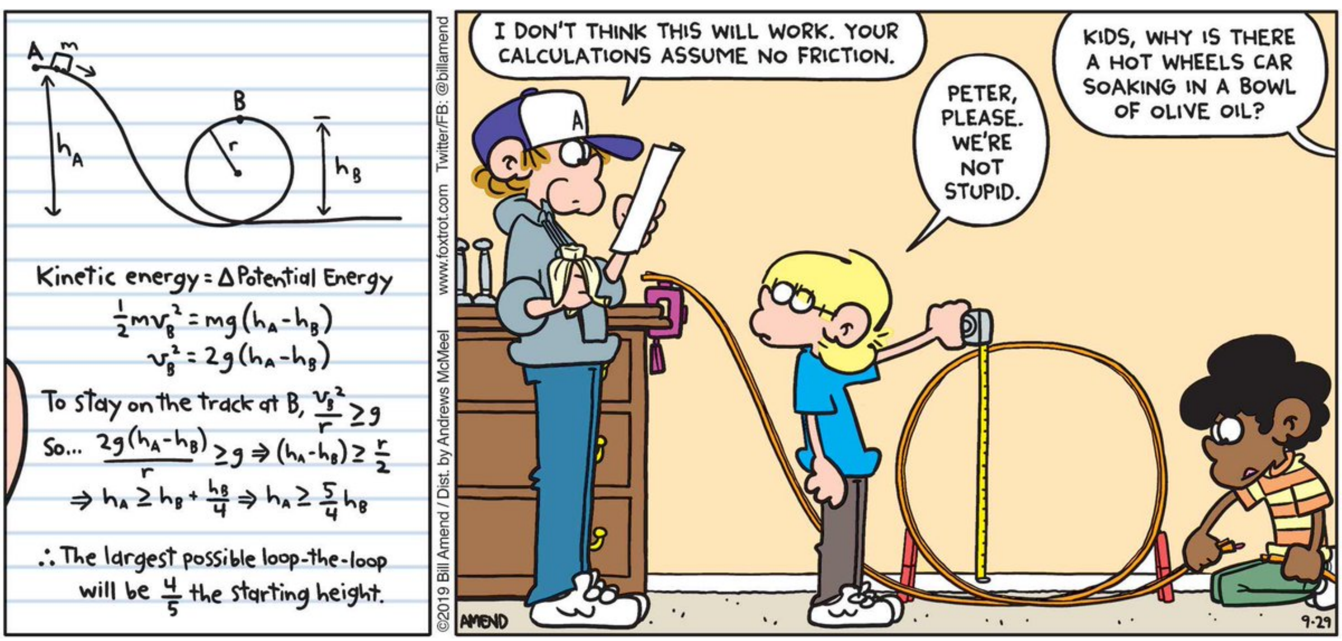
SCIENCE 10

unit 3: physics



book 1: kinetic & potential energy

NAME: Key

BLOCK: ______

moved = displacement = an object moved over a distance in a direction

part a – intro to energy & kinetic energy

Brainstorm:

What is WORK?

when a force is applied (push/pull) to an object that causes it to change its motion.

What is ENERGY?

- need energy to DO WORK
- capacity to be able to change an objects motion

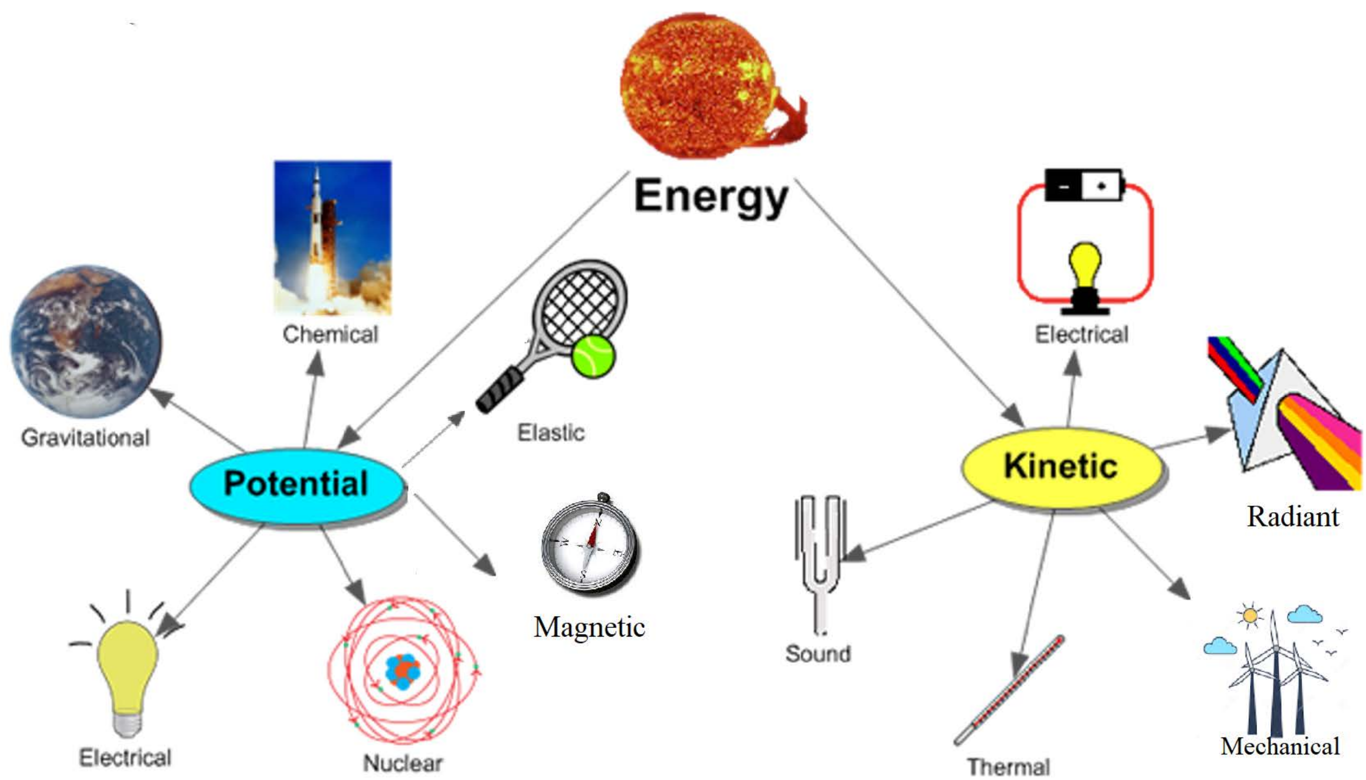
*"in physics, we say that if you have **done work**, **ENERGY** is transferred to another object or changed into something different"*

Energy Definition

Energy is the ability to do work which means that it can move an object over a distance.

Energy has no mass or volume. (ie: "Energy" is not matter)

Types of Energy



Energy Type		Definition & Example
Kinetic Energy	Mechanical	The energy of motion of objects that are larger than atoms and molecules. Any object that is moving has mechanical KE
	Radiant	The energy of electromagnetic waves that travel or "radiate" from an energy source.
		light bulbs (radiate UV radiation, visible light and infrared radiation) the Sun radiates the entire electromagnetic spectrum (solar energy)
	Thermal	Commonly known as "Heat Energy"; Energy of random motion of the particles that make up a substance. particles of matter are always moving
	Electrical	Energy of electrons moving along a wire or other conductor. A load (any electrical appliance) changes the electrical KE into another form, such as radiant energy (light bulb)
	Sound	Energy of vibrations or disturbances of teh particles that make up matter. Travels through substances as a pressure wave. As the wave passes, particles vibrate + collide
Potential Energy	Elastic	Energy stored in a stretched or compressed object, not just an elastic band or spring.
		eg. soles of your shoes, tennis ball + racquet
	Chemical	energy stored in chemical bonds. much of human society relies on the chem PE stored in fossil fuels.
		eg firefly: CPE--> light
	Gravitational	energy due to the position of an object relative to a reference point, such as the ground.
		eg. a roller coaster at the top of a large hill has more GPE than it does at the bottom
	Nuclear	Energy stored within the nucleus of an atom. Nuclear processes can release an enormous amount of energy
		eg nuclear power plant, radioactive decay
	Electric	energy stored by a separation of positive an negative charges
		an electrochemical cell, or battery
	Magnetic	A compass needle moves beause it's magnetic and is attracted by Earth's magnetic field. If you prevent the needle from moving, it has magnetic PE, because it now has the "potential" to move.

What is Kinetic Energy?

- ☐ Kinetic Energy (KE) is the energy of an object as a result of its motion
- ☐ The name comes from the Greek word "kinesis" meaning "motion"
- ☐ Kinetic energy can be transferred (same type KE → KE) between objects when they collide, or transformed into other types of energy. (diff. kind KE → sound)

(think of billiard balls colliding)

pool cue → ball₁ → ball₂ → ball₃

KE → PE → KE → KE → KE → KE (sound, sound, sound)

Units

In science, we use SI (system international) units.

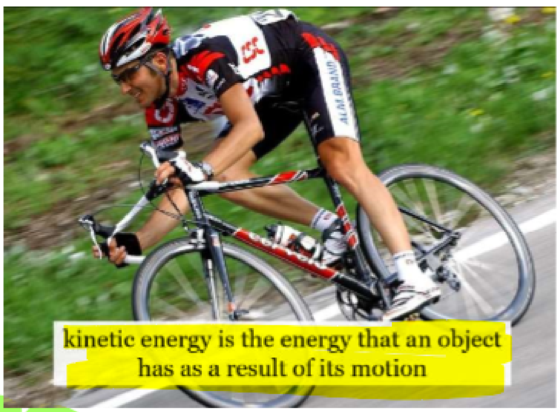
Length / distance: meters (m)

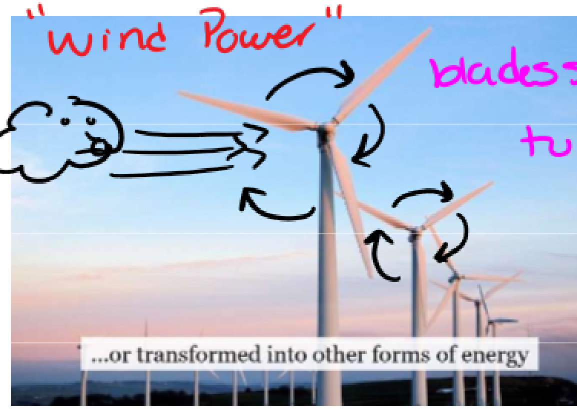
Mass: kilograms (kg)

Time: seconds (s)

100 cm = 1 m
1000 m = 1 km
1000 g = 1 kg
60 s = 1 min
60 min = 1 hr

- ☐ The SI unit of kinetic energy is the Joule, abbreviated J

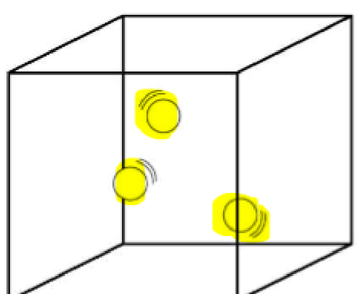




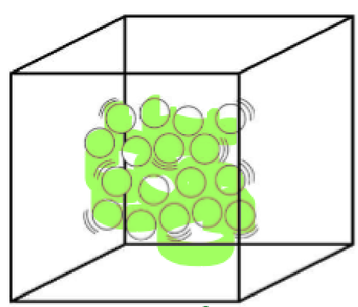
blades spin (KE)
turbines
Electric Energy

Mass

- ☐ The amount of matter in an object defines its mass
  - ☐ ***Example:*** 1 L of a gas has less mass than 1 L of a liquid because it contains fewer particles (less matter)



1 L of gas
(fewer particles = less mass)



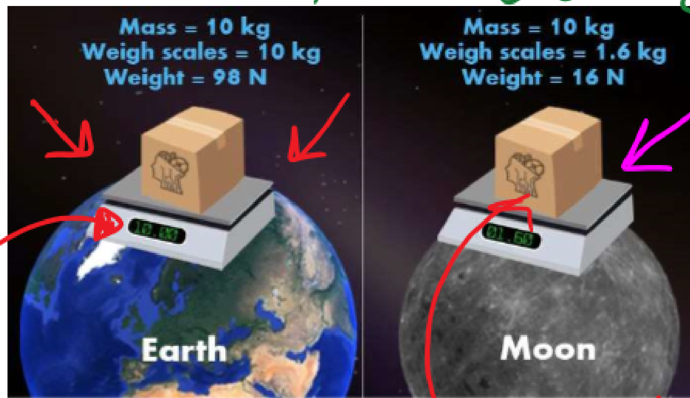
1 L of liquid.
(more particles = more mass)

- ☐ The mass of an object DOES NOT change unless something is removed or added to it.

$W = m \cdot g$

- The SI unit of mass is the Kilogram, abbreviated kg
  - BE CAREFUL! Mass is NOT the same as weight
    - Weight is a FORCE created by mass experiencing gravity

- ***Example:*** On the Moon you would have the SAME mass, but you would weigh less because the force due to gravity on the moon is less than Earth.



Force of gravity is less

weight = (10 kg)(9.8 m/s) mass = 10 kg
W = 98 N ← newtons (Force)

mass = 10 kg
weight = (10 kg)(1.6 m/s)
W = 16 N

Masses in Motion

- Objects in motion will stay in motion until acted upon by an another force, this is called "Inertia" ⇐ Newton's 1st Law
  - The greater the mass, more force is required to change its motion
- ***Example:*** it is easy to catch a feather with a tiny mass, but very difficult to catch a piano with a much higher mass
- This means that in order to make an object move, we need to APPLY a force to it

- The WORK that we do to move the object is transformed into (changed into) Kinetic Energy inside the moving object
- This means that KE is determined by the mass of the object and its velocity

Work = Force × dist.

→ related to force and work

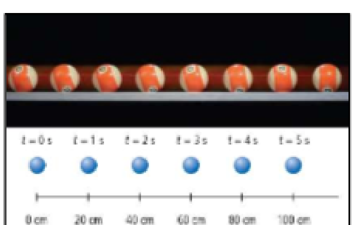
→ (like speed... but it has a specific direction)

Velocity

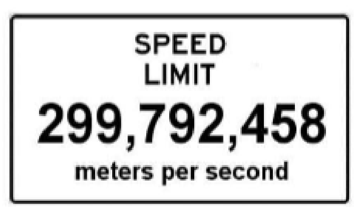
- All objects have a position relative to other objects
- When objects change their position, they have a velocity
  - The more their position changes every second, the greater their velocity

distance in a certain direction → (Δ position)

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$



billiard ball moving with constant velocity



What has the fastest velocity in the universe?
Light = 3.0×10^8 m/s

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{\vec{d}_f - \vec{d}_i}{t_f - t_i}$$

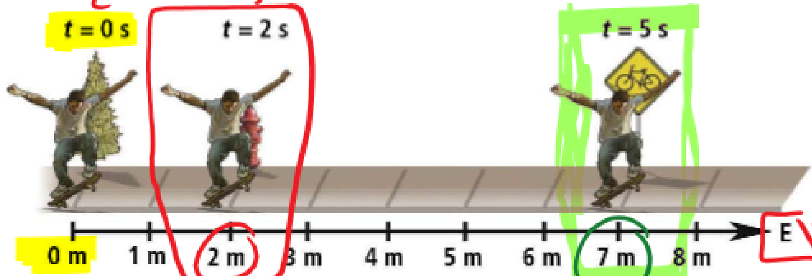
f: final
i: initial

"→" means: vector = has direction

Th

☐ The SI units of velocity are meters per second, abbreviated m/s $\frac{m}{s} = \frac{\Delta \vec{d}}{\Delta t}$

PRACTICE 1. Determine the skateboarder's velocity during the time intervals below.



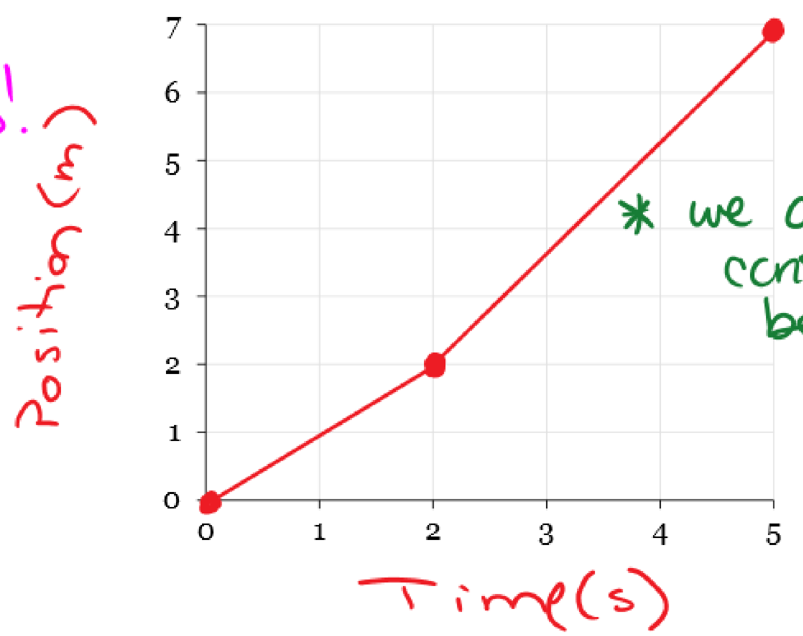
Skateboarder's Velocity from Time 0-2s:	Skateboarder's Velocity from Time 2-5s:
$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{\vec{d_f} - \vec{d_i}}{t_f - t_i} = \frac{2m - 0m}{2s - 0s}$ $\vec{v} = \frac{2m}{2s} = 1 m/s$ East "Δ" = delta = "change in"	$\vec{v} = \frac{\Delta \vec{d}}{\Delta t} = \frac{7m - 2m}{5s - 2s} = \frac{5m}{3s}$ $\vec{v} = 1.\overline{66}$ m/s $\vec{v} = 1.7$ m/s East

* over 0s → 5s he is increasing his velocity (accelerating)

2. Sketch a graph of the skateboarder's position versus time. Make sure to title the graph and the axes. Use a ruler!

axis need Title + units!

Graph 1: Wicked skate-guys sick kick flip



* we are assuming constant motion between the points 0s, 2s, 5s.

Calculating Kinetic Energy

- ☐ The formula for kinetic energy is: $KE = \frac{1}{2} m v^2$ (velocity is squared (not m, or ½))

always make sure units are in this form (convert)

☐ m is the __mass__ of the object in __kg__
☐ v is the __velocity__ of the object in __m/s__
☐ KE is the __Kinetic Energy__ in __J__

Tips for Using the Formula

- ☐ Remember from math that there is a correct order of operations (__BEDMAS__) (brackets, exponents, ÷ × + −)
  - ☐ This means we need to:
    1. __square the velocity (v^2)__
    2. __multiply__ the numbers

Reminders for Solving Calculations

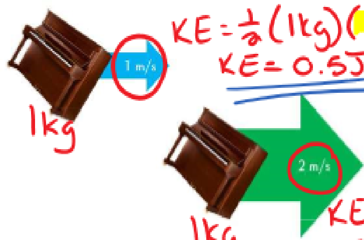
1. Follow a three-step method: 1) formula, 2) substitute values into brackets and perform calculations, and 3) write out the final answer (put a box or underline/circle)
2. Remember that for full marks you need to show your work and your answer must have __UNITS__
3. The number of significant figures in your answer is determined by the number with the __LEAST__ amount of significant figures in your calculations (LD − ½ no units)
4. Watch out for signs (+/−)!

LD $(14.0\text{ m/s}) \times (2.1\text{ kg}) = \frac{29.4}{2} = 14.7$ (3 s.f., 2 s.f. lowest, 3 s.f.) * answer must have 2 s.f. options: ① 15 ← 2 s.f. ② 1.47×10^1 (1.5×10^1) ← 2 s.f. } Scientific Notation

Practice: A 1,200 kg car is travelling at 28.5 m/s, what is its kinetic energy?	**Practice**: What is the KE of a baseball with mass 0.152 kg thrown at 32 m/s?
$KE = \frac{1}{2} \cdot m \cdot v^2$ $KE = (0.5) \cdot (1200\text{ kg}) \cdot (28.5\text{ m/s})^2$ (2 sf, 2 sf, 3 sf) $KE = (0.5)(1200\text{ kg})(812.25\text{ m/s})$ multiply $KE = 487\ 350\text{ J}$ move decimal 5 places left $KE = 4.87350 \times 10^5\text{ J}$ round to 2 sf $= 4.9 \times 10^5\text{ J}$	KE = ? m = 0.152 kg v = 32 m/s $KE = \frac{1}{2} \cdot m \cdot v^2$ $KE = (0.5)(0.152\text{ kg})(32\text{ m/s})^2$ (2 sf, 3 sf, 2 sf) $KE = (0.5)(0.152\text{ kg})(1024)$ $KE = 77.824$ move decimal 1 place $KE = 78\text{ J}$ ($7.8 \times 10^1\text{ J}$)

What Does the Formula Mean?

- ☐ Remember that the kinetic energy of an object is the result of the force applied to it in order to put it in MOTION (or to change its motion)
- ☐ The amount of force required to move an object depends on its mass, and the velocity of the object, and this is why the formula includes mass and velocity ⇒ $KE = \frac{1}{2} m \cdot v^2$
- ☐ Notice that the KE of an object depends on its velocity squared (the number multiplied by itself)
  - ☐ This means that an object travelling a 2 m/s has 4 times the kinetic energy of an object travelling at 1 m/s (because it is double the velocity)



1kg: $KE = \frac{1}{2}(1kg)(1m/s)^2$, $KE = 0.5J$

velocity ×2

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

Other Versions of the Same Formula

- ☐ The formula can be changed around to solve for mass or velocity like this:

$V = \sqrt{\left(\frac{KE}{\frac{1}{2}m}\right)}$	$m = \frac{KE}{\frac{1}{2}v^2}$
With this velocity equation, you will need to solve everything inside the square root (KE divided by half the mass) before you find the root	With this mass equation, don't forget to square the velocity first then multiply by $\frac{1}{2}$

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

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

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

- ☐ You will ALWAYS have ~~these~~ this formulas given to you (they are on your data page) → $KE = \frac{1}{2}mv^2$

Practice: A 46 kg cheetah has a kinetic energy of 15,500 J, how fast is it running?	**Practice**: What is the mass of a peregrine falcon flying at 88.9 m/s with a kinetic energy of 1780 J?
m = 46 kg, KE = 15,500 J, V = ? } List your knowns! $V = \sqrt{\frac{KE}{\frac{1}{2}m}}$ $= \sqrt{\left(\frac{15{,}500}{\frac{1}{2} \cdot 46}\right)}$ solve (inside) first.	m = ?, V = 88.9 m/s, KE = 1780 J (* 3 s.f.) $m = \frac{KE}{\frac{1}{2}(v^2)} = \frac{(1780J)}{\frac{1}{2}(88.9m/s)^2}$ ← square velocity. $= \frac{(1780)}{\frac{1}{2}(7903.21)}$ ← multiply by $\frac{1}{2}$

$= 15500 \div (1 \div 2 \times 46) = 673.913\ldots$

$= \sqrt{673.913\ldots}$

$V = 25.9598$ m/s (2 s.f.)

$V = 26$ m/s

$= \frac{(1780)}{3951.605}$

$m = 0.45044988$ kg

$m = 0.450$ kg

Summary of KINETIC ENERGY

Kinetic energy (E_k) is the energy of motion, which may be in any direction (like vertical or horizontal), or spinning motion. To calculate the E_k of a moving object, use the following formula:

$$E_k = ½ \text{ mass} \times \text{velocity}^2 \quad \text{or} \quad E_k = ½ mv^2$$

Steps for solving energy problems:

1. Diagram. what variables do you have? what is unknown?
2. Choose the version of KE formula you need.
3. Substitute in values, and solve using correct order of operations (BEDMAS)

Where:

Mass (m) is measured in kilograms (kg)
Velocity (v) is measured in meters per second (m/s)
E_k is measured in joules (J)

Note: To earn full marks when solving science word problems, you must **Show your work:**

1. State the unknown value. (What are you asked to find?)
2. List the information given in the problem (all the known values)
3. Identify a formula that may help you solve it.
4. Manipulate the formula so that the unknown is on the left side.
5. Substitute in the known values.
6. Calculate the answer. (Yes, now you may pick up your calculator)
7. State your answer with the correct units

Example Problem:

Roger Federer serves a tennis ball with a velocity of 35.0 m/s. If the ball has a mass of 0.150 kg, what is the kinetic energy (E_k) of the ball?

Known Values:

m = 0.150 kg,
v = 35.0 m/s

Formula: $E_k = ½ mv^2$

$= 0.5 \times 0.150 \times 35.0^2$
$= 0.5 \times 0.150 \times 1225$
$= 91.875$ (not rounded)
$= 91.9$ J (rounded, with units)

Assignment #1: Complete the following worksheet in the space provided below

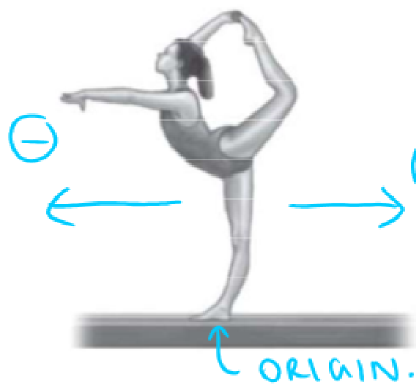
Science 10 – Physics

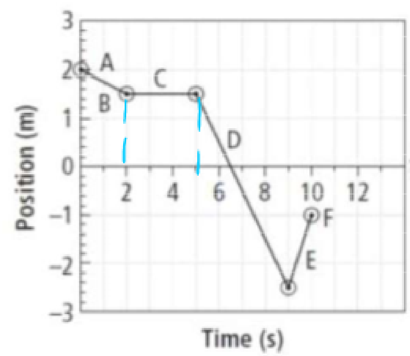
Name: KEY
Date: ______________

4.1 Worksheet

Part 1 – Position vs. Time Graphs. *Hint: for all questions, moving to the right/east is positive (+) and moving to the left/west is negative (-).*

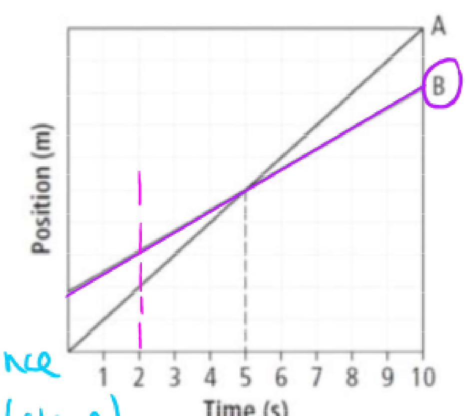
1. Use the following position-time graph showing the motion of a gymnast on a balance beam to match each descriptor below with the corresponding part of the graph. Each part of the graph may be used as often as necessary. Assume the centre of the balance beam is the reference point (origin).





C a) She stands still for 3 s.
E b) She moves even faster to the right for 1 s.
B c) She moves very slowly to the left for 2 s.
D d) She moves more quickly to the left for 4 s.
F e) She ends up 1 m left of the centre of the balance beam.
A f) She starts 2 m to the right of the centre of the balance beam.

2. Use the following position-time graph, showing the motion of two runners, to answer the questions below.



a) What does the y-intercept represent?

The position that the runner starts

b) Do the runners start at the same place?

NO : Runner B starts further ahead

c) At about 2 s, which runner is running faster? How can you tell?

At 2 s, Runner A is running faster, since their position is changing more quickly (slope)

d) What occurs at 5 s?

Both runners are at the same position

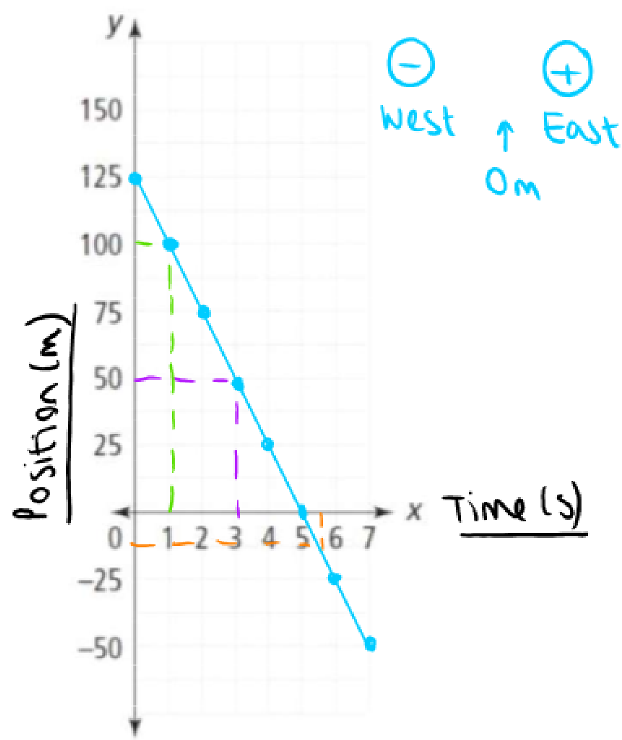
e) At 10 s, which runner is ahead?

Runner A

3. Use the following data table, showing a car's recorded positions over 7 seconds, to answer the questions below. Assume 0 m is the reference point.

a) Label the x-axis with Time (s) and the y-axis with Position (m). Use the grid to plot the data points from the data table. Draw a best-fit line through the points.

Time (s)	Position (m)
0	125
1	100
2	75
3	50
4	25
5	0
6	−25
7	−50



b) When was the car 50 m east of the reference point?

3 seconds

c) What was the car's position at 1 s?

100m east

d) Where was the car at 5.5 s?

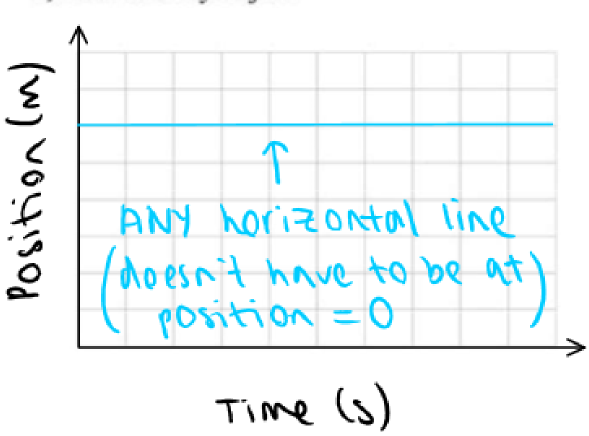
−12.5 m (12.5m west)

e) Describe the motion of the car during the time interval 2 s – 4 s.

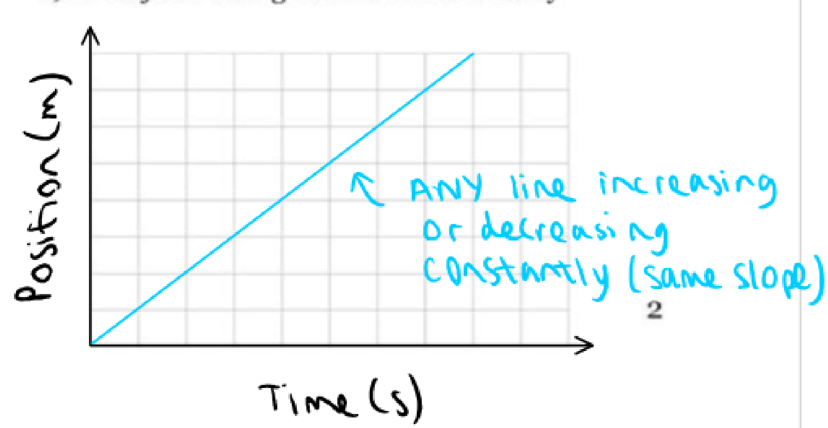
The car is moving westward towards 0m (the origin), with a constant velocity.

4. Draw a position vs. time graph to represent the following scenarios. Title and scale the axes!

a) A stationary object

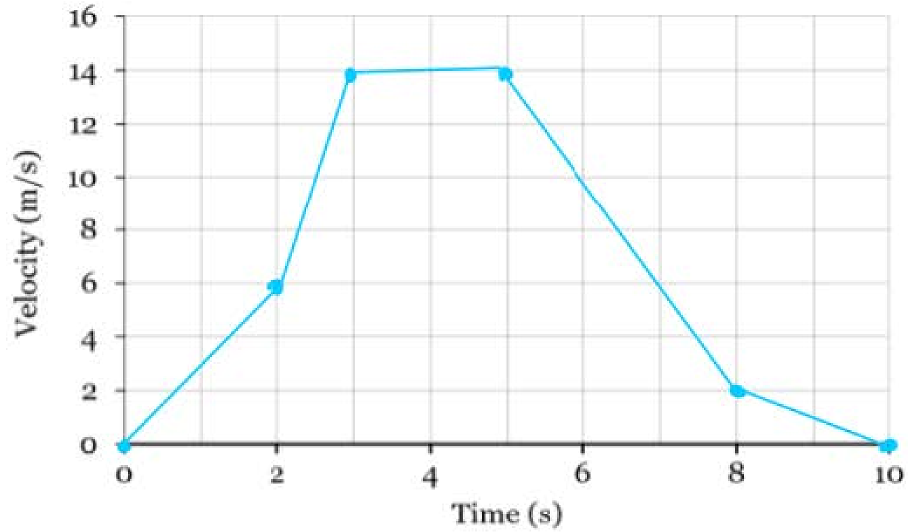


b) An object moving with constant velocity



Part 2 – Use the data table below to create a graph of velocity vs. time for a car with a mass of 852 kg. Use the graph to answer the questions below. Don't forget to show your work in the space provided.

Time (s)	Velocity (m/s)
0	0
2	6
3	14
5	14
8	2
10	0



5. What is the kinetic energy of the car at time 2 s?

v = 6 m/s (1 s.f.)
m = 852 kg (3 s.f.)
KE = ?

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(852)(6)^2$
$KE = \frac{1}{2}(852)(36)$

KE = 15336
KE = 15 336 J
(or 1.5×10^4 J)

6. What is the kinetic energy of the car between 3 s and 5 s?

v = 14 m/s (2 s.f.)
m = 852 kg (3 s.f)
KE = ?

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(852)(14)^2$
$KE = \frac{1}{2}(852)(196)$

KE = 83496
KE = 83496 J
(or 8.3×10^4 J)

7. What is the kinetic energy of the car at time 10 s?

v = 0 m/s
m = 852 kg (3 s.f)
KE = ?

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(852)(0)^2$
KE = 0 J

Part 3 –Word Problems

8. A girl is riding her bike at a velocity of 12 m/s. She weighs 55 kg and her bike weighs 22 kg. What is the kinetic energy of the girl and her bike?

$v = 12$ m/s (2 sf)
$m = 55\text{ kg} + 22\text{ kg}$
$= 77$ kg (2 sf)
$KE = ?$

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(77)(12)^2$
$KE = \frac{1}{2}(77)(144)$

$KE = 5544$
$KE: 5544$ J
(or 5.5×10^3 J)

9. Two objects were lifted by a machine. One object had a mass of 4 kg, and was lifted at a velocity of 2 m/s. The other had a mass of 2 kg and was lifted at a velocity of 3 m/s. Calculate which object had more kinetic energy while it was being lifted.

(1) $m = 4$ kg (1 sf)
$v = 2$ m/s (1 sf)
$KE = ?$

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(4)(2)^2$
$KE = \frac{1}{2}(4)(4)$

$KE = 8$ J

(2) $m = 2$ kg (1 sf)
$v = 3$ m/s (1 sf)
$KE = ?$

$KE = \frac{1}{2}mv^2$
$KE = \frac{1}{2}(2)(3)^2$
$KE = \frac{1}{2}(2)(9)$

$KE = 9$ J
↑
MORE KE

10. A moving dog with a mass of 34 kg has a kinetic energy of 25 J. How fast is the dog running?

$m = 34$ kg (2 sf)
$KE = 25$ J (2 sf)
$v = ?$

$v = \sqrt{\frac{KE}{\frac{1}{2}m}}$
$v = \sqrt{\frac{25}{\frac{1}{2}(34)}}$

$v = \sqrt{\frac{25}{17}}$
$v = \sqrt{1.47058...}$
$v = 1.21267...$

$v = 1.2$ m/s

11. A falling elephant with a velocity of 35 m/s has a kinetic energy of 1500 J. What is the mass of the elephant?

$v = 35$ m/s (2 sf)
$KE = 1500$ J (2 sf)
$m = ?$

$m = \frac{KE}{\frac{1}{2}v^2}$
$m = \frac{1500}{\frac{1}{2}(35)^2}$

$m = \frac{1500}{\frac{1}{2}(1225)}$
$m = \frac{1500}{612.5}$

$m = 2.4489...$
$m = 2.4$ kg

12. If a falling water droplet travels at 11 m/s and has a kinetic energy of 0.0096 J, what is the mass of the droplet?

$v = 11$ m/s (2 sf)

$KE = 0.0096$ J (2 sf)

$m = ?$

$m = \frac{KE}{\frac{1}{2}v^2}$ | $m = \frac{0.0096}{\frac{1}{2}(11)^2}$ | $m = \frac{0.0096}{\frac{1}{2}(121)}$ | $m = \frac{0.0096}{60.5}$

$m = 0.0001586...$

$m = 0.00016$ kg (or 1.6×10^{-4} kg)

13. A box hits the ground with 32,000 J of kinetic energy. If the box was traveling at 40.0 m/s when it hit, what must the mass of the box be?

$KE = 32000$ J (2 sf)

$v = 40.0$ m/s (3 sf)

$m = ?$

$m = \frac{KE}{\frac{1}{2}v^2}$ | $m = \frac{32000}{\frac{1}{2}(40.0)^2}$ | $m = \frac{32000}{\frac{1}{2}(1600)}$ | $m = \frac{32000}{800}$

$m = 40$

$m = 4.0\times10^1$ kg

14. Schwab is shot out of a cannon. If his mass is 68 kg and he has a kinetic energy of 706 J, how far does he travel in the first second after leaving the cannon?

$m = 68$ kg (2 sf)

$KE = 706$ J (3 sf)

$v = ?$

$v = \sqrt{\frac{KE}{\frac{1}{2}m}}$ | $v = \sqrt{\frac{706}{\frac{1}{2}(68)}}$ | $v = \sqrt{\frac{706}{34}}$ | $v = \sqrt{20.7647...}$

$v = 4.5568...$

$v = 4.6$ m/s

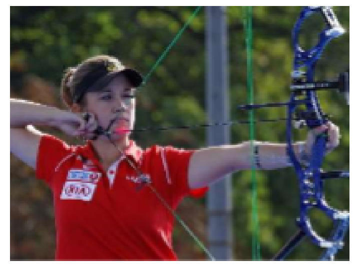
Schwab travels 4.6 m in the first second after leaving the cannon.

part b- potential energy

What is Potential Energy?

- ☐ **Potential energy** (PE) is the energy STORED inside of objects because of their position, stresses inside of the object, or their charge
- ☐ The name means that PE stored inside of an object is not useful until it is released and transformed into another type of energy (motion, heat); in other words, it is the "potential" to create other types of energy
  - ☐ ***Example:*** a stretched bow contains potential energy that is released when the archer releases the bowstring, this becomes kinetic energy in the arrow

PE → KE



- ☐ There are several kinds of PE, in Science 10 we will focus on the PE of objects in Earth's gravity
- ☐ the SI unit of potential energy is the Joule, abbreviated J

Acceleration "Let's go faster!"

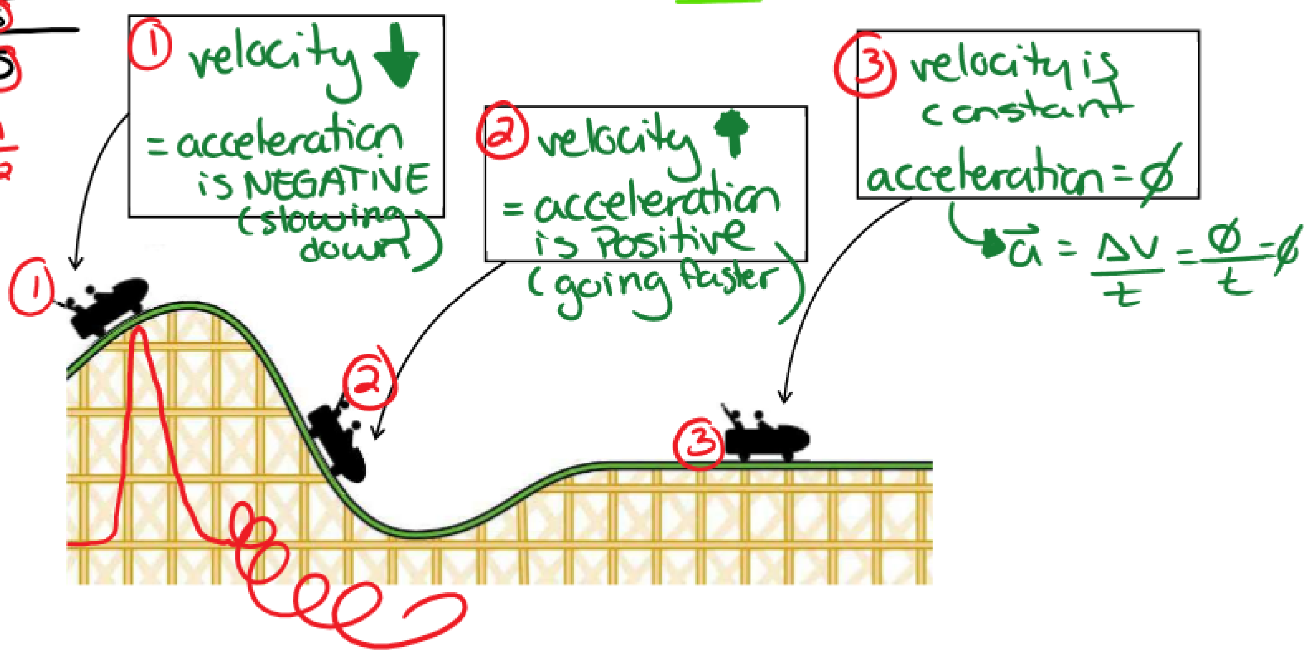
Newton's 1st Law

- ☐ Objects cannot instantly change their velocities due to inertia (which is the resistance of objects against changes in motion, remember)
- ☐ Instead their velocities must change by increasing or decreasing : change in velocity over time is called acceleration, measured in meters per second squared (m/s^2)
  - ☐ ***Example:***. as a rollercoaster climbs up its velocity decreases, when it rides down its velocity increases, and when it coasts its velocity is constant

$$\vec{a} = \frac{\Delta \vec{v}}{t}$$

$$\vec{a} = \frac{m/s}{s} = \frac{m}{s \cdot s}$$

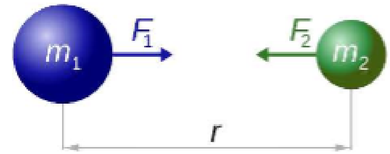
$$\vec{a} = \frac{m}{s^2}$$



Mass and Gravity

weight = is a force
$W = m \cdot g$

- ☐ Remember that mass is the amount of matter in an object
- ☐ All objects with mass are attracted towards each other by a force known as gravity, the larger the masses the MORE that they attract each other
- ☐ Gravity is the only force we are aware of which acts over the entire Universe: we are attracted to ALL of the masses in the universe and they are attracted to us.



- ☐ Gravity's attraction becomes weaker the further two objects are apart, so we really only experience one strong gravitational attraction towards the nearest and largest mass (The Earth)

Σobject

Acceleration of Gravity

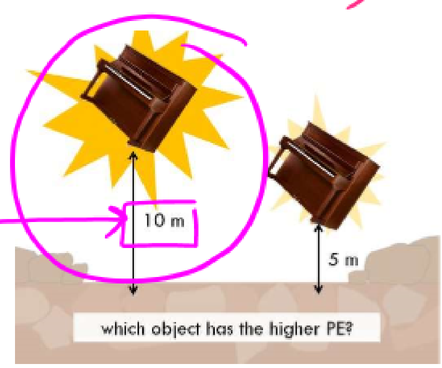
- ☐ All objects with mass are attracted downwards toward the Earth's enormous mass by gravity (actually towards the center of the Earth)
- ☐ This causes all objects to accelerate towards the Earth, in what is known as the acceleration of gravity $(9.81 m/s^2)$
- ☐ Despite what common sense tells you, the acceleration of gravity does NOT depend on mass: all objects accelerate towards the Earth at the same rate
  - ☐ ***Example:*** if you dropped a piano and a mouse from the same height (in a complete vacuum) they would both land at the same time

Height

considered to = ∅m

- ☐ The height of an object above the Earth's surface determines how much Potential Energy there is within the object
- ☐ The greater the height above the Earth's surface, the more PE an object has because the acceleration of gravity will act on it for a Longer time and it will gain more and more kinetic energy (gains more velocity the farther it travels)
- ☐ The SI unit of height is meters, abbreviated m

greater P.E. because it has a greater height.



•same mass
•same acceleration (on Earth)

Calculating Potential Energy

- ☐ The formula for potential energy is:

$$PE = m \cdot g \cdot h$$

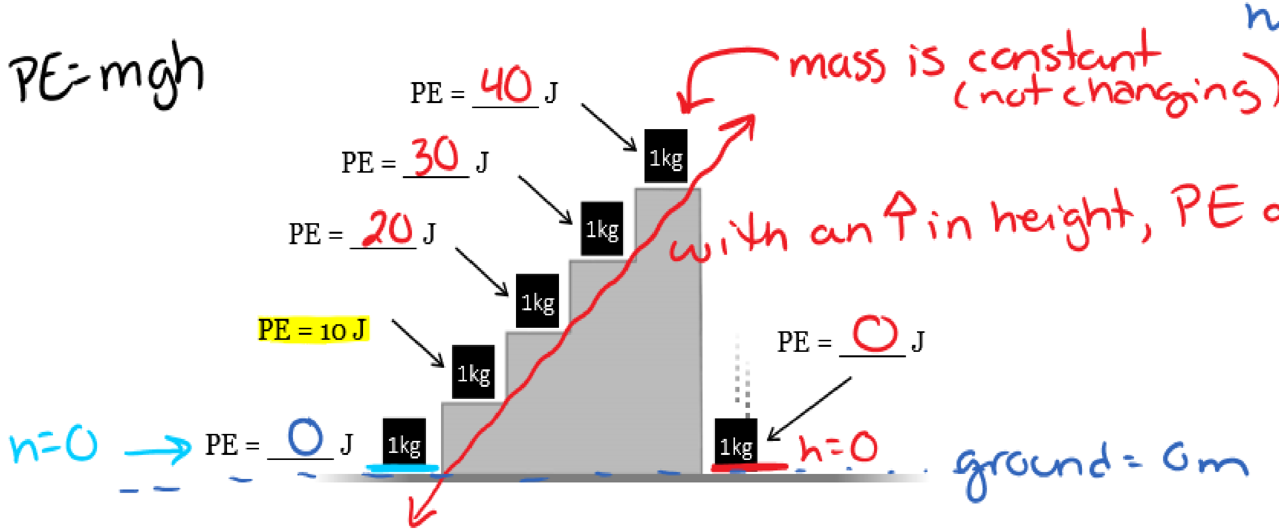
(multiply)

- ☐ m is the **mass** of the object in **kg**
- ☐ g is the **acceleration** of gravity in **m/s²**. It is ALWAYS **9.81 m/s² (on Earth)**
- ☐ h is the **height** in **m**
- ☐ PE is the **Potential Energy** in **J**

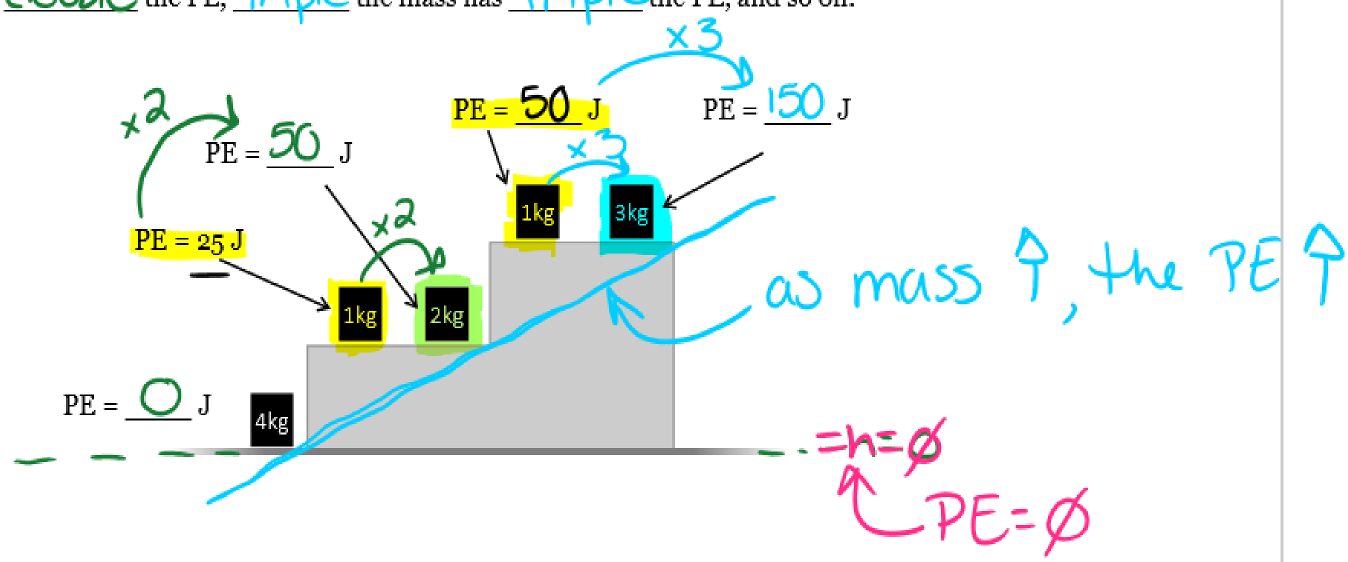
(Units) $\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{m/s}{s}$ ("change in")

What Does the Formula Mean?

- ☐ On Earth, the acceleration of gravity is a **constant** (it never changes)
- ☐ PE changes linearly with the height of the object, so an object with **double** the height has **double** the PE, **1/2** the height has **1/2** the PE, and so on:



- ☐ PE also changes linearly with the **MASS**, so an object with **double** the mass has **double** the PE, **triple** the mass has **triple** the PE, and so on:



$PE = m \cdot g \cdot h$

Tips for Using the Formula

- ☐ There is only __one operation__ in this formula (__multiplication__) so there is no order of operations to worry about
- ☐ Remember that the acceleration of gravity is always __$9.81\ m/s^2$__ on Earth, so this is not something that you need to calculate

PRACTICE

Practice: What is the potential energy of a 62 kg man when he walks a 415 m high tightrope?	**Practice**: What is the PE of a penny with mass 0.00235 kg held at 276 m on the top deck of the Eiffel Tower?
m = 62 kg; h = 415 m; g = 9.81 m/s²; PE = ? PE = mgh PE = (62)(9.81)(415) PE = 252411.3 J PE = 2.5 × 10⁵ J = 250 000 J (2 s.f.)	m = 0.00235 kg; h = 276 m; g = 9.81 m/s²; PE = ? PE = mgh PE = (0.00235)(9.81)(276) PE = 6.3627666 J (3 s.f.) PE = 6.36 J

Other Versions of the Same Formula

- ☐ The formula can be changed around to solve for mass or height like this:

$m = \frac{PE}{g \cdot h}$	$h = \frac{PE}{m \cdot g}$

- ☐ For both of these formulas you will find it easiest to solve the __denominator__ (bottom of the fraction) first, and then __divide__ the PE by that result

calc. in 1 step: $m = \frac{(PE)}{(g)(h)}$

PRACTICE

Practice: A 6.21 kg vulture has a potential energy of 4.4 x 10⁵ J, how high is it soaring?	**Practice**: What is the mass of a skydiver waiting to jump at 3800 m with a potential energy of 3.26 x 10⁶ J?
m = 6.21 kg; g = 9.81 m/s²; h = ?; PE = 4.4 × 10⁵ J $h = \frac{PE}{mg}$ $h = \frac{(4.4 \times 10^5 J)}{(6.21 \times 9.81)}$ h = 7222.575..... h = 7200 m or 7.2 × 10³ m	m = ?; h = 3800 m; g = 9.81 m/s²; PE = 3.26 × 10⁶ J $m = \frac{PE}{hg}$ $m = \frac{(3.26 \times 10^6)}{(3800 \times 9.81)}$ m = 87.45........ (2 s.f.) m = 87 kg or 8.7 × 10¹ kg

on calc: 4.4 [EE] 5 = 4.4 × 10⁵ = 440 000 ("means × 10"; EE / ×10ⁿ / 10ˣ)

SUMMARY of POTENTIAL ENERGY PROBLEMS

Gravitational potential energy (**E_p**) is the energy of a mass due to its position in a gravitational force field. For example: when you hike up a hill, you are moving your mass away from the center of the Earth. You are lifting your mass up inside Earth's gravitational force field, and that means that you could fall back down in the future. Because your mass now has the ability to make things move (you falling) , you have more potential energy. You gain **E_p** as you climb.

To calculate the **E_p** of an object (relative to a place where h = 0), use the following formula:

$$E_p = mgh$$

Where:

Mass (m) is measured in kilograms (kg)
Gravitational field strength (g) is measured in newtons per kilogram (N/kg)
Height (h) in measured in metres (m) [note: height is measured from some place where we have decided the height is zero]
E_p is measured in joules (J)

Note: To earn full marks when solving science word problems, you must **Show your work.** Please refer to the problem solving steps given in class. Don't forget to convert units into the proper base units before calculating.

Example Problem:

A ball of mass 1.30 kg is thrown upward and reaches a height of 24.0 m above the ground. What is the potential energy (**E_p**) of the ball relative to the ground?
Known Values:

m = 1.30 kg
h = 24.0 m
g = 9.80 N/kg (on Earth)
[we can assume we are on Earth unless otherwise mentioned]

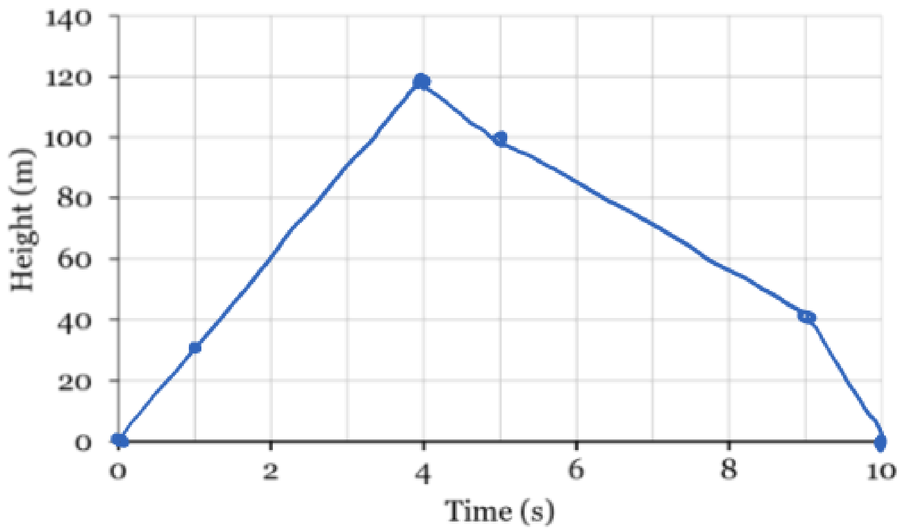
Formula: **E_p** = mgh
= (1.30)(9.80)(24.0)
= 305.76 (not rounded)
= 306 J (rounded, with units)

Homework

Assignment #2: Complete the following worksheet in the space provided below

Part 1 – Use the data table below to create a graph of height vs. time for a model rocket with a mass of 2.45 kg. Use the graph to answer the questions below. Don't forget to show your work in the space provided.

Time (s)	Height (m)
0	0
1	30.00
4	120.0
7	100.0
9	40.00
10	0



1. What is the potential energy of the rocket at time 4 s?

m = 2.45 kg (3 sf)
g = 9.81 m/s² (3 sf)
h = 120.0 m (4 sf)

PE = mgh
= (2.45)(9.81)(120.0)
= 2884.14

PE = 2880 J
(or 2.88×10^3 J)

2. What is the potential energy of the rocket at time 7 s?

m = 2.45 kg (3 sf)
g = 9.81 m/s² (3 sf)
h = 100.0 m (4 sf)

PE = mgh
= (2.45)(9.81)(100.0)
= 2403.45
= 2.40×10^3 J

Part 2 –Word problems

3. A box with a mass of 30 kg is sitting on a shelf 3 m above the ground. What is its potential energy?

m = 30 kg (1 sf)
g = 9.81 m/s² (3 sf)
h = 3 m (1 sf)

PE = mgh
= (30)(9.81)(3)
= 882.9

PE = 900 J

4. A rubber ball has 150 J of potential energy and a mass of 0.254 kg. How high is the ball off the ground?

PE = 150 J (2 sf)
m = 0.254 kg (3 sf)
g = 9.81 m/s² (3 sf)
h = ?

h = PE / mg
= 150 / (0.254)(9.81)

h = 60.1988...
h = 6.0×10^1 m

5. A pole vaulter at the top of her jump is 5.90 m above the ground. If her potential energy is 4942 J, what is her mass?

h = 5.90 m (3 sf)
PE = 4942 J (4 sf)
g = 9.81 m/s² (3 sf)
m = ?

$m = \frac{PE}{gh} = \frac{4942}{(9.81)(5.90)}$

m = 85.385...
m = 85.4 kg

6. In 1993, Cuban athlete Javier Sotomayor set the world record for high jump. If his potential energy at the top of the jump was 1970 J, and his mass was 82.0 kg, how high did he jump?

PE = 1970 J (3 sf)
m = 82.0 kg (3 sf)
g = 9.81 m/s² (3 sf)
h = ?

$h = \frac{PE}{mg} = \frac{1970}{(82.0)(9.81)}$

h = 2.4489...
h = 2.45 m

7. A can of spinach with mass of 0.14 kg loses 28 J of potential energy falling off of a shelf. How high was the can before it fell?

m = 0.14 kg (2 sf)
PE = 28 J (2 sf)
g = 9.81 m/s² (3 sf)
h = ?

$h = \frac{PE}{mg} = \frac{28}{(0.14)(9.8\ )}$

h = 20.387...
h = 2.0×10^1 m

8. In a lab activity, a group of students measures the velocity of a model car at 2.5 m/s at the bottom of a ramp. The car's starting position at the top of the ramp is 1.00 m above the floor.

a. If the model car had 2.35 J of potential energy at the top of the ramp, what is its mass?

PE = 2.35 J (3 sf)
h = 1.00 m (3 sf)
g = 9.81 m/s² (3 sf)
m = ?

$m = \frac{PE}{gh}$
$m = \frac{2.35}{(9.81)(1.00)}$

m = 0.2395..
m = 0.240 kg

b. What is the kinetic energy of the car at the bottom of the ramp?

KE = ?
m = 0.2397... (2 sf)
v = 2.5 m/s (2 sf)

$KE = \frac{1}{2} mv^2$
$= \frac{1}{2}(0.2397...)(2.5)^2$

KE = 0.74936...
KE ≈ 0.75 J

c. The energy of the moving car can be converted to heat due to the friction of the wheels on the ramp. The difference between the potential energy of the car and its kinetic energy at the bottom of the hill equals the energy lost due to friction. How much energy is lost due as heat for the group's car?

Energy Lost = 2.40 − 0.75
= 1.6 J

part c- scientific notation

<u>Regular Notation (RN)-</u> The standard way that we write our numbers.

Ex: Two Hundred and Eight Million is written – 280,000,000.

<u>Scientific Notation (SN)</u>- A shorthanded way of writing really large or really small numbers. In SN a number is written as the *product* of two factors.

Ex: 280,000,000 can be written in scientific notation as $2.8 \, x \, 10^8$.

$$2.8 \times 10^8$$

First Factor
A number that is between 1 and 10
It may or may not be a decimal.

Second Factor
Is always a power of 10.
The power of the exponent tells you how many places to move the decimal point.
The sign of the exponent tells you which direction to move it.

Regular Notation → Scientific Notation

If Decimal is moved left
Exponent will be positive

If Decimal is moved to Right
Exponent will be negative

Regular Notation	How to Change	Scientific Notation
420,000.	Move the decimal after the 4 and before the 2 That is 5 places to the left Multiply 4.2 by 10 to the 5th power	$4.2 \, x \, 10^5$
735,000,000.	Move the decimal after the 7 and before the 3 That is 8 places to the left Multiply 7.35 by 10 to the 8th power	$7.35 \, x \, 10^8$
.00897	Move the decimal after the 8 and before the 9 That is 3 places to the right Multiply 8.97 by 10 to the -3rd power	$8.97 \, x \, 10^{-3}$
.0000014	Move the decimal after the 1 and before the 4 That is 6 places to the right Multiply 1.4 by 10 to the -6th power	$1.4 \, x \, 10^{-6}$

Scientific Notation → Regular Notation

If exponent is Negative Move decimal to the Left Add zeros where needed.	If exponent is Positive Move decimal to the Right Add zeros where needed.

Scientific Notation	How to Change	Regular Notation
7.5×10^5	Exponent is positive 5. Move the decimal 5 places to the right	750,000.
3.8×10^4	Exponent is positive 4. Move the decimal 4 places to the right	38,000.
4.2×10^{-3}	Exponent is Negative 3. Move the decimal 3 places to the left.	.0042
7.51×10^{-5}	Exponent is Negative 5. Move the decimal 5 places to the left.	.0000751

Change from Regular Notation to Scientific Notation:		Change from Scientific Notation to Regular Notation:	
1.) 45,000	4.5×10^4	*1.)* 9.46×10^{-6}	.00000946
2.) 9,000,000	9×10^6	*2.)* 2.5×10^3	2500
3.) 7,450	7.45×10^3	*3.)* 1.6×10^{-2}	.016
4.) .0000378	3.78×10^{-7}	*4.)* 4×10^5	400,000
5.) .05	5×10^{-2}	*5.)* 7.25×10^4	72,500
6.) 670,400	6.704×10^5	*6.)* 3.2456×10^{-8}	.000000032456
7.) 7,070,000,000	7.070×10^9	*7.)* 6×10^{-3}	.006
8.) .00000089	8.9×10^{-7}	*8.)* 9.7×10^7	97,000,000
9.) .18900097	1.8900097×10^{-1}	*9.)* 5.06×10^{-4}	.000506
10.) 570,000,000	5.7×10^8	*10.)* 8×10^2	800

Homework

Assignment #3: Complete the following worksheet in the space provided below

CONVERT EACH NUMBER IN SCIENTIFIC NOTATION TO REGULAR NOTATION

If exponent is Negative	If exponent is Positive
Move decimal to the Left	Move decimal to the Right
Add zeros where needed.	Add zeros where needed.

1. 2.47×10^{-3}	0.0247	7. 4.5×10^{-5}	0.000045
2. 9.3×10^{7}	93,000,000	8. 5.5×10^{5}	550,000
3. 8.5×10^{-5}	0.000085	9. 6.3×10^{-1}	0.63
4. 2.07×10^{6}	2,070,000	10. 1.98×10^{4}	19,800
5. 7×10^{-8}	0.00000007	11. 2.4×10^{-5}	0.000024
6. 3×10^{2}	300	12. 9.2×10^{7}	92,000,000

CONVERT EACH NUMBER IN REGULAR NOTATION TO SCIENTIFIC NOTATION

If Decimal is moved left	If Decimal is moved to Right
Exponent will be positive	Exponent will be negative

1. 0.0024	2.4×10^{-3}	7. 0.0000035	3.5×10^{-6}
2. 5,604	5.604×10^{3}	8. 45,995	4.5995×10^{4}
3. 693.75	6.9375×10^{2}	9. 754.256	7.54256×10^{2}
4. 0.087	8.7×10^{2}	10. 0.0088	8.8×10^{-3}
5. 8,550,000	8.550×10^{-6}	11. 18.907	1.8×10^{1}
6. 12,000,000	1.2×10^{7}	12. 25,009	2.5009×10^{4}