Pre-Comp Study Guide- 7th grade Physics

This is a guide for everything covered this year so far in class. ****You don't need to memorize this packet**** The Review Question Packet follows along with this. Those questions are how and what you need to know. You will still want to have your notes and book with you to answer the questions. I wrote this based on the fact that you have already seen all of this.

I. Measurements and Units

Units

Unit- A quantity chosen as a standard of a measurement with which other quantities of the same measurement can be compared to. Scientists use units to describe quantitative measurements. Units give us a way to compare measurements objectively.

The 3 systems of measurements you need to know:

English- used in America

Metric- used pretty much every else. **The only difference between S.I. and metric is the measurement of temperature**. In metric, the unit of temperature is degrees Celsius (˚C), in SI units, the unit of temperature is Kelvin.

S.I.- International Standard Units. Used by scientists. The units we use in this class generally.

List of SI and English units you need to know:

Measurement	SI Unit	SI Symbol	English Unit	English Symbol
Time	second	s.	second	s.

Temperature	Kelvin	K	Fahrenheit	°F
Length	Meter	m.	Foot	ft.
Volume (solid)	Cubic Meter	m^3	Cubic Foot	ft^3
Weight (Force)	Newton	N.	Pounds	lb.
Mass	Kilogram	kg	Slug	sl

<u>Fundamental (or Base) Units-</u> a unit that cannot be expressed in terms of any other unit. The most basic unit.

**Fundamental units are measurements of quantities that can't be compared to anything else, that have only one unit. **

Fundamental S.I. Units you need to know-

Kilogram (kg) – measurement of mass

Second (s) – measurement of time

Meter (m) – measurement of length, width, and height

Kelvin (K) – measurement of temperature

Coulomb (C) – measurement of electric charge

Examples of combinations of fundamental units:

Velocity is measured in meters per second- m/s

Force is measured in Newtons (N) and

$$1N = 1kg \cdot m/s^2$$

Metric Prefixes

Metric prefixes are used to modify a metric or S.I. unit. They are words we put before the "base" unit that represent the power of ten we multiply the base unit by. We use them to simplify calculations and so we don't have to write out overly long numbers

Metric Prefixes and Multipliers you need to know:

Metric Prefix	Symbol	Numerical Multiplier	Exponential Multiplier (scientific notation)
Tera	T	1,000,000,000,000	10^{12}
Giga	G	1,000,000,000	10^{9}
Mega	M	1,000,000	10^{6}
Kilo	k	1000	10^{3}
Hecto	h	100	10^{2}
Deca	da	10	10^{1}
Base Unit	______________	1	10^{0}
Deci	d	0.1	10^{-1}
Centi	c	0.01	10^{-2}
Milli	m	0.001	10^{-3}
Micro	µ	0.000001	10^{-6}
Nano	n	0.000000001	10^{-9}
Pico	p	0.000000000001	10^{-12}

Unit Conversions

We need to be able to change one unit to another in order to compare measurements. We use **conversion factors** (**equations** that tell us how one unit compares to another) to find **unit multipliers** (ratios of one unit to another in the form of a fraction), and then we **multiply** the **original measurement** we were given **by** the **unit multiplier** to obtain **the original measurement in terms of the units we want.**

**** Remember: Equations are mathematical statements of equivalence. The most important thing in an equation is the equal sign. If it doesn't have an equal sign, it is not an equation****

3 steps in unit conversion:

1. **Find your conversion factor.** Find the equation that relates the units of the measurement you are given to the units you want to convert to
2. **Make your unit multiplier.** Divide each side of the conversion factor by the unit you want to get rid of i.e. the unit you are given. This leaves you with a fraction, your unit multiplier.
3. **Multiply the given measurement by the unit multiplier.** Follow the rules for multiplying fractions, and the original unit cancels out and you are left with the measurement in the units you want.

Examples

Example of converting between metric units:

54mm= ______ m

1. **Conversion factor**- when converting between metric units, the conversion factor can always be found by knowing the numerical multiplier the metric prefix is associated with.

   0.001m=1mm

2. **Unit Multiplier**- the given measurement is in units of mm, so I am going to divide each side of my conversion factor by mm and whatever factor is in from of it

$$\frac{0.001m}{1mm} = \frac{1\cancel{mm}}{1\cancel{mm}} = 1$$

** notice, the right side of my equation becomes 1, because anything divided by itself =1**

** the fraction on the left hand side will be my unit multiplier**

3. **Multiply the Unit Multiplier by the original measurement**

$$54mm\ x\ \left(\frac{0.001m}{1mm}\right) = 0.054m$$

notice, the units I want to get rid of cancel out because anything divided by itself is = 1

IMPORTANT REMINDER: when doing metric conversions between units that are larger than the base to smaller than the base unit, or vice versa, always convert to the base unit first, then to the desired unit.
For example, if I wanted to know how many cm where in 100km (100km = _____ cm), I would first convert 100km to meters (100,000m), then convert 100,000m to cm (10,000,000 cm)**

Example of converting English to Metric Units:

For this type of conversion, the conversion factor is never a multiple of ten. I will give you any conversion factors you are expected to use. I do not expect you to memorize them.

600N = _____ lb

1. **Conversion Factor**: when converting Newtons to pounds, the conversion factor is:

   1 lb = 4.45 N

2. **Unit Multiplier**: the unit I am given is N, so I am going to divide each side of my conversion factor by Newtons and whatever factor is in front of it

$$\frac{1lb}{4.45N} = \frac{4.45N}{4.45N} = 1$$

** notice the right side of the equation cancels to 1 again**

3. **Multiply the Unit Multiplier by the original (given) measurement**

$$600N\ x\ \left(\frac{1lb}{4.45N}\right) = 134.8\ lb$$

the units of Newtons on the left side canceled out and left me with units of pounds

A more complicated example: Converting m/s to mi/hr

343 m/s = ______ mi/hr

Even though this seems more complicated, it is still doing the same thing as the easier ones, only twice. In this, we have to convert meters to miles, and seconds to hours

Meters to Miles-

1. **Conversion Factor**:

   1 mile = 1609 meters

2. **Unit Multiplier:**

   Meters and Miles are both in the numerator of the original units, so the unit I want to end up with (miles) needs to be in the numerator of this conversion factor

$$\frac{1mi}{1609m} = \frac{1609\cancel{m}}{\cancel{1609m}} = 1$$

Seconds to Hours:

1. **Conversion factor**

   3600s = 1hr

2. **Unit Multiplier:**

   The units of hours and seconds are in the denominator of our original unit, so the unit I want to end up with (hours) needs to be in the denominator of my unit multiplier

$$\frac{3600s}{1hr} = \frac{1\ \cancel{hr}}{\cancel{1hr}} = 1$$

3. **Multiply the Unit Multipliers by the Original Measurement:**

$$343\ {}^{m}/_{s}\ \text{x}\ \left(\frac{1mi}{1609m}\right) \text{x}\ \left(\frac{3600s}{1hr}\right) = \left(\frac{343\ \text{x}\ 3600}{1609}\right)\frac{mi}{hr} = 767.4\ mi/hr$$

A note on conversion factors

I don't expect anyone to memorize English to Metric conversion factors, but things you need to know, common knowledge taught in previous grades

a. 1 foot = 12 inches
b. 1 yard = 3 feet
c. 1 mile = 5280 feet
d. 1 pound = 16 ounces
e. 1 hour = 60 mins = 3600s
f. 1 minute = 60 seconds
g. 1 day = 24 hours
h. 1 year = 365 days

II. Motion

In order to measure motion, you need a reference point…

Reference Point- An object at rest that is used to judge the motion of another object.

Motion- when an object changes position with respect to a reference point.

Position (x)- the point in space occupied by an object

Speed- the rate at which an object moves from one place to another with respect to a reference point.

Speed Equation:

$$Speed = \frac{distance}{time}$$

Unit of speed: m/s- S.I. or mi/hr- English

Average Speed- how fast a total distance is covered

Avg. Speed Equation

$$Average\ speed = \frac{Total\ Distance}{Total\ Time}$$

Example: Zakk walks 10m to the ice cream man in 20s, stays there for 45s to buy an ice cream cone, then walks back to his house 10m away in 30s. What was Zakk's average speed?

The total distance zakk walked was T.D.= 10m +10m = 20m

The total time his trip took was T.T. = 20s + 45s + 30s = 95s

$$Average\ Speed = \frac{T.D.}{T.T.} = \frac{20m}{95s} = 0.21\ {}^{m}/_{s}$$

Instantaneous Speed: An object's speed at one instant

Instantaneous speed is what a car's speedometer shows you. Instantaneous speed can vary a lot in any given trip.

Constant Speed: when the instantaneous speed of an object is not changing.

Only when an object has a constant speed does the instantaneous speed = average speed

<u>Vectors vs. Scalars</u>

There are 2 types of quantities we deal with in physics: vectors and scalars

Vector- a quantity that includes both magnitude (size, amount) and direction

Scalar- a quantity that only has a magnitude

Vector Quantities we discussed this year so far:

a. Displacement
b. Velocity
c. Acceleration

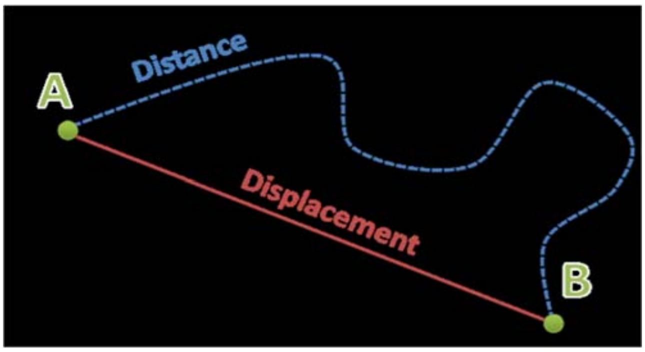
d. Force

Scalar Quantities we discussed so far this year:

a. Time
b. Mass
c. Temperature
d. Distance
e. Speed
f. Work
g. Energy
h. Power

When a scalar quantity is negative, that means the actual value is below zero (i.e. -10˚F means 10 degrees below 0˚F). Negative and positive values of Vectors only indicate direction of the vector (i.e. a velocity of -10 m/s in the x-direction means the velocity is pointed to the left, or west)

Distance vs. Displacement



Distance (d)- How much ground an object covers during its trip, measured in meters (m)

Displacement (Δx)- how far away an object is from its starting point, measured in meters (m)

** Remember the symbol Δ (the Greek letter delta) stands for "change in", or final minus initial. Whenever this symbol is in front of a variable, it means subtract the initial value of that variable from its final value**

Example of calculating distance and displacement:

Lilly walks 10m east of her house then walks back 5m west. Find her distance traveled and displacement

Distance:

This will just be the sum of all ground she covered

d = 10m +5m = 15m

Displacement:

To find Lilly's displacement, we need to think about where she actually ended up compared to her starting point. Displacement is a vector, so **when we are calculating a resultant vector (the combination of 2 or more vectors), no matter what the vector is, the method is: when vectors are in the same direction, we add them. When vectors are in opposite direction, we subtract them, and the resultant vector is in the direction of the larger quantity.**

Lilly travelled 10m east and 5m west, so

Δx = 10m east – 5m west = 5m east

When figuring out displacement, it is always helpful to draw a picture with arrows indicating the direction and magnitude of the individual displacements to help get a visual representation of where your final position is with respect to the initial

<u>Velocity vs. Speed</u>

Velocity: the speed of an object and the direction the object is moving in.

objects can be travelling at the same speed, but their velocities can be different if they are going in different directions

<u>Average Velocity</u> Equation

$$v = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

in general, and unless otherwise stated, **you can assume that t_i=0 because we can pick the start point to start at whatever time we want, 0 makes math easier**

Example of calculating avg. speed and avg. velocity:

An airplane flies 2000km west in 2.5 hours, then turns around and flies back 2000km east in 2.2 hours. Find the airplanes average speed and average velocity in km/hr

Average Speed:

Total distance T.D = 2000km + 2000km = 4000km

Total time T.T. = 2.5 hours + 2.2 hours = 4.7 hours

$$Avg.Speed = \frac{T.D.}{T.T.} = \frac{4000km}{4.7hr} = 851\ km/hr$$

Average Velocity:

Δt will be the same because we assume the start time, t_i, to be 0 and the end time, t_f, to be the time the airplane completed its trip.

$\Delta t = t_f - t_i$ = 4.7hrs – 0 hrs = 4.7 hours

The displacement will be

Δx = 2000km west – 2000km east = 0km

So, the average velocity

$$v = \frac{\Delta x}{\Delta t} = \frac{0km}{4.7\ hrs} = 0\ km/hr$$

** average velocity and displacement are always zero when the trip starts and ends at the same position**

Resultant Velocity (v_r): When we combine 2 or more velocities

Remember, velocity is a vector. So **when we are calculating a resultant vector (the combination of 2 or more vectors), no matter what the vector is, the method is: when vectors are in the same direction, we add them. When vectors are in opposite direction, we subtract them, and the resultant vector is in the direction of the larger quantity**

Example:

A hang-glider has a velocity of 40 m/s down when a gust of wind with a velocity of 10m/s up hits him. What is his resultant velocity?

v_1= 40 m/s down

v_2= 10 m/s up

Because they are in opposite directions, the two are subtracted

$v_r = v_1 - v_2$ = 40 m/s down – 10 m/s up = 30 m/s down

Acceleration

Acceleration (m/s^2): the rate of change of velocity. How fast an object is speeding up, slowing down, or changing direction. **Acceleration is a vector**!! It has direction and magnitude.

The 3 ways an object can accelerate:

1. Speed up
2. Slow down
3. Change direction

Equation for acceleration:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

where Δv is the change in velocity and Δt is the time it took for the velocity to change

Example:

A car is at a stoplight and when the light turns green, the car reaches a velocity of 20 m/s east in 10s. What was the acceleration of the car?

What do we **Know**? **(remember K.W.E.S.)**

The car was initially stopped, so v_i = 0. The car reached a velocity of 20 m/s, so v_f=20 m/s east, and it reached that final speed in a time interval of 10s, so

Δt = 10s

What do we **Want** to find?

We want to find a.

What **Equation** should we use?

We know v_f, v_i, and Δt, and we want a. So, the equation that contains the variables we know and the one we want is:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

Now, I can **Substitute** numbers for the variables into the equation and **Solve** for a:

$$a = \frac{20\frac{m}{s} - 0\frac{m}{s}}{10s} = \left(\frac{20-0}{10}\right) \mathrm{x} \left({}^{m}/_{s^2}\right) = 2\,{}^{m}/_{s^2} \;\; east$$

Position, Velocity, and Acceleration vs Time Graphs

In math, you learn how to graph points on an x-y graph. We do the same thing in physics, except the variables x and y represent physical quantities. We use graphs to help visually represent how different measurements affect each other.

Basics of graphs:

A graph visually represents a mathematical statement, an equation. We usually express things in terms of how y changes with x. Y is usually the dependent variable and x is usually the independent variable. **On an x-y axis, some value of y always equates to some value of x. There is always some value of y that tells you what some value of x is at the same time, and vice-versa. The two are not usually the same number, but they happen simultaneously.**

**** y is the vertical axis, x is the horizontal axis****

Linear Equation- an equation with 2 variables that makes a straight line when the numerical values of the variables are plotted on a graph

General Form of linear equations:

$$\boldsymbol{y = mx + b}$$

Where x and y are the variables that can change, m is the slope of the line and b is the x-intercept (the point on the graph where x = 0). M and b are both constants (they don't change).

To remember what the slope is, remember the phrase "rise over run" or "the change in y divided by the change in x". The equation is

$$m = \frac{\Delta y}{\Delta x} = \frac{y_f - y_i}{x_f - x_i}$$

Quadratic Equations- an equation with 2 variables that makes a parabola when the numerical values of the variables are graphed.

The most basic Quadratic Equation is $y = x^2$. Any equation that has an x^2 in it will have the shape of a parabola (it looks like a "U" or an upside-down "U" depending on whether the term x^2 is positive or negative in the equation)

General form of Quadratic Equations:

$$y = ax^2 + bx + c$$

Where x and y are the variables that change; a, b, and c are constants.

Example:

In the equation $y = 4x^2 + 3$, what are the values of a, b, and c? and calculate the values of y when x=1 and when x= -2

To find a, b, and c, all we have to do is compare the equation we are given to the general form. The coefficient in front the "x^2" term is 4. In the general form, the letter in front of "x^2" is a, so a=4. The letter b is in front of the "x" in the general form, but in the given equation there is no "x". That means that b must equal 0, because 0 times anything is 0. So, b=0. In the general form, c is a single number not multiplied by any variable, and in the given equation the single number not multiplied by a variable is 3. So, c=3.

To find the values of y when x = 1 and -2, simply substitute 1 and -2 in for x and solve

When x=1

$y = 4(1^2) + 3 = 4 + 3 = 7$

This would indicate a point on the graph of (1, 7)

when x = -2

$y = 4(-2^2) + 3 = 4(4) + 3 = 16 + 3 = 19$

This would indicate a point on the graph of (-2, 19)

Graphs in Physics

Position vs Time Graph- A line graph showing an object's position at any given time.

Velocity vs Time Graph- A line graph that shows an object's velocity at any given time.

Acceleration vs Time Graph- A line graph that shows an object's acceleration at any given time.

** When we say something vs something, remember its always **y vs x**. Whatever quantity is said first is plotted on the y-axis, whatever quantity comes after the vs is plotted on the x-axis**

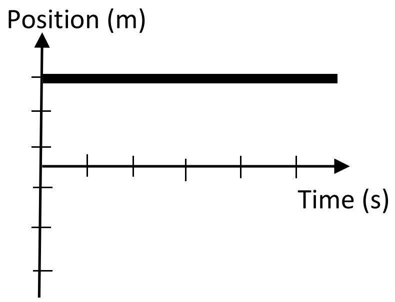
Rules for graphs-

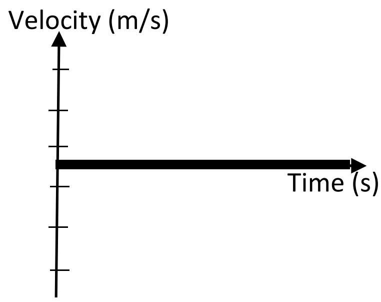
- **Always label your axes!! Include Units!!**
- **Velocity is the slope of the Position vs Time graph**
- **Acceleration is the slope of the Velocity vs. Time Graph**

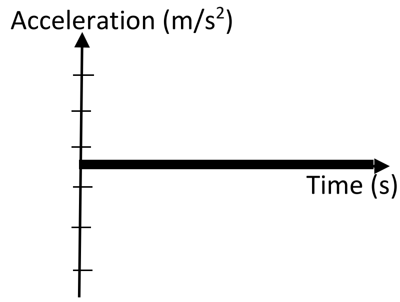
<u>When an object is at rest, v=0 and a=0</u>:

Position vs Time graph is a horizontal line at y= whatever the position of the object is, Velocity vs Time and Acceleration vs Time are a horizontal line at y=0

Examples of Graphs for an object at rest at a positive position:







<u>When an object is moving with a constant velocity, v=constant, a=0:</u>

When v is Positive-

Position vs Time graph is a straight line with a positive slope (linear equation)

Velocity vs Time graph is a horizontal line at the value of the velocity (on the positive side of the y-axis when v is positive)

Acceleration vs Time is a straight line at y=0

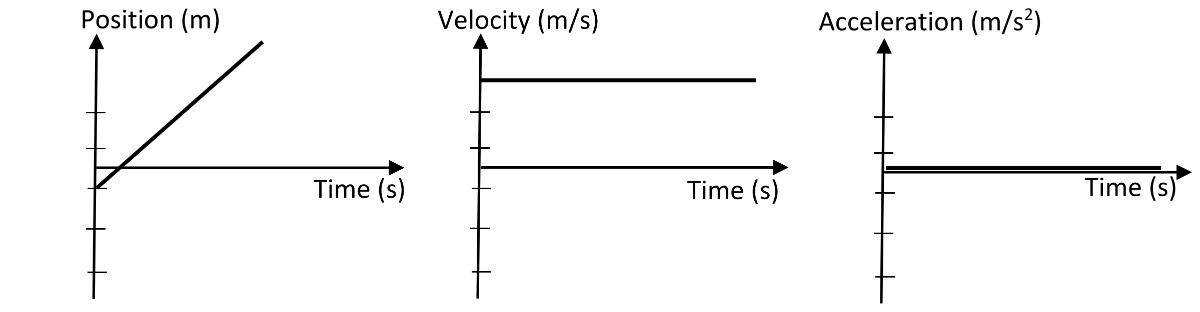
When v is Negative-

Position vs Time graph is a straight line with a negative slope (linear equation)

Velocity vs Time graph is a horizontal line at the value of the velocity (on the negative side of the y-axis when v is negative)

Acceleration vs Time is a straight line at y=0

Examples of graphs for an object with a <u>positive, constant velocity</u>.



<u>When an object has a constant acceleration:</u>

When a is positive…

Position vs Time graph is a parabola that opens up (a “U” shape)

Velocity vs Time graph is a straight line with a positive slope (linear equation)

Acceleration vs. Time is a horizontal line at the value of a (on the positive side of the y-axis)

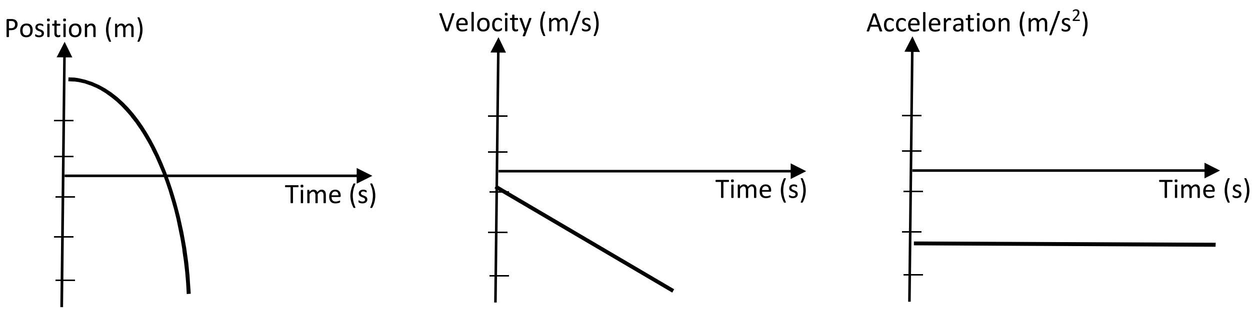
When a is negative…

Position vs Time graph is a parabola that opens down (an upside-down “U” shape)

Velocity vs Time graph is a straight line with a negative slope (linear equation)

Acceleration vs. Time is a horizontal line at the value of **a** (on the negative side of the y-axis)

Example of Graphs for an object with a <u>negative acceleration</u>:



**** What you really need to know in 7th grade physics about this****

a. **How to interpret a graph. For example, if I give you a position versus time graph, you have to know how to figure out the objects position at a given time, or the distance it travelled in a given time.**
b. **What the slopes of the lines mean. For example, you need to know that the slope of the velocity vs time graph is acceleration, and recognize a positive or negative slope. Also, if a line is horizontal, the slope is zero, therefore the quantity associated with it is 0. For example, if a position vs time graph is horizontal, then the object isn't moving and the velocity is 0.**

III. Newton's Laws of Motion and Forces

In this section, I will use the abbreviations N1L, N2L, and N3L to represent Newton's 3 Laws

Newton's 1st Law of motion (also called "The Law of Inertia")- An object at rest will remain at rest unless acted upon by unbalanced forces, and an object moving at a constant velocity will remain at a constant velocity unless acted upon by unbalanced forces.

**This means that when the forces are balanced, the acceleration of the object is zero (because the velocity doesn't change; no change in velocity means no acceleration), the object is in equilibrium. **

Inertia and Mass

Inertia: An object's resistance to change. The property of matter that makes anything with mass solid.

Mass (kg): the amount of inertia an object has; the measurement of inertia or matter an object has

Remember, mass is the measurement of inertia like…

a. Temperature is the measurement of how hot or cold something is
b. Weight is the measurement of the force of gravity acting on an object

**** WEIGHT IS NOT MASS****

c. Length is the measurement of how short, tall, wide something is
d. Volume is the measurement of how much space an object takes up

and so on…

Newton's 2nd Law of Motion- the **acceleration** of an object is **directly proportional** to **Force** acting on the object, and **inversely proportional** to the **mass** of the object.

In equation form, this means:

$$a = \frac{F}{m}$$

Where a is the acceleration of the object, F is the force acting on the object, and m is the mass of the object.

Force (N)- any push or pull on an object

Force is measured in Newtons (N)

$1N = {}^{1kgm}/_{s^2}$

Directly Proportional- When two quantities increase or decrease with each other; when one quantity gets larger or smaller, the other one does too.

Inversely Proportional- when 2 quantities do not increase or decrease with each other; when one gets larger, the other gets smaller, and vice versa.

****when two quantities (represented by variables) are on different sides of the equal sign, and both quantities (variables) are in the numerator (or both in the denominator), then the quantities are directly proportional. If one quantity is in the numerator and one is in the denominator, they are inversely proportional****

Other forms of the N2L equation:

$$F = ma$$

$$m = \frac{F}{a}$$

Newton's 3rd Law of Motion- Whenever one object exerts a force on a second, the second object exerts an equal but opposite force on the first object.

The 2 forces are called action-reaction forces. The two forces act on 2 separate objects

In equation form:

$$F_{1,2} = -F_{2,1}$$

Where $F_{1,2}$ is the force on object 1 by object 2, and $F_{2,1}$ is the force on object 2 by object 1.

Whenever you need to determine what the reaction force is to a given action force, remember the statement: **The Force <u>on Object 1</u> **by Object 2** is equal in magnitude but opposite in direction the Force <u>on Object 2</u> **by Object 1**** and figure out what Object 1 and Object 2 are, and just reverse them in the statement.

Examples 1- N3L action-reaction pairs

Action Force ($F_{1,2}$): a person pushing a box across a floor with a force of 20N east

$F_{1,2}$ = 20N east (or +20N in the x-direction)

Object 1- the box, the person is exerting the force on the box

Object 2- the person

The force on the box by the person is equal in magnitude but opposite in direction of the force on the person by the box

Reaction Force ($F_{2,1}$): the box pushing on the person

$F_{1,2}$ = 20N west (or 20N in the –x direction)

Example 2- N3L action-reaction pairs

Action Force ($F_{1,2}$): A ball falling down from a roof (without air resistance) with a weight of 10N

The force that causes this is the force of the Earth pulling down on the ball, the force of gravity acting on the ball

The force on the ball by the Earth is equal in magnitude but opposite in direction of the force on the Earth by the ball

Reaction Force: the force of the ball pulling up on the Earth

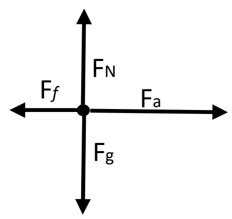
$F_{2,1}$ = 10N up

Free-body Diagrams

We use free-body diagrams to give a visual representation of the forces acting on an object.

1. Replace the object with a point
2. Label the mass of the object (if it is given)
3. Draw arrows representing the forces
   a. Magnitude- length of arrow
   b. Direction- arrow points in the direction of the force
4. Label all arrows with force notation and magnitude (if possible)

Example of a FBD for an object being pushed to the right along a surface with friction.



F_g

Types of Forces

ALL FORCES ARE MEASURED IN THE UNIT NEWTONS(N)

4 Fundamental Forces: There are 4 fundamental forces in the universe. Everything else is a combination or extension of them. They are

1. Electromagnetic Force- causes the interactions of electrically charged particles. This produces almost every force we experience on a daily basis other than gravity
2. Gravitational Force- Responsible for the attractive force between any objects with mass. **This is the weakest of all 4 fundamental forces**. Remember the problem we solved when we figured out the gravitational and electrical forces between 2 particles. The gravitational force was on the order of 10^{30} times smaller than the electric force.
3. Strong Nuclear Force- Binds the nucleus of the atom together. The force that produces the atomic bomb. **This is the strongest of all 4 fundamental forces!!**
4. Weak Nuclear Force- Causes spontaneous nuclear decay. The most uncommon and weakest of the 2 nuclear forces.

Contact Forces vs Action-at-a-Distance Forces

Contact Forces- a force experienced by objects which are literally touching each other, in contact

Examples: Normal Force, Tension Force, Applied Force, Friction

**** When an object is no longer touching another object that was applying a contact force, the contact force no longer exists****

****For example, when you throw a baseball, the instant the baseball leaves your hand, you are no longer in contact with it, and are no longer applying a force to it****

Action at a Distance Forces (or as I referred to them, **field forces**)-

A force which occurs when an object is **not in contact** with the object it is applying the force on

Examples: Gravitational Force, Electric Force, Magnetic Force

****For example, you do not need to be in contact with the Earth for it to pull you down. This is why we don't walk off roofs. We will fall. We fall because the Earth is pulling down on us, even though we are not in contact with it. If it didn't, we wouldn't fall.****

<u>Weight (F_g)</u>: the force of gravity acting on an object.

$$F_g = mg$$

Where F_g is the force of gravity acting on an object (in N), what we call the objects weight; m is the mass of the object (in kg); g is the acceleration due to the force of gravity (m/s^2)

** the mass of an object does not change, but the g does. It varies throughout the universe, and is dependent on the mass of the object creating the force. That's why an astronaut weighs less on the moon, g is different but m is still the same**

g on Earth is g= 9.8 m/s^2

Example:

A person has a mass of 55kg. How much does the person weigh on Earth?

Know:

The mass of the person

m = 55kg

The acceleration of gravity on Earth

g= 9.8 m/s^2 down (or -9.8)

Want: F_g

Equation:

$F_g = mg$

Substitute and Solve:

F_g = (55 kg)(9.8 m/s^2 down)= 539 N down (or -539 N in y)

Newton's Law of Universal Gravitation

The weight of an object on Earth is easy to calculate, because we know (approximately) what the acceleration from the pull of the Earth will be at any given point. BUT, this comes from the fact that all objects have a gravitational field, which is based on the mass of an object. The mass of the Earth is huge compared to anything on it, so we don't feel ourselves pulling on the Earth, but in reality, we do.

NLUG Statement: The gravitational force between 2 massive objects (massive doesn't mean large, it means anything that has mass) is directly proportional to the product of the mass of the 2 objects, and inversely proportional to the square of the distance between the objects.

NLUG Equation:

$$F_g = \frac{GM_1m_2}{r^2}$$

Where F_g is the gravitational force between 2 objects, G is the gravitational constant of the universe ($G=6.67\times10^{-11}$ m^3/kgs^2**)**, M_1 is the mass of one object, M_2 is the mass of the other object, and r is the distance between the two objects.

Inverse-Square Law

Gravitational Force is inversely proportional to the square of the distance between the objects, and vice versa

Example:

2 objects are separated by a distance of 4m and have an attractive force of 2N between them. If the distance is reduced to 2m, the attractive force becomes…

I **Know**:

distance r was halved (multiplied by ½)

Want to know:

Resultant Force

Equation:

You can use NLUG if you want, or remember, for NLUG, whatever the factor your given is reduced or increased by, take that number, flip it (take reciprocal), and square it. That's what you multiply the original by to find out what happens to it

$1/2r \rightarrow (2/1)^2 \cdot F = 4F = 4(2N) = 8N$

Normal Force (F_N)- a pushing force felt by an object in contact with a stable surface.

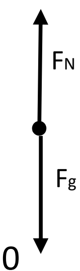
Normal forces balance applied forces. An object sitting on the floor experiences a normal force that balances the objects weight. A person pushing against a wall experiences a normal force that balances the amount of force the person is pushing with.

Normal Force is always perpendicular to the surface applying it

We know from N1L that an object at rest will stay at rest when acted on by balanced Forces, when all the forces acting on an object cancel each other out. This implies that when an object is at rest against a surface, the normal force on the object must cancel out the force the object applies.

Example:

Find the Normal force acting on a box at rest on the ground with a mass of 10kg.



Using N2L, we know that the sum of the forces in one direction (F_{net}) acting on an object is equal to the mass of the object times the net acceleration of the object. Since the box is at rest, the acceleration is 0

So, F_{net} must be zero. In equation form it looks like this…

$F_{net} = F_N + F_g = 0; \quad F_N = -F_g$

F_g of the box will be its weight

F_g = (10kg)(9.8 m/s^2 down) = 98 N down (or 98N in –y direction)

So, F_N = -(-98 N) = 98N up (or 98N in +y)

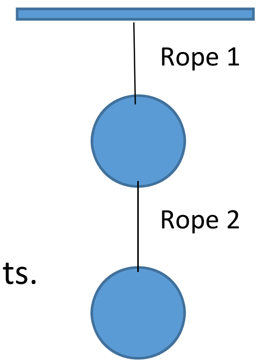
<u>Tension Force</u> (F_T)- A pulling force on an object exerted by a string, cable, chain, or similar object

Tension forces are like Normal forces, they balance out applied forces, but they balance pulls. Normal forces balance pushes

Example:

Two weights are hanging from the ceiling like in the picture shown. Both weights weigh 10N. Find the tension

a. in rope 2 and
b. in rope 1



The tension in both ropes have to balance the pull of the weights.

The weight of each one is given, F_g = 10N down (or -10N).

a. Rope 2 only has one weight attached to it, so Rope 2 only has to support one weight.

   F_{T2} = 10N up

b. The tension from rope 1 has to balance both weights, so

   F_{T1} = 10N up + 10N up = 20N up

<u>Friction Force (F_f)</u>- a force that opposes motion between 2 surfaces in contact.

2 types of Friction

Kinetic friction- when 2 objects are moving with respect to each other
Example: anything sliding

Static Friction- when there is a force applied but the two objects in contact are not moving with respect to eachother
Examples: When you try to open a jar that's stuck, walking (because your foot is not moving while in contact with the ground), an object that is rolling

Remember, friction is always opposite the direction of motion

Equation for friction:

$$\boldsymbol{F_f} = \mu \boldsymbol{F_N}$$

Where F_f is the force of friction, μ is the coefficient of friction (no units), and F_N is the normal force acting on the object.

Example of Calculating Friction-
A box with a mass of 10kg is sliding to the right on a wood floor with a coefficient of friction 0.3.

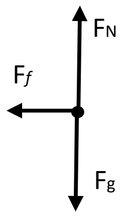
a. Find the magnitude and direction of the frictional force
b. Find the box's net acceleration.

a. Know:
   m = 10kg
   μ = 0.3

   Want:
   F_f

   Equation: $\boldsymbol{F_f} = \mu \boldsymbol{F_N}$

   For this problem, we can't just solve directly. We first need to find the normal force (F_N).



$F_{net} = F_N + F_g = 0$; $F_N = -F_g$

F_g of the box will be its weight

$F_g = (10kg)(9.8\ m/s^2$ down) = 98 N down (or 98N in –y direction)

So, $F_N = -(-98\ N) = 98N$ up (or 98N in +y)

Now, we can **substitute and solve**

$$\boldsymbol{F_f = \mu F_N = (0.3)(98N) = 29.4\ N}$$

Because the box is moving to the right, we know that the friction is to the left.

So, F_f = 29.4 N left (or -29.4 N in x)

b. To find a_{net}, we use N2L. The only force acting in x direction is friction, so the sum of the forces in x, $\sum F = F_f$

$$F_{net} = \sum F = F_f = ma_{net}$$

Know:	Equation:
$F_f = -29.4N$	$F_f = ma_{net}$
m= 10kg	Sub. And Solve
Want: a_{net}	$-29.4 = (10)a_{net}$
	$a_{net} = -2.94\ m/s^2$

Net Force (F_{net})- the sum or total of all the forces acting on an object.

In equation form it looks like

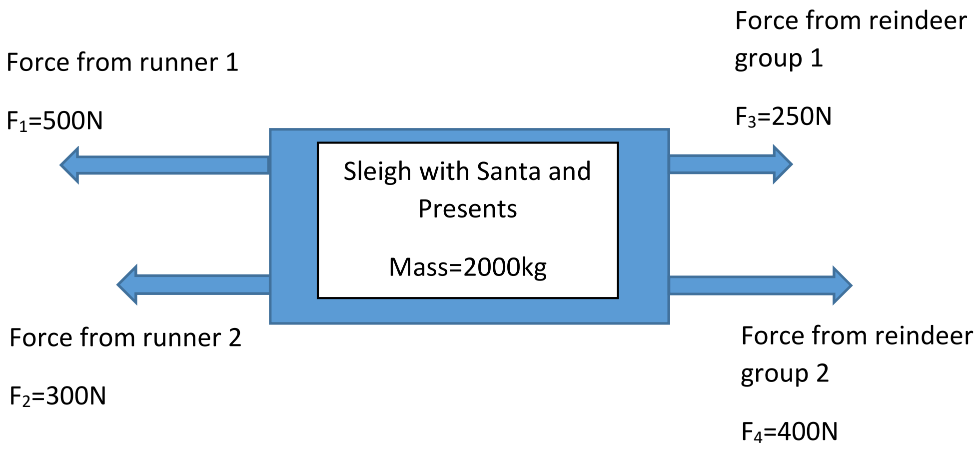
$$F_{net} = \sum F = ma_{net}$$

Where F_{net} is the net force on the object, $\sum F$ means the sum of all the forces, m is the mass of the object, and a_{net} is the net (over-all) acceleration of the object.

Remember, Force is a vector. So **when we are calculating a resultant vector (the combination of 2 or more vectors), no matter what the vector is, the method is: when vectors are in the same direction, we add them. When vectors are in opposite direction, we subtract them, and the resultant vector is in the direction of the larger quantity**

Example:

It's Christmas Eve and Santa's delivering toys in a sleigh being pulled by the reindeer. They are split into 2 groups, with Rudolph out front by himself. There are 2 reigns (straps) that the reindeer are hooked up to the sleigh with. As they land in New York City's Central Park, there is snow on the ground that helps the sleigh come to a stop. There are 2 "runners" (metal parts on the bottom of the sled) that experience the friction from ground, although the ground is uneven and the forces are not the same on each. A picture of the forces acting on the sleigh is shown below



Find the net force, magnitude and direction, acting on the sleigh (use left or right to indicate direction)

First, since there are 4 forces acting in the x- direction, the sum of the forces in x will be

$F_{net} = \sum F = F_1 + F_2 + F_3 + F_4$

F1 = -500N (- because it's to the left)

F2 = -350 N

F3 = 250N (+ because it's to the right)

F4 = 400N

Fnet = -500 + (-350) + 250 + 400 = -150 N (- means F_{net} is to the left)

Equilibrium- an object is in equilibrium when the forces on it are balanced.

Conditions for Equilibrium

$F_{net} = 0$

$a_{net} = 0$

Two types of equilibrium- Static and Dynamic

Static Equilibrium- an object in equilibrium that is not moving (v=0)

Dynamic Equilibrium- an object in equilibrium that is moving (v = constant)

IV. Work, Power, and Energy

Work

Work- when a force causes an object to move in the direction of the force.

Equation form:

$$W = F\Delta x$$

Where W is the work done by the force, F is the force doing work, and Δx is the displacement of the object while that force was acting on it.

Work is measured in units of Joules (J)

$1\,J = 1\,Nm = {kgm^2}/{s^2}$

****Work is a Scalar Quantity. It only has magnitude, no direction****

Conditions for a Force to do work on an object

1. The force must cause the object to move
2. The force must be in the direction of motion

Example:

A person pulls a suitcase along the floor, applying a force of 20N to the suitcase over a distance of 5m. What is the work the person did on the suitcase?

Know:

F=20N

Δx=5m

Equation: $W = F\Delta x$

Want: Work (W)

Substitute and Solve:

W = (20N)(5m) = 100 J

The work needed to raise an object to a given height is equal to the Weight of the object times the height it is lifted to

Power: the rate at which work is done; how fast an amount of work can be done

In equation form:

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

Where P is the power, W is the work done, and t is the amount of time it took to do the work

Power is measured in the units of Watts (W)

$1\,W = {}^{1J}/_{s}$

****Power is a Scalar Quantity. It only has magnitude, no direction****

Example:

A car has a power rating of 3000W. How much work can it do in 20s?

Know:

P = 3000W

t = 20s

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

Want: Work (W)

Substitute and Solve:

3000W = $\frac{W}{20s}$

To solve this, we multiply each side of the equation by 20s

3000W(20s)= W

W= 60,000 J

Energy

Energy- the ability to do work

Energy is measured in Joules as well (J)

Work can also be defined as a transfer of energy

****Energy is a Scalar Quantity. It only has magnitude, no direction****

Forms of energy-

Potential Energy- The energy stored by an object due to its shape or relative position to another object.

Examples:

A stretched spring

An object above the ground

Gravitational Potential Energy (E_g)- The energy stored by an object due to its height.

It is caused by the force of gravity attracting an object to the ground. “the object has the potential to fall because of gravitational potential energy”

** GPE is equal to the work done against gravity to lift an object to that height**

Equation Form

$$\boldsymbol{E_g = mgh}$$

Where E_g is the gravitational potential energy of an object, m is the mass, g is the acceleration due to gravity (on Earth, g= 9.8 m/s^2), and h is the height of the object.

Example:

A rock with a mass of 500g is on top of a mountain that is 4150m tall. What is the objects E_g?

Know:

h = 4150m

m = 500g

*** we need to convert to kg

500g $(\frac{1kg}{1000g})$ = 0.5kg

Want: Eg

Equation: $E_g = mgh$

Sub. and Solve:

Eg = (0.5kg)(9.8m/s2)(4150m)

Eg = 20,335J

Elastic Potential Energy- The energy stored by an object as a result of stretching or compressing it.

Examples:

A stretched out slinky, drawing a bow, springs

Chemical Potential Energy: The energy stored in objects due to the positions of the electrons within the atoms or molecules of a substance

Ex: Food, Gasoline, Matches

Kinetic Energy (E_k): The energy of motion.

any object in motion has kinetic energy

Equation for Kinetic Energy of an object

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

Where E_k is the kinetic energy of the object, m is the mass of the object, and v is the velocity of the object.

****E_k is directly proportional to m and v^2. If m is doubled, and v stays the same, E_k is doubled… but but but, if v is doubled and m stays the same, E_k is quadrupled!****

Example of how to calculate kinetic energy:

A car with a mass of 1500kg is travelling at a speed of 25 m/s. How much kinetic energy does the car have?

Know:

m = 1500kg

v = 25 m/s

Want: E_k

Equation:

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

Sub. And Solve:

E_k = ½ (1500)(25^2)

E_k = ½ (1500)(625)

E_k = ½ (937,500)

E_k = 46,750 J

Thermal Energy: The kinetic energy of the particles moving in an object.

Ex: Work done by friction creates thermal energy, the vibration of atoms in an object

Electric Potential Energy: The energy stored by a charged particle due to its position in an electric field.

any particle with a positive or negative charge has an electric field outside of it. That field gives electric potential energy to other charged particles around it, which then changes to kinetic energy and causes the particles to start moving

Example: Current in a wire

Sound Energy: the energy associated with the vibration or disturbance of matter.

Sound waves cannot move without matter, or objects that have mass. That's why in space, sound waves cannot travel. There are no air molecules or particles for the sound to vibrate

Electromagnetic Energy: Also called "radiation" or "light energy". It is the energy of an electromagnetic wave or particles of light called photons

Ex.: visible light, radio waves, microwaves, UV rays, gamma rays

the only difference between the energies of all the different kinds of EM waves is the wavelengths of each wave (or the distance from crest to crest of the wave)

Nuclear Energy: The energy of joining or splitting the nuclei of an atom

Nuclear fission- splitting the nucleus of an atom. This occurs in stars, in nuclear power plants, and in the atomic bomb

Nuclear Fusion- joining one or more nuclei together to form a new element. This only occurs in stars and is what is responsible for the existence of every element in the universe

Energy Conversion- any form of energy can be converted (transformed) into any other form of energy

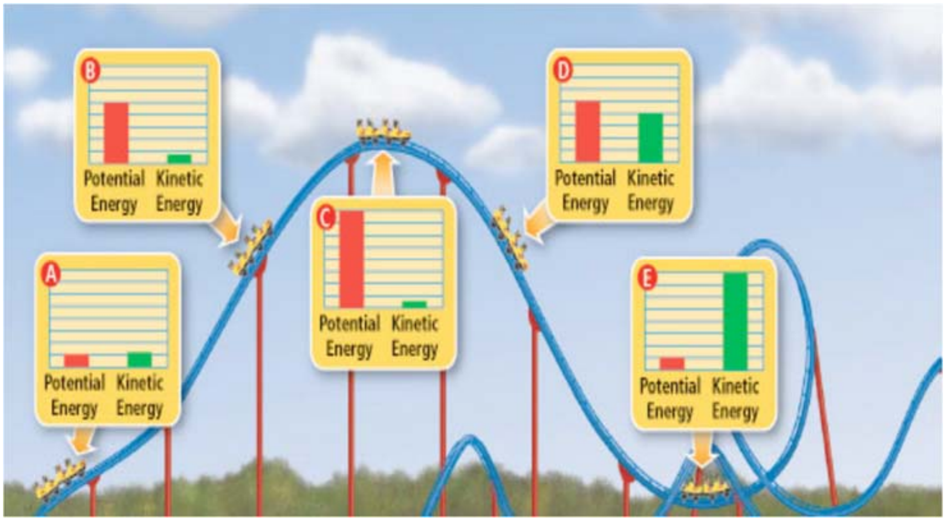
Total Mechanical Energy (E_{tot}): the total energy of motion and position of an object.

Since the energy of motion is the kinetic energy, and the energy of position is the potential energy of an object, the equation for total mechanical energy is

$$E_{tot} = E_k + E_p$$

Where E_{tot} is the total mechanical energy of an object, E_k is the kinetic energy, and E_p is the total potential energy of the object.

<u>Law of Conservation of Energy</u>: Energy cannot be created or destroyed, it can only change forms.



Notice how the potential energy and kinetic energy keep changing to and from each other at all the different points on the rollercoaster, but the over-all total stays the same!

In an isolated system, the total mechanical energy is a constant. The kinetic and potential energies may change, but the sum of the 2 remains the same

In equation form this looks like…

$$E_{toti} = E_{totf}$$

Where E_{toti} is the total initial mechanical energy and E_{totf} is the total final mechanical energy.

The equation is this form is not all that helpful for solving for, well, anything really. We need to expand the equation by substituting in the equations for Etot:

When solving for conservation of energy, we will only use gravitational potential energy

$E_{toti} = E_{ki} + E_{gi}$

$E_{totf} = E_{kf} + E_{gf}$

So, an expanded form of the COE equation is…

$$E_{ki} + E_{gi} = E_{kf} + E_{gf}$$

This equation allows to solve for all initial and final values of E_k and E_g, but what if we wanted to solve for final velocity or find initial height of an object? We can do this by substituting in the equations for E_k and E_g:

$$E_k = \frac{1}{2}mv^2 \qquad\qquad E_g = mgh$$

So, the final expanded form of the COE equation is:

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$$

This form of the COE of energy equation allows to solve for all initial and final values of velocity and position.

Example of solving a problem using conservation of energy:

A person standing on a roof at a height of 10m is holding a ball with a mass of 0.3kg. They dropped it and it fell to the ground.

a. Find E_{ki}, E_{gi}, and E_{toti} of the ball
b. Find E_{kf}, E_{gf}, and E_{totf} of the ball
c. What is the balls velocity right before it hits the ground?

****Sometimes in these problems, it's not easy to figure out what final and initial mean. With energy problems, initial means the initial state of the object (the height and velocity of the ball before there is any transformation of energy, where the object starts and how fast it was going at the start). Final means the final state of the object (the height and velocity of the object after an energy transformation has occurs, where the object ends up and how fast it's going when it gets there).****

In this problem, initial conditions are when the ball is at rest on the roof, the final conditions are when the ball reaches the ground.

a. Find E_{ki}, E_{gi}, and E_{toti} of the ball

Know:

h_i = 10m

Equations:

$E_{ki} = \frac{1}{2}mv_i^2$

v_i = 0m/s (because the ball is at rest)

$E_{gi} = mgh_i$

m = 0.3kg

$E_{toti} = E_{ki} + E_{gi}$

g = 9.8 m/s^2

Want: E_{ki}, E_{gi}, and E_{toti}

Substitute and Solve:
E_{ki} = ½(0.3)(0^2) = 0J
E_{gi} = (0.3)(9.8)(10) = 29.4J
E_{toti} = 0 + 29.4 = 29.4J

b. Find E_{kf}, E_{gf}, and E_{totf} of the ball

Know:

h_f = 0m (because the ball is on the ground)

m = 0.3kg

g = 9.8 m/s^2

E_{toti} = 29.4J

Want: E_{kf}, E_{gf}, and E_{totf}

Equations:

$E_{gf} = mgh_f$

$E_{toti} = E_{totf}$

$E_{totf} = E_{kf} + E_{gf}$

Substitute and Solve:
E_{gf} = (0.3)(9.8)(0) = 0J
E_{toti} = E_{totf} = 29.4J
29.4 = E_{kf} + 0; E_{kf} = 29.4J

c. What is the balls velocity right before it hits the ground?

Know:

E_{kf} = 29.4J

m = 0.3kg

Equation:

$E_{kf} = \frac{1}{2}mv_f^2$

Want: v_f

Substitute and Solve:
$29.4 = 1/2\ (0.3)v_f^2$
$(29.4 \times 2)/0.3 = v_f^2$
$v_f^2 = 196$
$v_f = \sqrt{196} = 14$ m/s