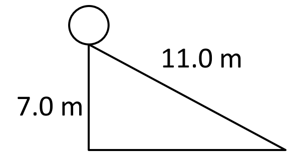
Worksheet 7.7: Thermal Energy, Heat and Specific Heat Capacity

1. How much heat is needed to rise the temperature of 462 g of water from 24.0 ^{o}C to 80.0 ^{o}C?

2. How much heat is required to raise the temperature of 462 g of copper from 24.0 ^{o}C to 80.0 ^{o}C?

3. A 0.240 kg chunk of carbon is heated to 215 ^{o}C and quickly placed into 0.275 kg of water that has a temperature of 12 ^{o}C. What will the final temperature of the water be?

4. A 3.0 kg ball rolls down from the top of a ramp as shown. If the ball is moving at 10.0 m/sat the bottom, how much energy was lost due to friction (thermal energy)?



5. A 1.00 g raindrop traveling at 40.0 m/s strikes the surface of 100 g of water in a glass. How much will the water's temperature change if we assume that:

i) all of the raindrop's kinetic energy is transformed into thermal energy, and

ii) the raindrop and the glass of water's temperatures are initially the same

Answer
1) 108000 J 2)101000J 3) 39 C 4)56 J 5) 0.0019 C

Worksheet 7.8 – **Latent Heat**

1. How much energy is required to evaporate (boil) 2.4 kg of liquid Silver?

2. (multistep) Solid Copper starts to melt at $1083\ °C$. Calculate the total amount need to bring 3kg of solid cooper at 25 °C to liquid copper at 2020 °C.
   Specific heat capacity of liquid copper $c = 490\ J/kg°C$
   Specific heat capacity of solid copper $c = 387\ J/kg°C$

3. a) How much energy does it take to melt 10g of ice? b) How long will this melting process take If an immersion heater rated at 150 W is used to heat up the block of ice? (*hint: need power of part b*)

4. (challenging) Lemonade can be cooled by adding lumps of ice to it. A student discovers that 70g of ice at a temperature of $0\ °C$ cools 0.3 kg of lemonade from $28\ °C$ to $7\ °C$. [The latent heat of fusion of ice is $L_f = 334000\ J/kg$ and the specific heat capacity of water is $c = 4186\ J/kg°C$].
   Determine:
   a) the energy gained by the ice in melting
   b) the energy gained by the melted ice
   c) the energy lost by the lemonade
   d) a value for the specific heat capacity of the lemonade

1. 5.6×10^6J 2. 3,007,228 J 3. a) 3340 J, b) 22.3 sec
4. a) 23380 J b) 2051 J c) -25431 J d) 4037 J/kg°C