Sci 25 Student Reference Guide

Prepared for

Kingsborough Learning Center

Preface

This study guide is intended to be used as a supplement for lecture sessions, self study, and tutoring sessions. This guide is designed to provide background and basic explanations for complex topics. Do not attempt to use this guide as your sole source of information. Please remember that your professors will be creating assignments and tests based on the material they present, which may have some differences from the materials in this guide.

Introduction

In comparison to Bio 11 and Bio 12, Sci 25 relies more heavily on spatial relationships and mathematics to understand concepts. In order to perform better, students should review their knowledge of algebra, and the relationships between variables in an equation

Algebraic Manipulation

Algebra takes the form of equations, where two mathematical expressions are set as equalling one another. The variables in these equations can be manipulated by performing mathematical operations on them. This typically involves removing a variable from one side of the equation by performing the opposite mathematical operation, while adding it to the other side through the same operation.

Ex: X*Y=Z can be changed to X=Z/Y by dividing both sides of the equation by Y.

In order to perform these manipulations, you will need to consider the order of operations, as well as knowing the appropriate operation to perform

Order of Operations

The order of operations refers to the order in which we perform mathematical functions. When there are multiple operations of the same type in an equation, perform them from the left to the right

1. Perform any operations inside of a parenthesis
2. Perform any exponential function ($2^2=4$)
3. Perform any multiplications and divisions
4. Perform any additions or subtractions

This will allow you evaluate complicated expressions such as 3+4*2/5^2

1. $3+4*2/5^2 \rightarrow 3+4*2/25$
2. 3+4*2/25 → 3+8/25 → 3+0.32
3. 3+0.32 = 3.32

List of Opposed Mathematical Operations

- Multiplication and division
- Addition and subtraction
- Roots and exponents
  - $\sqrt{x}$ removes the exponent of x^2, $\sqrt[3]{x}$ cancels x^3, etc
- Logarithms and powers of 10
  - Log(x) will cancel 10^x, leaving x

Scientific Notation

Scientific notation is a method to shorten long numbers. It involves multiplying a number by a power of 10. The power of 10 will represent manipulations of the decimal point. 10 to a positive number will shift the decimal point to the right, while 10 to a negative number will shift the decimal point to the left.

Ex: $15x10^3$ → 15000. $243x10^{-4}$ → 0.243.

When you are converting a number into scientific notation, you will be moving the decimal point left or right in order to shorten the number. For each decimal point you shift to the left, you are multiplying by a larger power of 10 (10^1, 10^2, 10^3, 10^4, etc.) For each decimal point you shift to the left, you are multiplying by a smaller power of 10 (10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, etc.)

Ex: 1,300,000 → $1.3*10^6$, since we have moved the decimal left 6 places.

0.0004 → $4.0*10^4$, since we have moved the decimal right 4 places.

Mathematics using Scientific Notation

When performing mathematical operations using scientific notation, we can separate the numbers from the exponents and perform the operations on each half, before multiplying them back together.

Multiplying Exponential Numbers

When multiplying exponential numbers of the same base (in this case 10), you can instead perform this problem as an addition of exponents.

Ex: 10^3*10^2 → $10^{(3 + 2)} = 10^5$.

As proof of this, if you converted these exponents into decimal numbers, the problem would become 1,000 * 100 = 100,000. 100,000 → $1x10^5$ or just 10^5.

If the sign of the exponent is negative, make sure you bring the negative into the addition you are performing.

Ex: $10^{-3}*10^4$ → $10^{(-3 + 4)} = 10^1$.

10^5*10^{-2} → $10^{(5 + -2)} = 10^3$.

$10^{-1}*10^{-3}$ → $10^{(-1 + -3)} = 10^{-4}$.

Dividing Exponential Numbers

When dividing exponential numbers of the same base (in this case 10), you can instead perform this problem as a subtraction of exponents.

Ex: $10^2/10^3$ → $10^{(2-3)} = 10^{-1}$.

As proof of this, if you converted these exponents into decimal numbers, the problem would become 100/1,000 = 0.1. 0.1 → $1x10^{-1}$, or just 10^{-1}.

Similarly to multiplication, make sure to bring in any negative signs from the exponents into the subtraction you are performing.

Ex: $10^2/10^{-1}$ → $10^{(2 - -1)} = 10^3$.

$10^{-5}/10^2$ → $10^{(-5 - 2)} = 10^{-7}$.

$10^{-3}/10^{-2}$ → $10^{(-3 - -2)} = 10^1$.

Units of Measurement

In common life in America however, we use the units of the imperial measurement system. Feet, inches, and miles are units of distance, Pounds and ounces are units of mass, and ounce, cup, quart, and gallon are units of volume. The problem is that the conversions between the units of the imperial system do not have consistent conversions.

Ex: 12 inches = 1 foot, 3 feet = 1 yard, 5280 feet = 1 mile.
8 fl oz = 1 cup, 4 cups = 1 quart. 4 quarts = 1 gallon.
16 oz = 1 pound.

In science, the primary units of measurement used are based on the metric system. This system describes distance using the unit meter, mass using the unit gram, and volume based on the unit liter. In the metric system, all conversions are based on factors of 10, making conversion between units very easy to perform.

Metric Conversion

A metric number has two parts, the numeral and the prefix before the unit. Metric prefixes represent a factor that you are multiplying the number by,

When converting between prefixes, you need to multiply the number by the difference in the two factors.

Using the powers associated with the prefixes can make this process easier. In **scientific notation** you are multiplying a number by the power of 10 to a number. This number represents the number of times you are moving a decimal point, positive moving to the right, and negative to the left..
Ex: $1x10^2$ = 100, or moving the decimal right 2 places

Prefix	Symbol	Factor	Power
mega	M	1 000 000	10^6
kilo	k	1 000	10^3
hecto	h	100	10^2
deca	da	10	10^1
(none)	(none)	1	10^0
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}

A simplified way to change prefixes is to take the exponent of the original prefix, and subtract the exponent of the final prefix from it. This will give you the difference in power between the two units. Using this, you move the decimal of the number right if the exponent is positive, or left if negative, that many places in order to complete the conversion

Ex: 10km → __Dm
$k = 10^3$ $D = 10^1$ → 3 - 1 = 2, move decimal right 2 places
10.km → 1000.Dm

Ex: 147mg → __g
$m= 10^{-3}$ no prefix = 10^0 → -3 - 0 = -3, move left 3 places
147mg → 0.147g

Conversions Between Metric and Imperial Units

To manage the differences between these units, we will need to use a series of conversions:

Distance

- 1 inch = 2.54cm.
- 3.3 feet = 1m
- 1 mile = 1.61km

Mass

- 1 ounce = 28.35g
- 1 pound = 2.2kg

Volume

- 1 fluid ounce = 29.6mL
- 1 cup = 240mL
- 1 quart = 0.95L

Dimensional analysis

Dimensional analysis is a method we can use to convert between base units, by creating a series of fractions and canceling out units.

To do conversions using dimensional analysis:

1. Place the original number given on the left side of an equation.
2. Place the desired final unit on the left side of the equation
3. Find the conversion factor that contains both of these units
4. Using this conversion factor, multiply the left side of the equation by the new unit, and divide it by the old unit.
5. Repeat step 4 until you have added the final desired unit to the left of the equation.
6. Cancel out any units that appear on both the top and bottom of a fraction, then carry out the division and multiplication in the equation.

Ex: Convert 5 ounces to kilograms

We do not have a direct conversion from ounces to kg, so we will need to perform two sets of conversions, either from ounces → grams → kilograms or from ounces → pounds → kg.

1+2) $5oz = x\ kg$

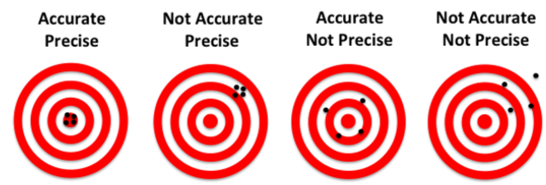
3+4) $5oz * \frac{1lb}{16oz} = x\ kg$

5) $5oz * \frac{1lb}{16oz} * \frac{1kg}{2.2lb} = x\ kg$

6) $5\cancel{oz} * \frac{1\cancel{lb}}{16\cancel{oz}} * \frac{1kg}{2.2\cancel{lb}} \rightarrow \frac{5*1*1\ kg}{16*2,2} = 0.14\ kg$

Accuracy and Precision of Measurement

When measuring values, we will often refer to accuracy and precision.
Accuracy describes how close the measured value is to the true value.
Precision describes how repeatable a measurement is, or how close the measured values are to each other.
The accuracy and precision of a measurement will influence how many digits are needed to describe the data.



Significant Figures

Significant figures (SF) are the digits of a number that are meaningful in terms of accuracy and precision. In general the more precise and accurate a method we use to measure is, the more digits there will be.
The following rules are used to describe which digits in a number are significant:

- All non-zero numbers are significant
- All zeros in between non-zero numbers are significant.
- Trailing zeros (zeroes to the left) are significant, ONLY if there is a decimal point
- Leading zeros are NEVER significant.
  Ex: the number 1.20 has three SF, since there is a decimal before the trailing zero, while 120 has two SF, since there is no decimal before or after the trailing zero.
  Ex: the number 0.005 has one SF, since leading zeros are not significant. This is because we can also write this number as 5×10^{-3}, which has one SF.

Significant Figures and Rounding

When performing mathematical functions, only some of the numbers will have a large effect on the answer. In recognition of this, some of the digits resulting from math operations may be dropped from the answer as being insignificant.
We can reduce the number of significant digits by rounding, dropping numbers based on the following rules:

- If the first non-significant digit is less than 5, remove the non-significant numbers (round down).
  - Ex: rounding 4.3212 to 3 digits becomes 4.32
- If the first non-significant digit is more than 5, add 1 to the last significant digit and remove the non-significant numbers (round up).
  - Ex: rounding 6.26 to 2 digits becomes 6.3
- If the first non-significant digit is 5, look at the next digit. If that digit is even, round the number down, otherwise round the number up.
  - Note that some professors will instruct you to round up all numbers 5 or greater.

Finding Significant Figures when Performing Math

- In multiplication and division, count the total number of significant digits in each number, then round the answer to the **lowest** number of significant digits.
  - Ex: 1.6*20. 1.6 has two significant digits, while 20 has one (due to no decimal) 1.6*20 = 32 since 32 has two significant digits, we round to 30, which has one.
- In addition and subtraction, count the number of significant digits **to the right of the decimal**. We will keep the whole number, while rounding the number to the right of the decimal to the lowest number of significant digits.
  - Ex: 1.05+37.4. 1.05 has two digits to the right of the decimal, 37.4 has one. 1.05+37.4 = 38.45. We will round this to 38.5, since we want one number to the right of the decimal.

Density

Density is a measurement of the amount of mass there is within a certain volume of space. The usual formula given is d = m/v., where d = density, m = mass, and v = volume. This formula would read as density is equal to mass divided by volume.

Mass is usually given as grams or kilograms, volume is often given as cm^3 (cubic centimeters), milliliters, or liters.

If asked to solve for mass or volume, you can manipulate the formula to solve for that value. You will need to isolate the variable you are solving for one one side of the equation, while the other variables are on the other side.

To solve for mass, we need to move volume from the left side of the equation to the right side. Since on the right side, volume is dividing mass, we can move it by multiplying both sides of the equation by volume
(d=m/v)*v → d*v = m

To solve for volume, we need volume by itself. Using the formula we just made, we can remove density from the left of the equation by dividing both sides by density.
(d*v = m) / d → v = m/d

Kinematics

Kinematics is the study of the motion of objects, without looking at the forces that cause them to move.

Definitions

There are several ways to describe the motion of objects. In mathematics, quantities can be described as being either a scalar or vector.

- A scalar quantity is described by only a number, representing the magnitude, or size of the quantity.
- A vector quantity gives information about a magnitude and a direction.
  Ex: In describing the motion of a car, a scalar quantity would describe the car as moving at 40 miles per hour. A vector quantity would describe the car as moving at 40 miles per hour toward the east.

In addition to describing the quantities of motion, we also need terminology to describe how far an object as moved,

- Distance describes how far an object has traveled. This is a scalar quantity, as it only gives information about the magnitude of how far the object has gone.
- Displacement describes how far from its origin an object is. This is a vector quantity, since it gives information about both the distance and direction from the origin.
- Speed describes how quickly an object is traveling. This is a scalar quantity since it only gives information about how much distance the object travels over time.
- Velocity describes the speed and direction of an object. This is a vector quantity since it gives information about speed and direction of travel.
- Acceleration describes the change in velocity of an object. This is a vector quantity since it gives information about if the object is getting faster or slower.

Formulas Describing the Motion of Objects

When describing the relationships between these terms, they are often discussed in terms of changes. To show that we are looking at the change in a value, we will use the symbol Δ (delta). In general, a change is described mathematically as the difference between the original value compared to the final value, or $\Delta x = x_{initial} - x_{final}$.

Speed and velocity describe the relationship between distance and time, specifically $V=\Delta d/\Delta t$.
Acceleration describes the relationship between velocity and time, $a=\Delta V/\Delta t$.
Due to this, we can also describe acceleration as $a=\Delta d/\Delta t/\Delta t$.

> When dividing a fraction by another fraction, we can rewrite the equation into a simpler form. $a/b/c/d \rightarrow a/b * d/c$.

Using the terms above, we would have $a=\Delta d/\Delta t/\Delta t/1 \rightarrow a=\Delta d/\Delta t*\Delta t \rightarrow a=\Delta d/\Delta t^2$, or acceleration is equal to change in distance divided by the square of the change in time.

By using these formulas, we can create a series of equations that can be used to describe the distance, initial and final velocities, and acceleration of an object over time. Depending on which information you are given and which information you are required to find, you will select one of these formulas. In order to use a formula, you must have all but one of the variables in that formula.
If you are told that an object starts from rest or is dropped, its $V_0 = 0$ (initial velocity = 0), if you are told that an object comes to a rest, its $V_f = 0$ (final velocity = 0), if you are told that the object travels at a constant velocity its acceleration = 0. If you are told gravity is causing the acceleration, a = 9.8m/s^2 (some professors will have you round to 10m/s^2).

1. $V_f = V_0 + a*t$
   This formula can be used if not given information about distance.
2. $d = (V_f - V_0)/2*t$
   This formula can be used if not given information about acceleration.
3. $d = V_0*t + at^2/2$
   This formula can be used if not given information about final velocity.
   If you are told that an object starts from rest, this formula can be simplified into
   a. $d = at^2/2$
      This formula can be used if not given information about velocity.
4. $V_f^2 = V_0^2 + 2a*d$
   This formula can be used if not given information about time.

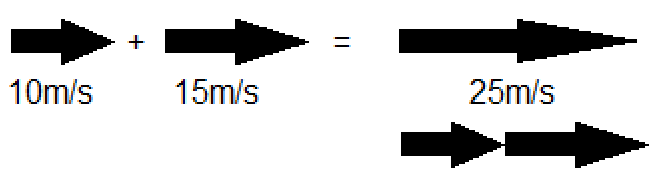
Applying Vectors

Often you will be given information in a question that will rely on you to visualize the motion of an object. This can be complicated by vector quantities, since you need to account for what happens when vectors interact.

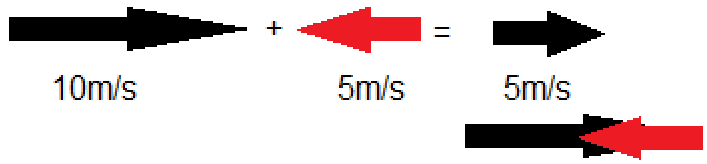
Parallel Vectors

If vectors are parallel to one another, they are either going in the same direction, or in opposite directions. In this case, the quantities of the vectors can be either added together, or subtracted from one another. Often drawing vectors as arrows of different lengths can help with this.

Ex: A car traveling at 15m/s increases its velocity by 10m/s.
In this case, we are combining two vectors going in the same direction, so we will draw two arrows representing the vectors.
To add them, we place the beginning of the second arrow at the end of the first arrow, then draw a new arrow from the start of the original arrow to the end of the second arrow.



Ex: A car traveling at 10m/s decreases its velocity by 5m/s.
In this case, the direction of the second vector is opposite of the first, decreasing the magnitude of the final vector when they are combined.



Perpendicular Vectors

When vectors are not going in the same direction, we can use a similar method of combining vector arrows to find the final vector. The difference here is that the two vector components make up the base and height of a triangle, while the final vector forms the hypotenuse.

In order to solve for the final vector, we will apply the pythagorean theorem, $a^2+b^2=c^2$, where a and b are the sides of a triangle and c is the hypotenuse. Since we want to solve for c, and not c^2, we will need to take the square root of both sides. $\sqrt{(a^2+b^2)} = c$, where c is the magnitude of the final vector.

Ex: a boat is traveling west at a speed of 20km/h, while the current is pushing it north at 4km/h. Find the total velocity of the boat.

$c = \sqrt{(a^2+b^2)} \rightarrow \sqrt{(20^2+4^2)} \rightarrow \sqrt{416} = 20.4$ km/h

Calculating Effects of Acceleration on Velocity and Distance

When considering the effects of acceleration on velocity, remember to consider that both acceleration and velocity are vectors, and may need to be calculated using the methods in the earlier section.

Acceleration will cause a change in velocity over time. An acceleration in the same direction as the velocity vector will increase the magnitude of the velocity, while an acceleration in the opposite direction as the velocity vector will decrease the magnitude of the velocity.

Ex: A car that was initially at rest accelerates at a rate of $2m/s^2$ for 10 seconds. Find the final velocity.
We can solve this either mathematically, or by using the relationship between acceleration and velocity.

- An acceleration of $2m/s^2$ will add 2m/s to the velocity of the object every second. At the end of the first second it will be moving at 2m/s, at the end of the 2nd second it will be moving at 4m/s, … at the end of the 5th second, it will be moving at 10m/s.
- Using the formula, $V_f = V_0 + a*t$, we can plug in $V_f = 0 + 2m/s^2 * 5s = 10m/s$

Ex: a ball is thrown upward at an initial velocity of 40m/s. How high will the ball travel?

This problem relies on the student to realize that a thrown object is subject to acceleration due to gravity. This acceleration is acting to increase the downward velocity of the object, and will reduce the velocity of the object as it moves upward.
Another thing that needs to be recognized is that the object will stop moving upward once it reaches its maximum height, before it begins moving downward.

In this problem, we are given an initial velocity, from the context we can determine the acceleration ($-10m/s^2$), and the final velocity (0), and we are solving for a distance. Using this info, we can look at the formulas above, and see that this matches the fourth formula, Vfinal V2 = $V_0^2 + 2a*d$.
We will need to modify this formula based on the information given: $V_{final} = 0$, and we need to solve for d.

1. $0 = V_0^2 + 2a*d$
   to isolate d, we will first move 2*a*d to the left side
2. $(0 = V_0^2 + 2a*d) -2a*d \rightarrow -2a*d = V_0^2$
   we can now isolate d by dividing by -2a
3. $(-2a*d = V_0^2) / -2a \rightarrow d = -V_0^2/2a$
   We can now plug in the values for $V_{initial}$ and a
4. $d = -(40m/s)^2/2*-10m/s^2 \rightarrow -1600m^2/s^2 / -20m/s^2 = 80m$

Newton’s Laws

Newton’s three laws of motion describe the relationship of a moving object and the forces acting on it.
Newton’s laws reference mass, which we have discussed previously but have not yet defined. Mass is the quantity of matter in an object, and is measured in kilograms. Mass is an inherent property of an object, and remains constant unless the object is physically altered (by adding or removing matter from it).

First Law of Motion

The third law of motion states “**A body continues in its state of rest, or in uniform motion in a straight line, unless acted upon by a force**”. This law is sometimes also called the “law of inertia”

Inertia is an object’s resistance to changes in velocity.

Second Law of Motion

The second law of motion describes the relationship between the acceleration of a mass and the force acting on that object. The formula for this is Force = mass*acceleration.

When describing forces, we use the unit Newton, which is defined as 1N = kg*m/s^2, or the amount of force that can cause a 1kg mass to accelerate by 1m/s^2.

When using the second law, please note that you must consider all of the forces acting on an object, or the net force. By adding together the vectors of all the forces, you can find the net force acting on an object, and then use this total force to find the acceleration.

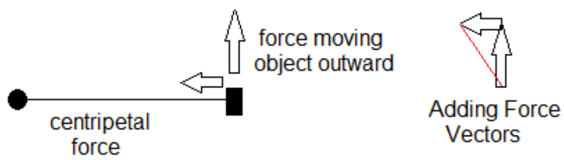
Third Law of Motion

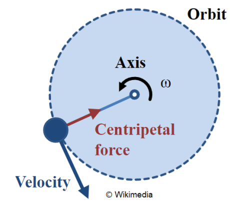
The third law of motion states that all forces exist in equal magnitude and opposite direction. In simpler terms, if a force is exerted on an object, an equal and opposite force will be applied by the object to the source of the force. This law describes interactions between different bodies.

An example of the third law is the interaction between weight and the **normal force**. Weight is the force caused by gravity accelerating objects downward. When one object is resting on top of another, gravity tries to accelerate this object. However, as the object is at rest, we can see that the net force acting on that object is zero. This is because the downward force acting on the object is being countered by an equal and opposite force, the normal force.

Centripetal Force

Centripetal force is a force that makes an object follow a curved path. This force pulls objects inward toward the midpoint of the circular path the object is following. This force may be due to tension in a rope, gravity, or other source. This force acts on the moving body, pulling it toward the object as it continues to move forward, creating a circular orbit where the forward velocity vector forms a tangent with the circumference of the circle





If the centripetal force is removed from the object, it will resume straight line motion along its velocity vector.

Centripetal force follows the formula $F_C = m*v^2/r$
From this formula the following relationships can be predicted:

- If mass changes, force changes by the same amount.
- If velocity changes, force changes by an amount equal to the square of the change in velocity. Ex: if we double velocity, we multiply force by 2^2, or 4x.
- If radius changes, force changes by the opposite amount.

Ex: if the mass of an object is tripled, while the radius is doubled, what happens to the force?

If mass is multiplied by 3, force is multiplied by 3. If radius is multiplied by 2, force is divided by 2, so the final force is being multiplied by 3/2, or 1.5x original force.

Newton's law of Gravitation

Newton's law of gravitation describes the amount of force objects exert on each other due to gravitational interaction. The law states that "every particle attracts every other particle in the universe with a force that is directly proportional to their masses, and inversely proportional to the square of the distance between those masses.
The formula for this law can be written as: $F = G*m_1*m_2/d^2$
From this formula the following relationships can be predicted:

- If one mass changes, force changes by the same amount. This means if both masses change, force will be affected by both changes.
- If distance changes, force changes by an amount equal to the inverse square of the change in distance. If distance increases, force will decrease by an amount equal to the square of the change in distance.

Ex: If one mass is increased by 2x, the second mass is increased by 5x, and the distance is doubled, what happens to gravitational force?

Force is multiplied by 2 and 5 due to the change in mass, and divided by 4 (2^2) due to change in radius, for a total increase of 2*5/4 = 2.5x increase in gravitational force.

Work and Energy

Terms and Definitions

In physics, energy is the capacity for doing work. Work is the energy transferred to or from an object by applying a force that causes a displacement.

We can describe work by the formula W = f * d.

Work uses the unit Joule. A joule is defined as the amount of work done when a force of 1N moves an object 1m ($J = kg*m^2/s^2$).

Power describes how much work is performed over time.

We can describe power by the formula P = W/t

Power uses the unit Watt. 1 watt is the amount of power needed to perform 1J of work in 1 second ($W = kg*m^2/s^3 = J/s$).

Kinetic Energy

Kinetic energy is the energy of motion. Earlier we defined work as causing displacement (motion), meaning that the amount of work done on an object will be equal to the change in kinetic energy of the object ($W = \Delta KE$).

As work is applied to an object, it causes acceleration in an object that causes movement. The kinetic energy caused by this movement is shown by: $KE = mv^2/2$

From this formula the following relationships can be predicted:

- If mass changes, KE changes by the same amount.
- If velocity changes, KE changes by an amount equal to the square of the change in velocity. Ex: if we double velocity, we multiply KE by 2^2, or 4x.

Ex: A 5kg object is traveling at 10m/s, calculate its kinetic energy.

$KE = m*v^2/2 \rightarrow 5kg *(10m/s)^2/2 = 250J$

Ex: if an object's mass decreases by a factor of 4, and its velocity doubles, what happens to its KE.

KE is divided by 4 due to change in mass, and multiplied by 2^2 due to change in velocity.

4/4 = no change in KE

Gravitational Potential Energy

In order to lift an object, we need to use work to create a force greater equal to the object’s weight. By combining the formulas for weight and work, we find W = m*g*h.

The energy added to the object by this work is referred to as gravitational potential energy, or just potential energy. This energy can later be converted into kinetic or other types of energies. PE is directly proportional to both mass and height.

Conservation of Energy

The law of conservation of energy states that energy cannot be created or destroyed, only converted into another form. When converting energy, the total amount of energy gained must equal the amount of energy lost. By reducing the amount of kinetic energy in an object, we can increase its potential energy; and by reducing the amount of kinetic energy, we can increase its kinetic energy.
From this, we can make the formula: TE = KE + PE

Ex: a person with a mass of 100kg stands at the top of a 20m cliff.
a)How much PE, KE, and TE do they have?
b)If they jump off the cliff, how much kinetic energy do they have half way down?

a) PE = m*g*h → 100kg*10m/s^2*20m = 20,000J (20kJ)
   KE = m*v^2/2 → 100*0^2/2 = 0J
   TE = 20kJ + 0J = 20kJ

b) Half way down the cliff, since the height of the person is ½ of the original, the amount of PE is ½ of the original. Since TE = KE + PE → 20kJ = KE + 10kJ → KE = 10kJ

Momentum

Momentum is a vector that describes the mass and velocity of an object. Objects that are not moving do not have momentum.
Linear momentum is the momentum of a movement in a straight line, while angular momentum is the momentum of an object moving in a curve or circle.
Linear momentum is a single vector, and is equal to mass*velocity. P = m*v
Angular momentum is a product of two vectors, and is equal to mas*velocity*radius. L = m*v*r

When objects interact, momentum is conserved due to Newton's third law. If two objects collide, an equal and opposite force is exerted between the two objects. This force will increase the momentum of one object, and decrease the momentum of the second. Since they are equal forces, the amount of momentum gained by one will be the amount of momentum lost by the other.

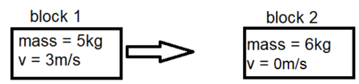
Collisions

When objects collide, momentum is transferred between the two objects. There are two general outcomes of a collision. If the objects bounce apart, we describe this as an elastic collision. If the objects stick together, we describe this as an inelastic collision. In this course, we will focus on inelastic collisions.

In a collision, we need to make sure the amount of total momentum is the same before and after the impact. To do this:

1. Calculate the momentum of the objects prior to the collision
2. Find the total momentum based on the vectors of the objects.
3. Use the total momentum to calculate the velocity of the objects after the collision, using the momentum formula and their masses. P/m = v

Ex: If a 5kg block moving at 3m/s hits a 6kg stationary block and sticks to it, find the velocity that the block will move at.



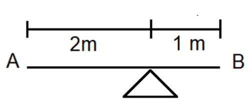
1) Find momentum of blocks. P_1 = 5kg*3m/s. P_2 = 6kg*0m/s
2) $P_{total} = P_1+P_2$ = 15kg*m/s
3) (15kg*m/s)/11k = 1.4m/s

Mechanical Advantage

Mechanical advantage is using a tool or mechanism to increase the amount of force acting on an object, allowing it to be moved more easily. We can describe the effect of mechanical advantage by the formula $F_{output} = MA * F_{input}$, or that mechanical advantage multiplies the amount of force in the system.

Lever Systems

Lever systems use a beam attached to a pivot point in order to create mechanical advantage. The amount of mechanical advantage applied is proportional to the length of the lever on either side of the pivot. If label the beam on one side of the pivot as A, and the beam on the other side as B, MA = A/B.

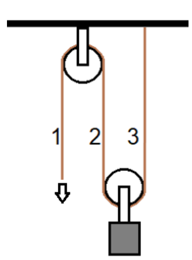


In this lever system, force applied from side A has an MA of 2 (2/1) based on the lengths of the levers.

This effect is caused by the longer side of the lever traveling over more distance than the shorter side does when the lever is moved. Since work is equal to force*distance, if work remains constant and distance increases, the amount of force will decrease.

Pulley Systems

Pulley systems use a series of wheels and ropes in order to generate mechanical advantage.



Due to the pulleys, the length of the rope that needs to be moved is longer than the distance that the object will be traveling. Similar to the lever system, by increasing the distance traveled, the amount of force needed to perform the work decreases.

MA in pulley systems is usually equal to 1+ the number of pulleys.

A more exact definition is, MA = length of rope/distance the object moves

Matter and Heat

Matter

Matter is any physical substance that takes up space and has mass. When describing matter, we generally describe it as being in three phases, solid, liquid, or gas.

Solids are materials that maintain a fixed shape and volume.
Liquids are materials that have a variable shape and fixed volume.
Gasses are materials that have a variable shape and volume.

Temperature

Temperature is the measure of heat. The metric units of temperature are celsius and kelvin, while the imperial units of temperature are fahrenheit.

Celsius and Fahrenheit

Both of these units use physical events as reference points for specific temperatures, specifically the boiling and freezing point of water.

In celsius, water will freeze at 0°C, and boil at 100°C.

- Due to these numbers, there are 100 points of measure between boiling and freezing

In fahrenheit, water will freeze at 32°F, and boil at 212°F.

- Due to these numbers, there are 180 points of measure between boiling and freezing.

This means that there are 180 fahrenheit in 100 celsius, or 1.8 fahrenheit in 1 celsius, giving us a conversion factor. There is also a difference between where the scales begin, with fahrenheit starting 32 points above celsius

When converting from celsius to fahrenheit, we multiply °C by 1.8, and then add 32 to make up for the offset. This gives us the formula: °F = (°C*1.8)+32

When converting from fahrenheit to celsius, we first subtract 32 to remove the offset between starting points, then divide °F by 1.8 due to the conversion factor.
This gives us the formula: °C = (°F-32)/1.8

Kelvin

The kelvin scale uses units that are the same size as the celsius scale, but starting from a different point. Kelvin temperatures are based on the concept of absolute zero, the lowest possible temperature that matter can have. This point occurs at -273°C
To convert from °K to celsius, we subtract 273 from °K.
To convert from °C to kelvin, we add 273 to °C

Specific Heat Capacity

Specific heat capacity describes the amount of heat energy that needs to be added to a substance in order to raise the temperature of one gram by one degree celsius. The units of specific heat capacity are cal/g*°C

When discussing heat energy, the units used are either the Joule, or the calorie.
1 calorie is equal to 4.18J, and is defined as the amount of heat required to raise the temperature of water by 1°C. 1 Calorie is equal to 1000 calories, or 1kcal.

Calculating Changes in Temperature

When we are calculating changes in temperature, we will be using the relationship described in specific heat capacity.
The formula we will be using is ΔT = Q*/m*c or Q = m*c*ΔT
Where Q is the heat energy added, and c is the specific heat capacity of a substance.

Ex: By how much does the temperature change if 100 calories of heat are added to 5g of a material with a specific heat capacity of 0.5cal/g*°c?

> Using the formula ΔT = Q*/m*c, we can plug in Q = 100, m = 5, and c = 0.5
> 100/5*.5 = 40°c

Pressure

Pressure is defined as a force applied to an area. To calculate pressure we use the formula:
P = force/area, where force is in newtons, and area is in square meters.
The metric unit of pressure is the Pascal, and is defined as 1N of force applied to $1m^2$.

Ex: Calculate the pressure exerted on a $10cm^2$ area by 2N of force.

> In this problem, recognize that in order to use the unit pascal, the area must be in m^2.
> Convert $cm^2 \rightarrow m^2$. Since we are dealing with areas, this conversion is slightly harder.
> 10^2cm =r 1m. When finding an area, we need to take the square of the lengths.
> $(10^2cm)^2 = (1m)^2 \rightarrow 10^4cm^2 = 1m^2$
> Since we were given $10cm^2$, we need to divide this by 10^4 to find m^2.
> $10^1/10^4 \rightarrow 10^{(1-4)} = 10^{-3}m^2$
> We can now take this area and divide the number of newtons by it.
> $2N/10^{-3}m \rightarrow 2*(10^0/10^{-3}) \rightarrow 2*10^{(0 - -3)} = 2*10^3$ Pa

The imperial unit of pressure is pounds per square inch (psi).
In medicine, the common unit of measure is mmHg.
Another way to measure pressure is in multiples of atmospheric pressure (ATM)

Atmospheric pressure

Atmospheric pressure is caused by the mass of the gasses that make up the atmosphere pressing down on the material below them.

Atmospheric pressure when measured in the units above is:
$1.01x10^5$ Pa, 1 ATM, 14.7 psi, and 760mmHg.

Buoyancy and Archimedes Principle

Buoyancy is an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object.. Archimedes' principle states that the buoyant force is equal to the weight of the displaced fluid.

The buoyant force is defined by the formula F= D*g*V
It states that the amount of buoyant force is equal to the density of the fluid times the volume of the displaced fluid times gravity.

If the buoyant force is greater than the weight of an object, that object will float. If the buoyant force is less than the weight of the object, it will sink.

Since buoyant force is dependent on volume of the displaced fluid, we can maximize the buoyant force by increasing the volume of the object.

Gas Laws

The gas laws help us to understand the changes that will occur within a gas as pressure, volume, and temperature change.

Ideal Gas Law

In this course, we do not use the ideal gas law, but it is the basis of the other gas laws. The ideal gas law describes the relationship between pressure, volume, temperature, and quantity of atoms in gas.

The formula for the Ideal gas law is PV = nRT
P = pressure, V = volume, n = gas constant, R = quantity of gas, and T = temperature.
When using the gas laws, remember that the temperature used must be in kelvin.

The ideal gas law allows us to create formulas where two or more variables change, but the others remain the same
For example, if we wanted to make a formula that compares pressure and temperature, while the other variables remain constant, we could write it as:
$P_1V_1 = nRT = P_2V_2 \rightarrow P_1V_1 = P_2V_2$

Boyle's Law

Boyle's law describes the relationship between the pressure and the volume of a gas, while the temperature remains constant. It states that there is an inverse relationship between pressure and volume, so that if pressure increases, volume decreases, and vice versa.
The formula for Boyle's law is $P_1V_1 = P_2V_2$

> Ex: A balloon is filled with 200mL of air at sea level, and then carried underwater by a diver. At depth, the surrounding pressure is equal to 3atm. What is the volume of the balloon?
> To solve this, recognize that you are given an initial volume and the final pressure, while asked to find the final volume. By mentioning that the balloon is filled at sea level, you can figure out that the initial pressure is equal to 1atm.
> Plugging these values into the formula we get 1 atm*200 mL = 3 atm*x mL. If we divide both sides by 3atm, we get: 1 atm*200 mL / 3 atm = x mL → 200/3 ml = x mL = 66.7mL

Charles' Law

Charles' law describes the relationship between the volume and the temperature of a gas, while the pressure remains constant. It states that there is a direct relationship between volume and temperature, so that if volume increases, temperature increases, and vice versa.
The formula for Charles' law is $V_1/T_1 = V_2/T_2$ **When using this law, remember that the temperature used must be in kelvin.**

> Ex: 1 L of a gas is initially at 20°C, before being heated to 200°C. Find the new volume of the gas.

First, convert the temperatures into °K. Remember °K = °C+273,
T_1 = 293°K, T_2 = 473°K.
Plugging these values in we get: 1 L/293°K = x L/473°K. If we multiply both sides by 473°K., we get 1 L * 473°K./293°K = x L → 473/293 L = x L = 1.61L

Gay-Lussac's Law

Gay-Lussac's law describes the relationship between the pressure and the temperature of a gas, while the volume remains constant. It states that there is a direct relationship between pressure and temperature , so that if pressure increases, temperature increases, and vice versa.
The formula for Gay-Lussac's law is $P_1/T_1 = P_2/T_2$ **When using this law, remember that the temperature used must be in kelvin.**

Ex: After being cooled from 100°C to 0°C, a gas exerts 0.15atm of pressure. Find the initial pressure of this gas.

In this problem, other than converting the temperatures, be sure to identify what you are solving for. You have been given T_1, T_2, and P_2, and need to solve for P_1.
T_1 = 373°K, T_2 = 273°K.
Plugging in these values we get: X atm/373°K = 0.15atm/273°K. If we multiply both sides by 373°K, we get: X atm = 0.15atm * 373°K / 273°K → 0.15*373/273 = 0.20 atm

Kinetic Theory of Matter

The kinetic theory of matter says that all matter consists of many very small particles which are constantly moving. These particles do not normally interact, but when they collide there is no loss of kinetic energy.

The amount of movement these particles have is determined by the amount of energy they have. If energy is added to matter, the particles within that matter will gain kinetic energy, moving farther and faster, and causing them to exert force on their surroundings. This force can cause surrounding materials to be moved as the material expands, meaning that work has been performed on the surroundings.
If energy is removed from matter, the particles within the matter will lose kinetic energy, moving more slowly. As the particle's movement decreases, the amount of force they exert on the surroundings decreases. This allows the surroundings to perform work on the matter, forcing it to contract.

If you could remove all of the energy from a piece of matter, the particles within that matter would stop moving. At this point, no additional energy can be removed from this matter. This represents the concept of "absolute zero", which the kelvin scale is based on.

In the kinetic theory of matter, temperature represents the average kinetic energy of the particles in a system.

First Law of Thermodynamics

The first law of thermodynamics builds on the law of conservation of energy. It explains that any change in energy of a system will be related to a change in heat, or due to work.
The formula for the first law is: $\Delta U = Q - W$, where ΔU is the energy of a closed system, Q is heat energy added to the system, and W is the work done by the system.

This means that in order to maintain conservation of energy, a gain of heat energy will be balanced by losing energy through performing work.

Heat transfer

Conduction

Conduction is the transfer of heat between two materials that are in contact with each other. The transfer of heat occurs when there is a difference in temperature, and causes heat energy to go from the hotter substance to the cooler substance. This causes the temperature of the objects to become the same, creating thermal equilibrium.

Convection

Convection is the transfer of heat through a fluid (liquid or gas) caused by the tendency of hotter, less dense materials to rise, and colder, denser materials to sink. As hot material rises, and cold materials sink, the temperature in the fluid becomes evenly distributed, creating thermal equilibrium.

Radiation

Radiation is the transfer of heat through electromagnetic energy, directly from a heat source to another object, through emission of electromagnetic waves in the infrared spectrum.

Change of Phases of Matter

As stated earlier, there are three main phases of matter: solids, liquids, and gasses. Under the kinetic theory of matter, solids have the least amount of energy, liquids have more than solids, and gasses have more than liquids.

By adding or removing energy from matter, it is possible to cause a change in phase.

- Melting is the change from solid to liquid
- Freezing is the change from liquid to solid
- Evaporation is the change from liquid to gas
- Condensation is the change from gas to liquid
- Sublimation is the change from solid to gas
- Deposition is the change from gas to solid

Entropy and the Second Law of Thermodynamics

Entropy describes how disordered, or random a system is. It is usually easier to consider entropy as being the opposite of order and organization. Entropy reduces the amount of energy in a system that can be used to perform work.

The second law of thermodynamics states that from all systems, some energy will be lost to the surrounding universe, increasing the entropy of the universe. Because of this, if there is an option between a reaction that increases entropy, and a reaction that decreases energy, the one that will increase entropy will be the one that occurs.

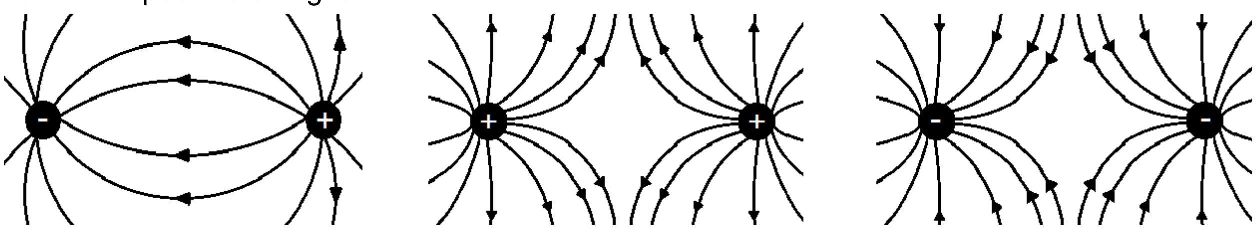
Electricity and Magnetism

Electric Charge

Electrical charges are created by the particles that make up the atoms of matter. In atoms, there are positively charged protons, and negatively charged electrons that surround them. The charges between these particles are opposites of each other.

Electric Field Lines

According to Faraday's experiments, positive charges will release electrical field lines, while negative charges will absorb these field lines. When identifying unknown charges, look for the arrows on the field lines
This means that in matter, the field lines from positive charges will be attracted to and connect to negative charges, while if they run into, while being pushed away from outgoing field lines from other positive charges.



Units of Electric Charge

When measuring electrical charges, we use the unit Coulomb.
Protons have a charge of +1.6x10^{-19} Coulombs
Electrons have a charge of -1.6x10^{-19} Coulombs
This allows the charge emitted by a single proton to be absorbed by a single electron.

Coulomb's law

Coulomb's law allows for the calculation of the force between two charges.
The formula for Coulomb's law is $|F| = K\frac{|q1*q2|}{d^2}$, where K is Coulomb's constant, which is ~9x10^9, q1 is the amount of charge in the first charge, q2 is the amount of charge in the second charge, and d is the distance between charges.
The sign of the charges influences the direction of the force, but not the magnitude. If the charges are the same, the force will push the charges apart. If the charges are different, the force will pull the charges toward each other.

From this formula the following relationships can be predicted:

- If one charge changes, force changes by the same amount. This means if both charges change, force will be affected by both changes.
- If distance changes, force changes by an amount equal to the inverse square of the change in distance. If distance increases, force will decrease by an amount equal to the square of the change in distance.

Electrical Conduction

Electrical charges are able to move through some types of matter, while being unable to move through others. In order to move between atoms in a material, charges must enter the conduction band. The conduction band is the farthest point from the protons that the electrons in an atom can get. Due to the distance between the protons and electrons, it makes it easier for electrons to leave the atom and travel to an adjacent one. In order to reach the conduction band, the electrons must gain energy. The quantity of energy they need to gain is called the energy gap.

Insulators are materials that prevent the flow of electrical charges. The atoms in electrical insulators have tightly bound electrons that remain close to the protons. Since the electrons are close to the protons the size of the energy gap is much larger, making it more difficult to move electrons into the conduction band, and preventing the movement of charges between atoms.

Conductors are materials that allow the flow of electrical charges. The electrons in these materials extend farther out from the atom, reducing the size of the energy gap and making it easier for charges to move between atoms.

Semiconductors are materials that have energy gaps that are between conductors and insulators. These are used in solar panels, to create a flow of charge by absorbing the energy from sunlight, and in electronics to create current when they receive radio or other signals.

Superconductors are materials that have no resistance to the movement of charges. This allows charges to flow through a superconductor with no energy loss.

Electric Current

Current (I)is a stream of charged particles flowing through an electrical conductor. It is measured by counting the number of charges passing through a point in a given amount of time. To measure current, we use the unit ampere, which is defined as the flow of one Coulomb of charge per second, or $I = Q/t$.

Electrical charges will move from areas of higher energy to areas of lower energy.

Electric Potential Difference

Electric potential difference describes the difference in electrical charge in different areas. The difference in charge between two areas will determine how much work it takes to move electrical charges from one area to another.
Electrical potential difference is measured in volts (V). A voltage represents the amount of work needed to move electric charges, divided by the number of electric charges. V = W/Q
One volt is defined as one joule of energy per one coulomb of charge.

As the difference in charges increases, the amount of work needed to move charges will decrease, and the speed that the charges move will increase, increasing the electric current. As the difference between charges decreases, the amount of work needed to move charges will decrease, and current will decrease. Once the electrical potential between two points becomes equal, charges stop moving.

Resistance

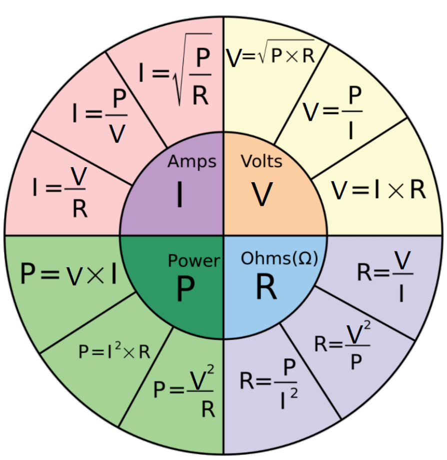
Electrical resistance (R) describes a material's opposition to the flow of electric current. These resistors will dissipate some of the electrical energy in the form of heat, reducing the amount of energy that is available to perform the work of moving charges. The unit of resistance is the Ohm (Ω). One ohm is defined as the amount of resistance when one volt of electrical potential can cause one ampere of current.

Ohm's Law

Ohm's law defines the relationship between voltage, current, and resistance in the formula V=I*R, which can be rewritten as I = V/R, and R=V/I.

Electrical Power

Electrical power is the measure of the rate of electrical energy transfer. The formula for electrical power is P=IV, where P = power in watts, I is current in amperes, and V is voltage.



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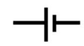
This diagram is a tool that shows all of the formulas for calculating current, voltage, resistance, and power.

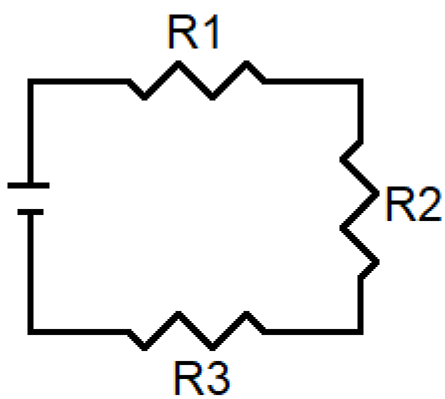
For each of these values, there are a total of three equations that will each use two of the other values. These equations are created by combining the formula for ohm's law and electrical power.

Electrical Circuits

An electrical circuit is a pathway that electrical current can flow through, from a power source to a power sink. Devices attached to an electrical circuit will draw off some electrical power, causing resistance.
Electrical circuit diagrams are drawn using symbols to represent power sources and resistors. Resistors are drawn as , and power sources are drawn as .

In a single circuit, there may be multiple resistors. It is possible to determine the total equivalent resistance (R_{eq}) in a circuit based on how these resistors are connected to each other.

Series Circuits



In a series circuit, a wire will carry current into one resistor, then into the next, and so on, passing through all of the resistors one at a time. Charges moving through a series circuit pass through all of the resistors of the circuit.

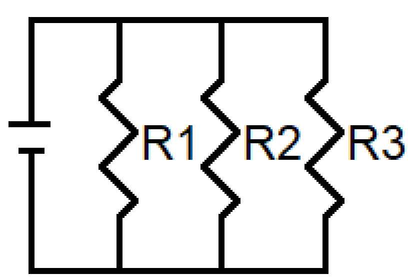
As charges pass through each resistor, the voltage will drop, but the current will remain constant through the entire circuit. This is because while the voltage has gone down, increasing the amount of work it takes to move charges, the resistance has also gone down, reducing the energy lost as charges move.

To calculate the total equivalent resistance, add up the resistances of each resistor in the circuit.
$R_{eq} = R_1+R_2+....R_x$

Ex: A series circuit has three resistors. R1 = 5Ω, R2 = 2Ω, R3 =10Ω. Find R_{eq}

$R_{eq} = 5+2+10 = 17Ω$

Parallel Circuits



In a parallel series, a wire will connect to multiple resistors, each of which will end at the same point. Charges will only pass through a single resistor in a parallel circuit.

In a parallel circuit, voltage in each resistor is the same, as they all start and end at the same point, and have equal electrical potential. Current in each resistor is different, due to differences in resistance affecting the rate that the charges can move.

Calculating equivalent resistance in parallel circuits is more difficult than in series, and uses the formula $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ... \frac{1}{R_x}$. Bear in mind this solves for $1/R_{eq}$, so you will need to take the inverse of the answer to find R_{eq}.
Remember when adding fractions that you must convert to the lowest common denominator first.

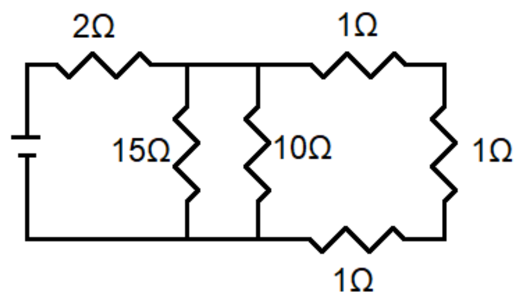
Ex: a parallel circuit has four resistors. R1 = 4Ω, R2 = 8Ω, R3 = 2Ω, R4 = 1Ω. Find R_{eq}

$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{8} + \frac{1}{2} + \frac{1}{1} \rightarrow \frac{2}{8} + \frac{1}{8} + \frac{4}{8} + \frac{8}{8} = \frac{15}{8}\Omega \rightarrow R_{eq} = \frac{1}{\frac{15}{8}} = 0.53\Omega$$

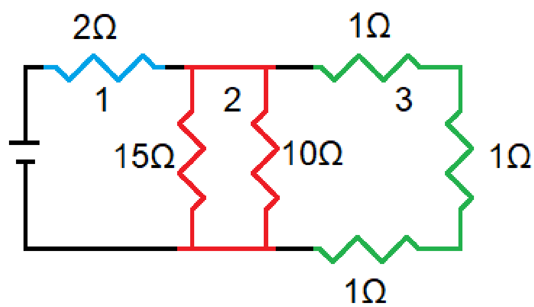
Combination Circuits

Combination circuits have sections that run in series, and other sections that run in parallel. To calculate R_{eq},calculate parallel portions individually, then treat those parallel sections as being in series with the sections before and after them, and calculate the overall R_{eq} by the series formula.

Ex: calculate the R_{eq} of the following circuit.



First, start by identifying which areas are in series and which are in parallel



Section 1 is in series with section 2. The resistors in section 2 are in parallel with each other, and with section 3. The resistors in section 3 are in series, and form a parallel connection with section 2

$$R_{eq} = R1 + \frac{1}{\frac{1}{R2} + \frac{1}{R3}}$$

R1 = 2Ω, R2 = $\frac{1}{\frac{1}{15} + \frac{1}{10}}$ = 6Ω, R3 = 1Ω+1Ω+1Ω = 3Ω.

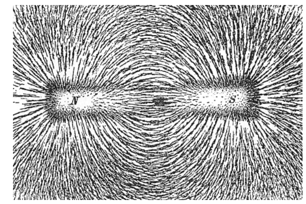
$$R_{eq} = 2\Omega + \frac{1}{\frac{1}{6\Omega} + \frac{1}{3\Omega}} = 5\Omega$$

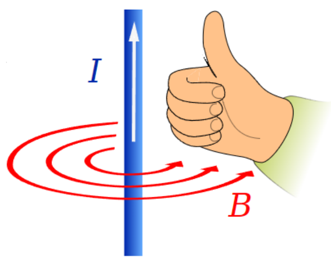
Magnetism

Magnetic Fields

All magnetic fields are created by moving electrical charges, regardless of what type of magnet we are discussing.

In permanent magnets, the atoms that make up the magnet will all have their outermost electrons circling in the same direction. The rotating electrical field will create a magnetic field that moves at a right angle to the direction the electrons are rotating in. The atoms in a permanent magnet will be aligned so that the magnetic field of each atom will be aligned in the same direction, causing the field to enter one end of the magnet, and exit the other end.





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As charges flow through a wire, magnetic field lines will form concentric circles perpendicular to the direction the current moves.

A trick to determine the direction of the magnetic field is called the "right hand grip" rule. When you form a fist with your right hand, if you point your thumb in the direction the current is moving, your curved fingers will show the direction that the magnetic field moves.

Magnetic Force

When charged particles move through a magnetic field, as they break magnetic field lines, they will be deflected by magnetic force. Positive charges will be moved in the same direction the magnetic field lines travel, while negative charges will be moved in the opposite direction as the magnetic field lines.

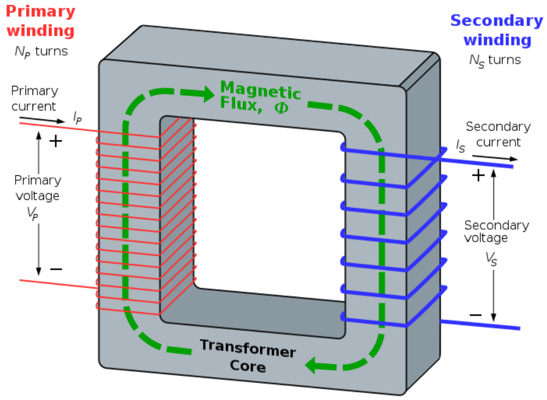
Electrical Generation

If a conductor is passed through a magnetic field, the electrons within the conductor will be moved as they pass through the magnetic field lines, creating a current. The typical method of electrical generation involves taking a coil of wires, and rotating it within a magnetic field. The rotation is performed using mechanical force, either from water, steam, or other methods.

Electrical Transformers

Electrical transformers are used to alter the voltage and current in electrical power. When electrical current passes through wires, some energy is lost due to resistance. The amount of energy lost is directly proportional to the amount of current passing through the wire, as current increases, resistance and power loss increases.

To overcome this, we want to transform the electrical energy in order to decrease the current. According to the formula for electrical power, P=I*V, there is an inverse relationship between current and voltage. By increasing the voltage, current can be reduced.



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To change the voltage, we make use of transformers. Transformers use two coils of wire wrapped around sections of a circular piece of iron. As electricity passes through one set of coils, it creates a magnetic field that passes through the iron. As this magnetic field passes through the coils on the other side, the moving magnetic field will create an electrical current in these wires.

Transformer voltage determined by the formula

$\frac{Np}{Ns} = \frac{V_{in}}{V_{out}}$ or $V_{out} = \frac{V_{in} * Ns}{Np}$

Where V_{out} is the voltage leaving the secondary coil of the transformer, V_{in} is the voltage entering the primary coil of the transformer, N_p is the number of times the wire is wrapped around the core in the primary winding, and N_s is the number of times the wire is wrapped around the core in the secondary winding.

If there are more coils in the primary winding than the secondary winding, the output voltage will be lower than the input voltage.
If there are more coils in the secondary winding than the primary winding, the output voltage will be higher than the input voltage.

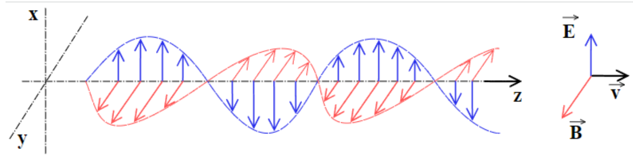
Ex: 120V enters a transformer with 100 wraps in the primary winding. How many wraps must be in the secondary winding in order to produce an output voltage of 500V?

Using the formula $\frac{Np}{Ns} = \frac{V_{in}}{V_{out}}$, we can plug in for N_p, V_{in}, V_{out}, and solve for N_s

$\frac{100}{Ns} = \frac{120}{500} \rightarrow Ns = \frac{100*500}{120} = 417$

Electromagnetic Waves

Electromagnetic (EM) waves are produced by synchronized oscillations of electric and magnetic fields. The electrical and magnetic field will move perpendicular to each other, as well as to the direction the wave is traveling. EM waves will transport energy from one location to another.



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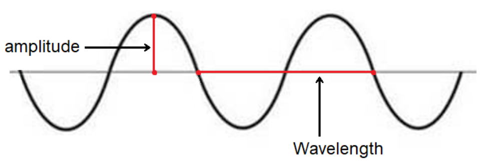
All electromagnetic waves will move at the speed of light (c) in vacuum, approximately $3x10^8$m/s.

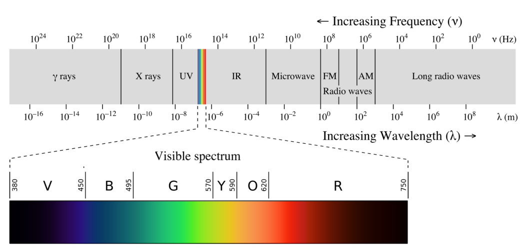


A wave can be described by its wavelength, frequency, period, and amplitude. Wavelength (λ) is the distance between repeating points within a wave, and is measured in meters. Frequency (f) is a measure of how many oscillations occur every second, and is measured in Hertz (Hz). One hertz is defined as one oscillation per second. The energy transported by a wave is directly proportional to its frequency. Period is the amount of time it takes for one cycle of the wave to complete. Period can be found by taking the inverse of the frequency (p=1/f). Amplitude describes how far from its center point the wave oscillates.

The wavelength and the frequency of a wave are related to its speed. $V_{wave}=\lambda*f$. Based on this formula, frequency and wavelength are inversely proportional. When one of the values increases, the other will decrease.
In electromagnetic waves, this formula becomes $c = \lambda*f$. Since c is a constant, we can use this formula to find wavelength or frequency instead. $f = 3x10^8/\lambda$, or $\lambda = 3x10^8/f$

Electromagnetic Spectrum

The electromagnetic spectrum describes all of the wavelengths and frequencies carried by EM waves. These are divided into sections, and are used to describe ranges of waves.
From highest to lowest wavelength are: radio waves, microwaves, infrared waves, visible light, ultraviolet, x-rays, and gamma rays.



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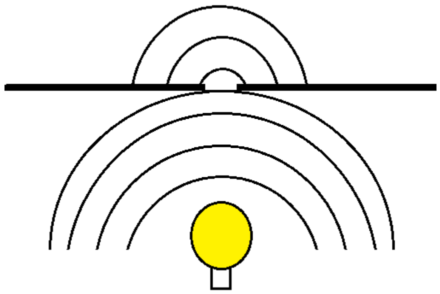
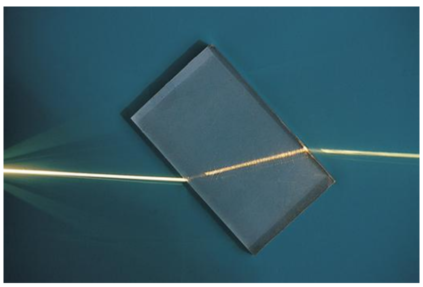
Properties of Waves

Diffraction



When waves pass an obstacle, they will bend around the corners and spread (propagate) out into the surrounding area. The waves treat the object they are diffracting around as if it were a source of the waves.



Refraction

Refraction is the change in direction in a wave, when passing from one type of medium to another. When this occurs, the frequency of the waves do not change, but the wavelength does.

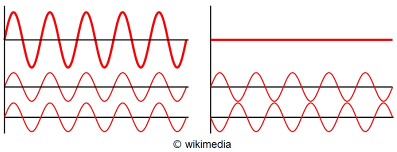
In the image on the left, you can see a beam of yellow light entering a block of plastic, changing direction. In the plastic, the light appears orange, due to the change in wavelength of the light. When exiting the plastic, the light returns to its original wavelength and direction.

This occurs due to the phase velocity of light in different materials. Earlier, we said that the speed of light in vacuum is 3×10^8m/s. In different materials, light will move more slowly due to matter getting in the way and slowing it. Since the formula for the speed of a wave is $V_{wave}=\lambda * f$, if frequency remains constant and the velocity of the wave decreases, wavelength must decrease as well.

Interference

Interference occurs when two waves of the same frequency overlap (superimpose) on each other. When this happens, the waves will be added together. Waves of the same frequency will have the same sinusoidal shape, but the high and low points on the wave may not line up.
We use the term “phase” to describe the offset of the two waves from each other. An offset of 0° means the waves start at the same time, while an offset of 180° means that one wave starts midway through the second.
Waves with an offset of 0° are described as being “in phase”, and will compliment each other, creating constructive interference. Waves that are not in phase with each other will either partially or completely cancel each other out, creating destructive interference.

In the diagram below, the top line shows the result of combining the two waves below it.



On the left side, the waves are in phase, creating constructive interference and making a wave with a higher amplitude (distance from the midpoint of the wave).
On the right side, the waves are out of phase, causing destructive interference to cancel out the waves.
Interference will always change the amplitude of the wave, multiplying it by between 2 and 0

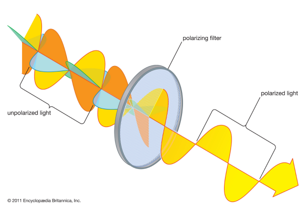
Types of Waves

We can identify different types of waves by describing the direction they move (propagate), compared to the direction they oscillate

Transverse

Transverse waves will have an oscillation that is perpendicular to the direction of motion. All EM radiation will create transverse waves.

Polarization



Polarization is a property of transverse waves that allows the direction of the oscillation to be limited to one direction. This can be done by using a filter that blocks waves that do not oscillate in the correct direction.

Longitudinal

Longitudinal waves will have an oscillation that is parallel to the direction of motion.

Longitudinal waves will create compression and expansion as the waves pass through a medium. Longitudinal waves cannot be polarized. Examples of longitudinal waves include sound waves, waves in water, and oscillations in a spring.

Doppler Effect

The doppler effect is a change in frequency of a wave, based on the relative motion between the source of the wave and the observer. It is easiest to notice the doppler effect in sound waves, since the speed of sound through air is much slower than the speed of EM radiation.

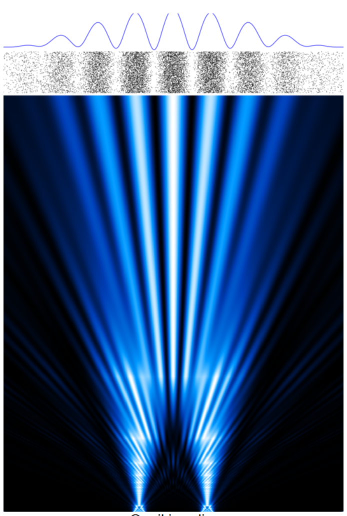
If the distance between the source of the waves and the observer is decreasing, each successive wave begins closer to the observer than the previous wave did. Since there is less

distance to travel, the wave arrives sooner, increasing the frequency of the waves arriving at the observer.
If the distance between the source of the waves and the observer is increasing, each successive wave begins farther from the observer than the previous wave did. Since there is more distance to travel, the time between waves increases, decreasing the frequency of the waves arriving at the observer.

Wave-Particle Duality

In physics, there is a concept called wave-particle duality, which states that particles can act both as particles, as well as like waves. The photoelectric effect describes how em waves can act like a series of discrete particles , rather than as a continuous wave. When looking at electron orbits around atoms, rather than acting as a particle circling the nucleus, they instead act like stable standing waves, which contributes to the stability of matter.
Observing a particle requires bouncing something off of it in order to obtain information, either photons (em waves), electrons, or other particles. However, by impacting something on the particle, we have added energy to it, changing its vector. This means that it is impossible to measure both the position and the velocity of the particle. This is known as the Heisenberg uncertainty principle.

Double Slit Experiment



The double slit experiment involves shining a single light source toward two slits, and observing the resulting constructive and destructive interference caused by the refraction.

A version of the double slit experiment was performed, where instead of using a constant light source, a single photon was released at a time, with its location recorded. After repeating this multiple times, it formed the scatter plot on top of the picture to the left.
Even though there was only a single photon released at once, with nothing to interfere with it, it still acted as a wave, and landed in the portions that corresponded to the areas where constructive interference occurs.

Lenses

A lens is a transparent optical device used to converge or diverge transmitted light. There are two primary lens shapes, converging and diverging.
Converging lenses are made of two convex surfaces, and bend light inward toward their midpoint, creating a real image to form if the object is more than 1 focal length away from the lens, and a virtual image to form if the object is within 1 focal length of the lens.

Diverging lenses are made of two concave surfaces, and bend light outward away from the midpoint of the lens. This creates a virtual image that is located between the lens and the light source.

Lens formula: $\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$ where f = focal length, d_o = distance from object to lens, and d_i = distance from image to lens.

The Atom

The atom is divided into two main sections, the nucleus and the electron orbits. The nucleus of the atom is composed of protons and neutrons connected to each other by the nuclear force (also called the strong force). The neutrons act as a glue to help hold the similarly charged protons together. The nucleus is approximately $1x10^{-15}$m across (1 femtometer).

The electrons are held in orbits surrounding the nucleus by the electric force. The electrons are widely spaced, leaving a large amount of the atom being made of empty space. The orbits of the electrons are stable, allowing the electrons to remain in place without losing any energy.

All atoms are electrically neutral, having the same number of protons and electrons, allowing their charges to cancel out.

Properties of atomic particles

In the atom, there are three particles, the proton, the neutron, and the electron. Protons carry a positive charge, and have a mass of approximately 1 atomic mass unit (amu). Neutrons are neutrally charged, and have a mass of approximately 1 amu. Electrons carry a negative charge, and have a miniscule mass, close to 0 amu.

The vast majority of the mass of the atom is found in the nucleus, as that is where the protons and neutrons are located.

Elements

Elements are groups of atoms that have the same number of protons. Different elements will have different numbers of protons, neutrons, and electrons. The periodic table of the elements lists atoms in order of number of protons, and gives information about their mass and electron orbits.

Ions

Ions are atoms that have gained or lost electrons. Since these do not have equal numbers of protons and electrons, they will have charges. When an atom loses an electron, it will have more positive charges than negative charges, and will become a + ion, called a cation. When an atom gains an electron, it will have more negative charges than positive charges, and become a - ion, called an anion.

Isotopes

Isotopes are atoms of an element that have a different number of neutrons. Because they have a different number of neutrons, these atoms will have a different mass compared to other atoms of that element. When describing isotopes, we will sometimes use the following notation:

$^{z}_{y}X$, where X is the symbol of the element, y is the number of protons, and z is the number of nucleons. Protons and neutrons are both nucleons, particles found in the nucleus.

Using hydrogen as an example, standard hydrogen is written as $^{1}_{1}H$, meaning it has 1 proton and 0 neutrons (1+0 = 1 nucleons). Because it only has 1 proton and no neutrons, hydrogen is also sometimes called protium. One isotope of hydrogen is called deuterium and is written as $^{2}_{1}H$, meaning it has 1 proton and 1 neutron (1+1=2 nucleons). A second isotope of hydrogen is called tritium and is written as $^{3}_{1}H$, meaning it has 1 proton and 2 neutrons (1+2=3 nucleons).

Nucleosynthesis

Nucleosynthesis is the process of creating new atoms, by combining the nuclei of atoms together. This process is also called nuclear fusion. All atoms in the universe were produced by this process. In stars, hydrogen nuclei are fused to form helium nuclei $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$, and helium nuclei are fused to form carbon nuclei $^{4}_{2}He + ^{4}_{2}He + ^{4}_{2}He \rightarrow ^{12}_{6}C$, and other elements up to iron. Elements heavier than iron are produced by the extreme environments created when stars explode in a supernova.

Nuclear Stability

The nucleus of an atom can become unstable due to its composition. Most stable elements have a ratio of protons to neutrons that are between 1:1 and 1:1.5. Having too many neutrons makes the element unstable. The second factor is the number of protons in the nucleus. Elements with 83 or more protons are all unstable.

Due to this instability, the nuclei of these atoms will want to lose nucleons in order to become more stable, in a process called radiation.

Radioactive Decay

Radioactive decay occurs in atoms with an unstable nucleus. The goal of radioactive decay is to remove the cause of the instability, creating a stable nucleus.

Radiation

Alpha (α) decay occurs when there are too many protons and neutrons in the nucleus of the atom.

- Alpha decay will release an alpha particle composed of 2 protons, and 2 neutrons. This alpha particle is the same as a helium nucleus, $^{4}_{2}He$. When alpha decay occurs, the nucleus loses 2 protons and a total of 4 nucleons.
    - Alpha emission does not penetrate matter well due to its size and charge.

Beta (β) decay can occur in order to convert a proton into a neutron, or a neutron into a proton to change the proton to neutron ratio.

- Negative beta decay (β-) will change a neutron into a proton $^{1}_{0}n \rightarrow \ ^{1}_{1}p \ + \ ^{0}_{-1}e$. In order to conserve the charge, when a neutral neutron becomes a positively charged proton, a negatively charged electron is produced to balance the reaction. This electron is then ejected from the nucleus at very high speeds.
    - Beta negative decay adds 1 to the number of protons, changing the element.
    - Beta emissions can penetrate through all but very dense matter
- Positive beta decay (β+) will change a neutron into a proton $^{1}_{1}p \rightarrow \ ^{1}_{0}n \ + \ ^{0}_{1}e$. In order to conserve the charge, when a positively charged proton becomes a neutral neutron, a positively charged positron is produced to balance the reaction. A positron is a form of antimatter, and is the opposite of an electron. This positron is then ejected from the nucleus at very high speeds.
    - Beta positive decay subtracts 1 from the number of protons, changing the element.
    - Beta emissions can penetrate through all but very dense matter.

Gamma (γ) decay occurs when the nucleus of the atom contains too much energy.

- Gamma decay releases energy from the nucleus in the form of a high energy photon $^{0}_{0}\gamma$ rather than one of the nuclear particles.
    - Gamma decay does not change the composition of the nucleus.
    - Gamma emission has the highest penetration of all radiation types.

Radioactive Decay Equations

It is possible to write out a radioactive decay in the form of an equation, where the left side of the equation is the original atom and any materials that were absorbed, and the left side holds the final atom and any materials that were emitted.

Ex: Uranium-238 undergoes 8 α decays, and 6 β- decays.

$$^{238}_{92}U \rightarrow 8 \ ^{4}_{2}\alpha \ + \ 6 \ ^{0}_{-1}\beta \ + \ ^{y}_{z}X$$

To solve this, you can write this out as two sets of equations, one for the number of nucleons and one for the number of protons.

238 = 8*4 + 6*0 + y → 238 = 32 +y → y = 206

92 = 8*2 + 6*-1 + z → 92 = 16 - 6 + z → z = 82

Combining these we find the answer is $^{206}_{82}Pb$. To find the element symbol, look up the element on the periodic table using the number of protons.

Half Life

Half life is a way to describe the speed of radioactive decay. A half life is the period of time it takes for 50% of a material to change by radioactive decay. After each half life, we reduce the quantity of the original material by an additional 50%. Since each halflife divides the quantity by 2, recognizing powers of 2 will help identify how many half lifes have occurred.
2^1=2, 2^2=4, 2^3=8, 2^4=16, 2^5=32, 2^6=64, 2^7=128, 2^8=128…
If you know the number of half lives that have occurred and the total amount of time that has elapsed, you can find how long each half life is by dividing time/# of half lives.
If you know the amount of original material and the number of half lives, you can solve for the amount that currently remains through the equation $current = original * \frac{1}{2^{HL}}$, where HL is the number of half lives that have occurred.

Ex: if 1/64 of a sample remains, how many half lives have occurred?
1/64 = 1/2^6, so 6 half lives have occured

Nuclear Fission

Nuclear fission is a reaction where a nucleus splits into two or more smaller nuclei. In nuclear fission, a neutron is added to a nucleus of a fissionable element such as ^{235}U, or ^{239}P, causing it to become unstable and break apart into large pieces called the fission products, as well as neutrons.
The neutrons that are emitted will impact nearby atoms, and will cause fission in fissionable atoms. Since each atom releases two neutrons, this can cause an exponential chain reaction, where a very large number of atoms undergo fission and release a large quantity of energy. This is what occurs in nuclear weapons.
Nuclear power uses a controlled version of fission, where there are materials used to absorb excess neutrons, preventing the fission of too many atoms at once. This causes less energy to be released at once, but allows for the release of energy over a very long time. Due to absorbing neutrons, the materials within the nuclear will form unstable isotopes that will undergo radioactive decay.

Electron Orbits

The electrons surround the nucleus of an atom in a series of layers called the electron orbits. These orbits mark the stable points where electrons can stay without losing energy. In order to move between electron orbits, the electron requires a certain amount of energy. The farther away from the nucleus an orbit is, the more energy it takes to reach that orbit.
Each of these orbits can only hold a certain number of electrons, as described by the Pauli exclusion principle. If too many electrons are in the same orbit, some of them will be forced to move to a higher orbit.

Emissions spectrum

In order to gain energy, electrons will absorb energy from photons that impact them. However, an electron will only absorb energy from a photon that delivers exactly the amount of energy it would need to move to the next orbit. If a photon that has too much or too little energy impacts the electron, it will not interact with it, and the photon will move through it. This is called transparency.

If an electron absorbs energy from a photon and moves to a higher orbit, it will want to return to its lowest possible energy state, and drop back down to a lower orbit. In order to drop back down, the electron will need to release energy in the form of a photon. The frequency of the photon released depends on the type of element, and is referred to as the spectra of that element. These photons could be in the visible light or the infrared spectrum.

Electron Configuration

Electron configuration refers to how electrons are arranged in an atoms' electron orbits. Each orbit, or shell, refers to a layer surrounding the nucleus and the previous layer of electrons. These orbits can be broken down into subshells and electron orbitals.

In the first electron orbit, there is only room for a single "s" subshell. An s subshell contains two electron orbits.

The second electron orbit contains an s and a "p" subshell. The p subshell contains a total of 6 electron orbits.

The third electron orbit contains an s, p, and a "d" subshell. The d subshell contains a total of 10 electron orbits.

Electron orbits above the third contain an s, p, d, and an "f" subshell. The f subshell contains a total of 14 electron orbits.

The electron orbits are sometimes numbered, using the symbol m. m = 1 is the first orbital level, m = 2 is the second, etc.

The subshells are also numbered, using the symbol "l". l = 0 represents an s orbital, l = 1 represents a p orbital, l = 3 is a d orbital, l = 4 is an 4 orbital.

Electron orbits are filled according to the Madelung rule. Under this rule, add the m+l values, and place electrons into the shell with the lowest values first. Following this rule, we get the following order:

1s→2s→2p→3s→3p→4s→3d→4p→5s→4d→5p→6s→4f→5d→6p→5f→6d….

Valence Electrons

Valence electrons are the electrons in the outermost electron orbit of an atom. These are the electrons that are able to interact with surrounding atoms. Under the octet rule, all atoms want to have a full valence shell. Atoms with one electron orbit can have a maximum of 2 electrons, while atoms with two or more electron orbits can have a maximum of 8 electrons

Periodic Table Groups

Each column on the periodic table represents one group of elements. Each of these groups is organized by the number of valence electrons they have. All groups ending in A (1A, 2A, 3A, 4A, 5A, 6A, 7A, 8A) represent the number of valence electrons in the atoms of that group. Only the elements of group 8A have a full valence shell. Elements in the same group will have similar chemical properties due to having the same number of valence electrons.

Completing a Valence Shell

In order to fill their valence shell, atoms will want to either gain or lose electrons. Losing electrons can lead to a full valence shell, because under each incomplete shell is a previously completed one.

Valence Electrons	Gain	Lose
1	7	1
2	6	2
3	5	3
4	4	4
5	3	5
6	2	6
7	1	7
8	0	0

This chart shows how many electrons elements in each of these groups would need to gain or lose in order to reach a full valence shell.

Elements with 1-3 valence electrons will find it easier to lose electrons to complete a valence shell compared to filling a shell by gaining electrons. These are the metals.

Elements with 4-7 valence electrons will find it easier to gain electrons to complete a valence shell compared to filling a shell by losing electrons. These are the nonmetals.

Chemical Bonding

Chemical bonds occur in order to exchange electrons between atoms in order to complete their valence shells. There are two primary types of chemical bonds, Ionic bonds and Covalent bonds.

Ionic Bonds

Ionic bonds are formed when one atom takes an electron from another. These are most commonly seen between atoms in periods 1-3A and atoms in period 7A. Another way to describe this is to say ionic bonds are created between metals and nonmetals, where nonmetals are the elements that make up the upper right corner of periods 4-7A.

When the first atom loses the electron, it becomes a positively charged cation, and at the same time the second atom gains the electron and becomes a negatively charged anion. Due to having opposite charges, these atoms will attract each other, forming a bond.

When writing out an ionic bond, make sure to pay attention to the period of the atoms involved. The total charge in the bond must balance out to 0. If there are too many charges from one atom, add additional atoms to balance.

Period	1A	2A	3A	5A	6A	7A
Charge	+1	+2	+3	-3	-2	-1

Ex: An ionic bond forms between sodium (1A) and Sulfur (6A), what is the material formed?

Na^{+1} + S^{2-} we need to balance the number of charges. Since there are 2 negative charges, we need 2 positive charges. We can do this by adding a second sodium

$2Na^{+1} + S^{2-} \rightarrow Na_2S$

A trick for balancing charges: The charge of each atom tells you how many of the other atoms you need.

Ex: If I want to form a bond between X^{+2} and Y^{-3}, the shortcut above says I need 3X and 2Y. This works because it is a method to find the lowest common multiple of the charge, $3*2^+ = 6^+$. $2*3^- = 6^-$, balancing the charges.

Naming Ionic Compounds

When naming ionic compounds, the name will be made of two words. The first word is the name of the cation, while the second will be the root of the name of the anion, with a suffix. If the anion is a single type of atom, attach the suffix “-ide”. If the anion is polyatomic, select the name from the chart of polyatomic ions

Ex: $CaO \rightarrow$ Calcium Oxide

Sodium Phosphate $\rightarrow Na_3PO_4$

Name	Formula
Ammonium	$(NH_4)^+$
Hydronium	$(H_3O)^+$
Nitrite	$(NO_2)^-$
Nitrate	$(NO_3)^-$
Sulfite	$(SO_3)^{2-}$
Sulfate	$(SO_4)^{2-}$
Phosphate	$(PO_4)^{3-}$

Name	Formula
Cyanide	$(CN)^-$
Hydroxide	$(OH)^-$
Permanganate	$(MnO_4)^-$
Peroxide	$(O_2)^{2-}$
hypochlorite	$(ClO)^-$
Chlorite	$(ClO_2)^-$

Name	Formula
Chlorate	$(ClO_3)^-$
Perchlorate	$(ClO_4)^-$
Bromate	$(BrO_3)^-$
Acetate	$(C_2H_3O_2)^-$
Chromate	$(CrO_4)^{2-}$
Carbonate	$(CO_3)^{2-}$

Transition Metals (Group B)

The elements of group B have valence electrons in more than one shell, and may have multiple oxidation states. When discussing these elements, we usually indicate their oxidation state by writing the oxidation state in roman numerals in a set of parentheses after the name. Two examples of this are copper and iron.
Copper has two oxidation states, $Copper_{(I)}$ which is +1 and $Copper_{(II)}$ which is +2. When forming ionic compounds, Copper(I) is called cuprous and Copper(II) is called cupric.
Iron also has two oxidation states, $Iron_{(II)}$ which is +2, and $Iron_{(III)}$ which is +3. When forming ionic compounds, $Iron_{(II)}$ is called ferrous, and $Iron_{(III)}$ is called ferric.

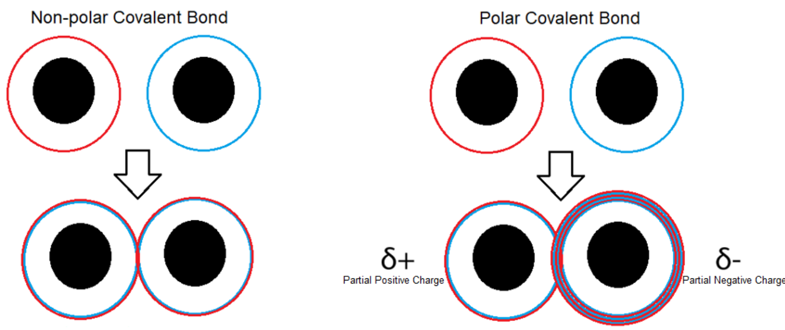
Covalent Bonds

Covalent bonding occurs when pairs of nonmetal atoms will share electrons with one another. In this case, the electrons will pass around both atoms, counting toward the valence shell of both.

When atoms have an equal attraction toward electrons, the shared electrons spend equal amounts of time around each of the atoms. When one atom attracts the electrons more strongly than the other, the electrons will spend more time orbiting that aton compared to the second. There are two types of covalent bonding: polar covalent bonding, and nonpolar covalent bonding.

Polar covalent bonds occur in atoms that have different levels of attraction toward electrons, leading the electrons to spend more time around one atom than the other. This creates one atom with a small negative charge, and one atom with a small positive charge.

Nonpolar covalent bonds occur in atoms that have the same level of attraction toward electrons, leading to equal sharing of the electrons and their charges. In nonpolar molecules, there are no charges on the atoms



Naming Covalent Bonds

When naming covalent bonds, we use a prefix to describe the number of atoms in the compound, then name it like ionic compounds, "first chemical" "root of second chemical"-ide
1 = mono, 2 = di, 3 = tri, 4 = tetra, 5 = penta, 6 = hexa, 7 = hepta, 8 = octa, 9 = nona, 10 = deca
If there is only one of the first chemical, we often drop the prefix.
Remember: These rules are only for bonds of two nonmetals, if a metal is involved it is ionic

Ex: Nitrogen dioxide → NO_2

N_5Cl_6 → Pentanitrogen Hexachloride

Chemical Reactions

A chemical reaction is a process that results in the rearrangement of the molecular or ionic structure of a substance.

Chemical Equations

Chemical equations show the materials that are present at the start of a chemical reaction, called the reactants on the left side, and the chemicals that are created by the reaction, the products, on the right side. Instead of an equal sign, the sides of the reaction are separated by an arrow that shows the direction of the chemical reaction.
Using $xA + yB \rightarrow zC$ as an example of a chemical equation, x,y, and z are coefficients that show how many of each chemical is involved in the reaction, while A and B are the reactants that are consumed to produce C, the product.

Balancing Chemical Reactions

When performing chemical reactions, we need to conserve the elements involved in the reaction. Any element that appears as a reactant must also appear in the same quantity in the products.
Steps to balance a reaction

1. List the chemicals present, with quantities on each side
2. Pick an element that is present in only one compound on each side
3. Add a coefficient to that element to balance the numbers on each side.
4. Repeat these steps for all atoms except hydrogen and oxygen
5. Pick the compound with the fewest hydrogen atoms, add a coefficient to balance it
6. Pick the compound with the fewest oxygen atoms, add a coefficient to balance it
   Ex: Balance $\_C_7H_{16} + \_O_2 \rightarrow \_CO_2 + \_\ H_2O$
   1) 7 C 1
      16 H 2
      2 O 3
   2) Choose CO_2 on product side, add coefficient of 7, $\_C_7H_{16} + \_O_2 \rightarrow 7CO_2 + \_\ H_2O$
      7 C 7
      16 H 2
      2 O 15
   3) No other chemicals are present, go to 5
   4) Choose H_2O on product side, add coefficient of 8 $\_C_7H_{16} + \_O_2 \rightarrow 7CO_2 + 8H_2O$
      7 C 7
      16 H 16
      2 O 22
   5) Choose O_2 on reactant side, add coefficient of 11 $\_C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$
      7 C 7
      16 H 16
      22 O 22

Types of Chemical Reactions

Combination/Synthesis

Combine multiple reactants into a single product, have the form A + B → C

Decomposition

Break a single reactant into multiple products, have the form A → B + C

Single Replacement

Replaces a single element in a polyatomic molecule. A + BC → B + AC

Double Replacement

Two polyatomic molecules will switch elements. AB + CD → AC + BD

Combustion

Combustion reactions will have oxygen as a reactant, and water and carbon dioxide as products

Mole Unit

The mole is the metric unit of quantity, and represents $6.02x10^{23}$ of an object. This is also called Avogadro's number (N_a). The units of mass on the periodic table use Avogadro's number as a conversion factor to grams. The mass of one mole of an element in grams will be the same number as that element's mass in amu.

Ex: Carbon has an atomic mass of 12.01 amu. 1 mole of carbon weighs 12.01g.

Molecular mass

When calculating the mass of a molecule, we can add up the masses of all of the atoms within that element.

Ex: Glucose ($C_6H_{12}O_6$) 6C = 12x6, 12H = 1x12, 6O = 16x6
72+12+96 = 180g/mol.

Performing Conversions using Molecular Mass

Molecular mass can be used to convert between moles of a substance and mass of a substance.

- Moles = mass/molecular mass
- Mass = moles* molecular mass

Percent composition

If you are asked to find what percent of a molecule's mass an element makes up, first find the total molecular mass, divide the mass of the desired element by the mass of the molecule, then multiply the result by 100%

Ex: what percent of the mass of Glucose comes from oxygen?

Mass of oxygen/mass of glucose x100% → 96/180*100% = 53.3%

Calculating the Number of Particles

If you are asked to calculate the number of particles present, first find out the number of moles present, before multiplying the number of moles by N_A ($6x10^{23}$)

Ex: Calculate the number of Oxygen atoms present in 1.5 moles of Calcium Phosphate.

1. Find the chemical formula of the molecule $Ca_3(PO_4)_2$
2. Calculate the number of moles of atoms in the compound. O_4*2 = 8 O atoms per 1 mole of the compound.
3. Multiply by the number of moles of the compound. 8*1.5 = 12 moles of O atoms total.
4. Multiply the number of moles by N_A. 12*$6x10^{23}$ = $7.2x10^{24}$

Solubility

Solubility refers to the ability of a solid, liquid, or gas to dissolve into a liquid. The substance being dissolved is called the solute, while the liquid is called the solvent. Water is the most commonly used solvent, but other chemicals may also be used. A liquid mixture that uses alcohol as a solvent is called a tincture.

The type of chemical bonds found in the solute will affect its ability to dissolve different substances. Polar solvents are able to dissolve polar and ionic solutes, but cannot dissolve nonpolar solutes. Nonpolar solvents are able to dissolve nonpolar solutes, but not polar or ionic solutes.

Typically, there is a limit to the amount of solutes that can be dissolved in any quantity of solvent. Once the solution has the maximum amount of solutes dissolved, we describe this solution as saturated. If any additional solutes are added, they will be unable to mix with the solvent.

Factors affecting solubility

Temperature changes can alter solubility, depending on the type of solute. Solubility of solids is directly proportional to temperature, as temperature increases, solubility increases. The solubility of gasses are inversely proportional to temperature of the solute, as temperature increases, solubility decreases.

Pressure changes also affect solubility of gasses. Pressure and solubility are directly proportional, with higher pressures increasing the amount of gas that will dissolve into the solvent.
Surface area will change the rate that a solute will dissolve, but does not affect the total amount that can be dissolved. Rate of dissolving will be directly proportional to surface area, with a higher surface area increasing the rate the material dissolves at.

Supersaturation occurs when the solubility of a saturated solution is decreased. When a supersaturated solution is disturbed, the material that exceeds the maximum will leave the solution. Dissolved solids will form a precipitate and fall to the bottom. Dissolved gasses will form bubbles and float to the top. Dissolved liquids will separate and form a layer above or below the solute based on their density.

Types of Solutions

True solutions contain solutes of very small size. These solutes cannot be filtered out of the solution, and will not settle out over time. When shining light through a true solution, the fluid appears transparent, with no scattering of light off of particles (Tyndall effect)

Colloidal solutions contain solutes that are larger than those in true solutions. These solutes can be filtered out of the solution, and will settle over time. When light is shined through a colloid, the fluid appears translucent and light is scattered off of the particles in the solution

Suspensions have the largest solutes. The solutes can be filtered out of the solution, and will settle quickly. When light is shined through a colloid light is scattered off of the particles in the solution, and does not pass through the entire solution.

An amalgam is a solidified solution of materials that were melted, mixed together, then allowed to cool.

Calculating Concentration

When measuring concentration of a solution, we use the units Molarity. Molarity is defined as being the number of moles of solute per mole of solvent, or M = moles/L

Ex: find the molarity of a solution of 500mL of water and 200g of calcium carbonate

1) Find the molar mass of $CaCO_3$ = 40+12+(16*3) = 100g/mole
2) Find the number of moles of $CaCO_3$ 200g/100g/mole = 2 moles
3) Find the number of liters of water: 500mL → 0.5L
4) Plug into M = moles/L → 2/0.5 = 4 molar.

Performing Chemical Reactions

When performing a chemical reaction, you must have all of the reactants listed in the reaction equation. The units used in the chemical equations are moles, so if given grams you must convert using molar mass.

A chemical reaction will run until you exhaust at least one reactant. You can calculate how many reactions worth of reactants you have by dividing the moles of reactant by the coefficient of that reactant. The chemical reactant that allows for the fewest number of reactions will be the limiting reactant. Once this reactant is exhausted, the chemical reaction will end.
You can predict how much product the reaction is capable of producing, by multiplying the number of reactions possible from the limiting reactant and the coefficient of the products.

Ex: Given the reaction $A + 2B \rightarrow 3C$. If you start with 3 moles of A and 5 moles of B, how many moles of C can be produced?

1. Calculate the numbers of reactions possible for reach reactant:
   A = 3/1 = 3 reaction. B = 5/2 = 2.5 reactions.
   Since B can support fewer reactions than A, it is the limiting reactant.
2. Multiply the coefficient of the product by the number of reactions possible from the limiting reactant. 3*2.5 = 7.5 moles of C produced.

Acids and Bases

Acids and bases can be defined by several different theories.

- Arrhenius theory describes acids as chemicals that dissolve in water to form hydronium ions (H_3O^+), and bases as dissolving in water and producing hydroxide ions (OH^-)
- Bronsted-Lowry Theory describes acids as proton donors, releasing H^+ ions , while bases act as proton receptors, absorbing H^+ ions
  - In the Bronsted-Lowry theory, water can act as an acid or as a base (amphiprotic)

The strength of an acid is related to the amount of acid molecules that break up to release H^+, not just the total quantity of the molecules added to a solution. Similarly, the strength of a base is related to the amount of H^+ the base is able to bond, not just the quantity of the base

In chemistry, a strong acid is any acid that 100% ionizes.
Strong acids include: Chloric acid: $HClO_3$, Hydrobromic acid: HBr, Hydrochloric acid: HCl, Hydroiodic acid: HI, Nitric acid: HNO_3, Perchloric acid: $HClO_4$. Sulfuric acid: H_2SO_4.
All other acids will only partially ionize and are called weak acids.

Most acids release a single proton, and are called monoprotic acids. Acids that release two protons are called diprotic acids. An acid that could release three protons would be triprotic.

In the Bronsted-Lowry theory, after an acid releases its proton, the chemical that is formed is capable of accepting a proton, and is called a conjugate base. SImilarly, a base that has accepted a proton is now capable of releasing that proton, and is called a conjugate acid.

Ex: When HNO_3 releases a proton, it forms its conjugate base, NO_3^-.
When ammonia (NH_3) absorbs a proton, it forms its conjugate acid, ammonium ($NH4^+$)

pH scale

The pH scale is used to measure the concentration of acids and bases. It is a logarithmic scale, operating on powers of 10, with each number on the scale being 10 times more or less than the previous number. pH is calculated by taking the logarithm of the proton (or hydronium) concentration, then negating it, or: pH = -log[H_3O^+]
Remember, log is the opposite as 10^x, allowing you to cross them both out.

In pure water, at room temperature, the concentration of H_3O^+ and OH^- are both 1x10^7M. This allows us to set up an equivalence, with [H_3O^+]*[OH^-]=1x10^{14}. Using this we can calculate the concentration of hydronium if we know the concentration of hydroxide, and the concentration of hydroxide if we know the concentration of hydronium.
[H_3O^+]=1x10^{-14}/[OH^-] and [OH^-]=1x10^{-14}/[H_3O^+]

Ex: if the OH^- concentration is 1x$10^{-4,}$ find the pH

1. Find [H_3O^+]: [H_3O^+]=1x10^{-14}/1x10^{-4} = 1x$10^{(-14 - -4)}$ = 1x10^{-10}
2. Plug in [H_3O^+] to pH formula: pH = ~~-log~~*~~10~~$^{-10}$ → pH = -*-10 = 10

When equal concentrations of hydronium and hydroxide are present, they will react together, forming water. This will naturally occur when the hydronium concentration is 1x10^{-7}. If we plug this number into the pH formula, we get pH = -log(10^{-7}) = 7. This is why we describe pH 7 as being neutral, since the acid and the bases in water will neutralize each other at this concentration.
As concentrations of hydronium increase, pH numbers decrease, meaning pH below 7 are acidic.

Ex: pH 6 has a hydronium concentration of 10^{-6}, while pH 5 is 10^{-5}, 10x larger.

As concentrations of hydronium decrease, concentration of hydroxide and pH numbers both increase, meaning pH above 7 are basic.

Organic Chemistry

Organic Chemistry is chemistry involving carbon compounds. Carbon has 4 valence electrons, allowing it to make 4 bonds. This allows carbon to form complex molecules

Lewis Structures

Lewis structures are a way of drawing out the chemical structure of a molecule. In a Lewis structure, atoms are drawn surrounded by a number of dots equal to their valence electrons. Lines representing covalent bonds are then drawn between single dots of adjacent atoms. A single bond is represented by one line, two bonds are represented by two lines, and 3 bonds are represented by three lines connecting the atoms.

Naming Organic Compounds

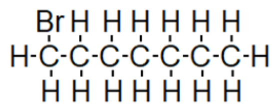
The basic structure of an organic compound is a hydrocarbon chain, that is a chain of carbon molecules bonded to two other carbons, with any additional available bonds being used to attach to hydrogen. These chains are given a prefix based on the number of carbon atoms in the molecule.
1 = meth, 2 = eth, 3 = prop, 4 = but, 5 = pent, 6 = hex, 7 = hept, 8 = oct, 9 = non, 10 = dec.
The suffix attached is based on the types of bonds between the carbons in the chain.

- If the chain contains only single bonds, it is called an alkane, and adds the suffix -ane.
  - Alkanes have a ratio of $2n+2$ hydrogens for each carbon in the chain
- If the chain contains a double bond, it is called an alkene, adding the suffix -ene.
  - Alkenes have a ratio of $2n$ hydrogens for each carbon in the chain.
- If the chain contains a triple bond, it is called an alkyne, adding the suffix -yne.
  - Alkynes have a ratio of $2n-2$ hydrogens for each carbon in the chain.
- Alkyl groups contain single bonds, but are missing one hydrogen, they add the suffix -yl.
  - Alkyls have a ratio of $2n+1$ hydrogens for each carbon in the chain.

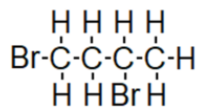
Substituents are functional groups (specific molecules), elements, or alkyl groups added in the place of a hydrogen atom. When naming organic compounds, we must list the substituents, and identify which carbon in the chain it is attached to. Carbons are numbered by counting from the substituent to the end of the chain, choosing whichever is the smallest number.
If there is more than one of the same substituents present, write the numbers of the carbons they are attached to, separated by commas, then a prefix for the number of substituents, followed by the name of the substituent. If multiple types of substituents are present, they are listed in alphabetical order, and numbered individually.

Naming hydrocarbons:

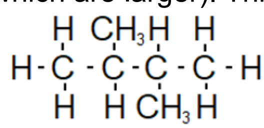
1. Identify the longest chain of carbons to select the appropriate prefix
2. Identify the bonds of the carbons to select the suffix.
    a. If a double or triple bond is present, identify which carbon the bond is at
3. Identify substituents and the carbons they are attached to
4. List alphabetically the numbers of the carbons the substituents are attached to, then the name of the substituent with the appropriate prefixes for quantities

    Ex: Name this compound 

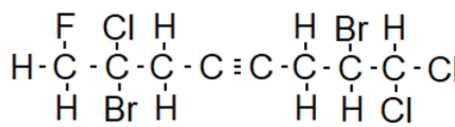
    This compound contains 7 carbons, single bonded (Heptane), and has a bromine attached to the first carbon from the left, or the seventh from the right. Thus the name is 1-bromoheptane.

    Ex: Name this compound 

    This compound contains 4 carbons in its longest chain, and has only single bonds (butane), and has 2 bromines, attached to carbons #1 and 3 (since counting from the other side gives 2 and 4, which are larger). This gives the name 1,3-dibromoheptane.

    Ex: Name this compound 

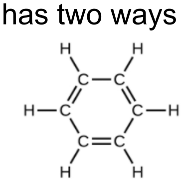
    This compound has 4 carbons in its longest chain, contains only single bonds, and has two methyl (CH_3) groups attached at carbons 2 and 3. This gives the name 2,3-dimethylbutane

    Ex: name this compound 

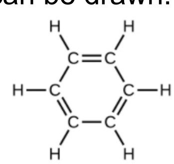
    This compound has 8 carbons in its longest chain. There is a triple bond at carbon #4. Three different elements are added as substituents: 2 bromine on carbons 2 and 7, 2 chlorines on carbon 1 and 1 chlorine on carbon 7, and 1 fluorine on carbon 8. This gives the name: 2,7-dibromo-1,1,7-trichloro-1-fluoro-4-octyne.

Aromatic Compounds

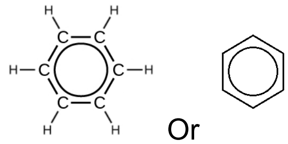
Aromatic compounds that include a ring of hydrocarbons. The simplest aromatic is benzene, with the formula C_6H_6. Benzene has two ways it can be drawn:



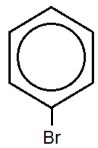
Or



Because there are two different ways to draw the locations of the double bonds, we describe this as a resonance structure, and draw the structure as

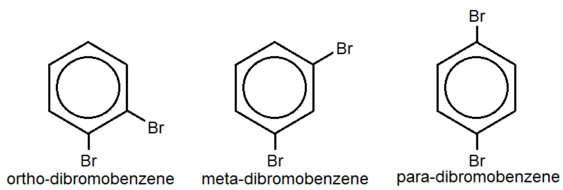


Aromatic structures can also have substitutions added. With a single substitution, the compound is named (name of the substituent)-benzene

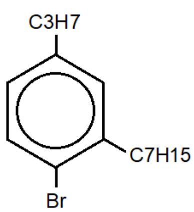
Ex: Name 

Bromobenzene

When there are two substituents, there are special terms based on the spacing between the substituents. When substituents are on adjacent carbons, we call this as “ortho”. When the substituents are separated by one carbon, we call this as “meta”. When the substituents are separated by two carbons, we call this “para”



If there are more than two substituents, identify the substituents and the carbons they are attached to and list them in alphabetical order.

Ex: 

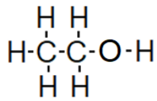
1-bromo-2-heptyl-4-propyl butane

Functional Groups

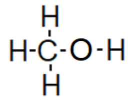
Functional groups are specific atoms bonded in a certain arrangement that give a compound certain physical and chemical properties.

Alcohol: An alcohol is an OH molecule single bonded to an alkyl chain.

Alcohols are named for the alkyl + with the suffix “anol”

Ex: 

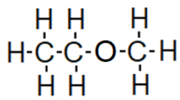
Ethanol



Methanol

Ether: An Ether is an oxygen atom single bonded to two alkyl groups.

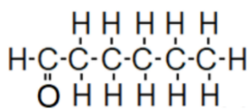
Ethers are named for the alkyl groups on either side of the oxygen + “ ether”

Ex: 

Ethyl-Methyl Ether

Aldehyde: These are similar to ketones, but instead of bonding to two alkyl groups, there is a bond to one alkyl, and a hydrogen.

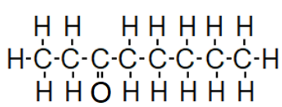
Aldehydes are named for the alkane, then replacing the final “e” with “al”, or by naming the alkyl and adding the suffix “aldehyde”

Ex: 

Hexanal or Hexanaldehyde

Ketones: A Ketone is a carbon that forms a single bond with two alkyl groups, and a double bond with oxygen.

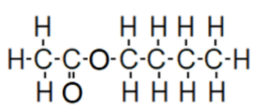
Ketones are named for the alkane, then replacing the final “e” with “one”, or by listing the alkyl groups with the suffix “ketone”

Ex: 

3-octanone or ethyl-pentyl-ketone

Ester: An Ester is a Carbon with a single bond to an alkyl, a double bond to an oxygen, and a single bond to a second oxygen that then attaches to another alkyl.

Esters are named for the alkane, then replacing the final “e” with “oate”

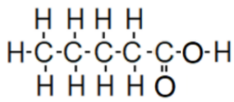
Ex: 

Ethyl-Butanoate

Carboxyl: A Carboxyl group is a Carbon with a single bond to an alkyl, a double bond to an oxygen, and a single bond to an alcohol group.

Carboxyl groups are used to form esters, aldehydes, and ketones.

Carboxyl groups are named for the alkane, then replacing the final “e” with “oic acid”

Ex: 

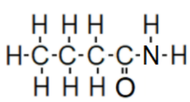
pentanoic acid

Amide: Amides are an ammonia derivative (NH_3) that forms a bond with a ketone. Primary amides are NH_2 attached to the ketone. Secondary Amides will have NH attached to the ketone on one side, and an alkyl chain attached on the other side. Tertiary amides will have N attached to the ketone on one side, and two alkyl chains attached on the other side.

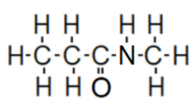
Primary amides are named for the alkane, replacing the final “e” with “amide”

Secondary amides add an “N” to the start of the name.

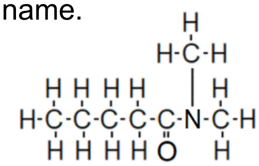
Tertiary amides add “N,N” to the start of the name.

Ex: 

Butanamide
Primary
Amide



N-Methylpropanamide
Secondary
Amide



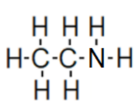
N,N-Dimethylpentamide
Tertiary
Amide

Amine: Amines are derivatives of ammonia (NH_3) that form bonds with alkyls by removing a hydrogen. Primary amines have one alkyl chain attached to NH_2. Secondary Amines have one alkyl attached to NH. Tertiary Amines have three alkyls attached to a N.

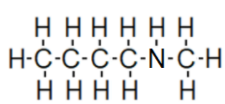
Primary amines are named for the alkane, and treated as substitutions called “amino”

Secondary amines add an “N” to the start of the name.

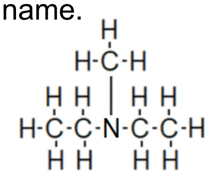
Tertiary amines add “N,N” to the start of the name.

Ex: 

Ethylamine
Primary
Amine



N-Methylbutylamine
Secondary
Amine



N,N-Diethylmethylamine
Tertiary
Amine

Practice Exam Questions WIth Solutions

Exam 1 Review

1. Evaluate the following to the correct number of significant figures:
a) $6.000x10^8$/ $0.15x10^{-6}$ b) 66.666 x 10^{-9}/3.3 x 10^{-3} c) 10^{-11} /10^{-23} d) 3.33333 x 2

a) $6.000x10^8$ has 4sf, $0.15x10^{-6}$ has 2sf, so the answer should have 2sf. = $4.0x10^3$
b) 66.666 x 10^{-9} has 5sf, 3.3 x 10^{-3} has 2sf, so the answer should have 2sf. = $2.0x10^{11}$
c)10^{-11} has 1 sf, 10^{-23} has one 1sf, so the answer will have 1sf. = 10^{+12}
d) 3.33333 has 6sf, 2 has 1 sf, so the answer will have 1sf. = 2

2. What is the momentum & KE of a 20 N object moving at 3 m/s ?

Note, you are not given mass, which is required for p and KE, so find it first.
Weight = m*g → m = weight/g. m =20/10 = 2kg
Momentum: p = m*v → 2*3 = kgm/s
KE = $1/2mv^2$ → $2*3^2/2$ = 9J

3. A 10 kg object moving at a speed of 30 m/s decelerates at a rate of -4 m/ $s^2$for 4 seconds. What is the new speed of the object?

Given: V_0, a, t Find: V_f
Using the formula a = Δv/t, rearrange the formula to make V_f= a*t+V_0→ -4*4+30 = 14m/s

4. A 60 kg diver stands on top of a cliff with a total energy of 90,000 joules. How high is the cliff and what is her speed when she is ¼ of the way down.

TE = PE+KE, initial KE = 0, so initial PE = 90,000J.
PE = m*g*h → 90,000 = 60*10*h → h = 150m
¼ of the way down, ¼ of the PE has become KE.
KE = $1/2mv^2$ → 22,500 = ½*60*v^2 → √(2*22500/60) = v = 27.4m/s

5. A ball is thrown straight upward at a speed of 60 m/s. (a) How long does it take to reach its maximum height? (b) How long is it in the air? C(c) What is the ball's speed when it gets back into the throwers' hand?

a) a = Δv/t → t = Δv/a → 60/10 = 6s
b) The path the ball takes down is the same as the path it took up, so the times and velocities are the same. 6s up + 6s down = 12s.
c) Initial speed was 60m/s, so per b), final speed is 60m/s

6. A toy is dropped from a height of 200 m. How long does it take to hit the ground?

Given: d, V_0=0, a = gravity. Find: t
Using the formula d = V_0*t+½*a*t^2 → d = ½*a*t^2 → √(2d/a) = t → √40 = t = 6.3s

7. A stone is dropped from a tree branch and hits the ground 4 seconds later. How high is the branch?

Using the formula d = V_0*t+½*a*t^2→ d = ½*a*t^2 → ½*10*16 = 80m

8. An object undergoes uniform circular motion. If both the mass and speed of the object are doubled, what happens to the centripetal force on the object? Suppose that the mass & speed remain constant but the radius of the circle is halved, what then happens to the centripetal force?

Centripetal force = mv^2/r. x2 mass = x2 force, x2 speed = x4 force. 2*4 = 8x force. If radius decreases, force increases by the same amount. ½ radius = 2x force

9. What is the mass & weight of a 68 N object?

The weight is 68N, mass = weight/g = 6.8kg

10. Consider the gravitational force between two masses. What happens to this force if each mass is tripled while the distance between the masses is halved?

F_g=G*m_1*m_2/r^2, F=3*3/$(0.5)^2$ = 9/0.25 = 36x.

11. How many significant figures do each of the following have?

a) 202.004 b) 300 c) 00.00303030300 d) 468.110 e) 0.00040

a) 6sf 202.004 b) 1sf 300 c) 9sf 00.00303030300 d) 6sf 468.110 3) 2sf 0.00040

12. If the mass & velocity of an object are each quadrupled, what then happens to the PE? KE? Momentum?

PE = m*g*h, if mass x4, PEx4

KE = ½ m*v^2. If mass x4 and v x4, then KE 4*4^2=64x

Momentum = M*V If mass x4 and v x4, then momentum x16

13. A 4 kg object moving at 20 m/s collides with a 2 kg object initially at rest. After the collision, the two objects stick together & move off at a velocity V. Find V.

1) Find momentum before collision: p = m*v = 20*4 = 80kg*m/s
2) Apply momentum to the total mass of 2 objects. v=p/m → 80/6 = 13.3m/s

14. A 10 N force acts due East on a 4 kg object while a 7 N force acts due North What is the acceleration of the object?

Since there are multiple force vectors, we need total force.

Form a triangle with sides 10 and 7. The hypotenuse represents the total force

$10^2+7^2 = x^2 \rightarrow \sqrt{(10^2+7^2)} = x = 12.2$N

F = m*a → F/m =a → 12.2/4 = 3m/s

15. A 10 N force, 20 N force & 60 N force all act due West on a 2 kg particle while a 30 N force, 6N force & 4 N force all act due East on the particle . What is the acceleration of the particle?

Find total forces for each direction

West = 10+20+60 = 90. East = 30+6+4 = 40.

Subtract opposite forces: 90W - 40E = 50N west

F=m*a → F/m = a → 50/2 = 25m/s

16 An ideal gas is held at constant temperature. If the initial pressure & volume are 20 atm and 6 mL, respectively, what will be the new volume if the pressure is reduced to 4 atm?

Constant temperature, changing P + V = Boyles law

$P_1V_1=P_2V_2$. → $P_1V_1/P_2=V_2$→ 20*6/4 = 30mL

17. An ideal gas is held at constant pressure. If the initial temperature & volume are 427°C and 11 L, respectively, what will be the new temperature (in°C) if the volume is increased to 33 L?

Constant pressure, changing V + T = Charles' law - **convert to kelvin**

$V_1/T_1 = V_2/T_2$ → T_1*$V_2/V_1 = T_2$ → 700*11/33 = 233.33°K→ -39.7°C

18. An ideal gas is held at constant volume. If the initial temperature & pressure are 1127°C and 40 kPa, respectively, what will be the new temperature (in°C) if the pressure is reduced to 10 kPa?

Constant volume, changing P + V = Gay-Lussac's law - **convert to kelvin**

$P_1/T_1 = P_2/T_2$ → T_1*$P_2/P_1 = T_2$→ 1400*10/40 = 350°K → 77°C

19. What is the pressure exerted by a 40 gram object on an area of 100 mm^2? Give answer in Pascals.

Weight = m*g → 0.04*10 = 0.4N

Convert area to m^2: $(10^3 mm)^2 = 1m^2$ $10^2/10^6 = 10^{-4} m^2$.

Pa = N/m^2 → $0.4/10^{-4}$ = 4000Pa

20. What volume does 4 g of element X occupy if it has a density of 0.02 g/cm^3?

D = m*v → D/m = v → 0.02/4 = 0.005cm^3

21. When 2 Kcal of heat are added to 50 g of element Y, its temperature is raised by 200°C. What is the specific heat capacity of element Y?

Q = m*c*Δt → Q/m*Δt = c → 2000/50*200 = 0.2 cal/g*°c

22. Evaluate the following:

i) 100 m = 10^4 cm = 10^7 mm = 10^{13} nm

ii) 10^6 mm = 10^3 m = 10^5 cm = 1 km

iii) 10^{-4} cm = 10^{-6} m = 10^{-3} mm = 10^{-12} km

iv) 1 inch = 2.5 cm = 2.5x10^{-2} m = 2.5x10^7 nm = 2.5x10^{-5} km

v) 10^{-8} km = 10^{-5} m = 10^{-3} cm = 10^{-2} mm

23. A 4 N object is lifted a distance of 20 m in 6 seconds. How much work was done and how much power was expended?

Work = F*d, Power = Work/t

4*20 = 80J, 80J/6s = 13W

24. 100°F = 37.8°C = 311 Kelvin.

25. 10^6 cm^3 = 1 m^3 = 10^9 mm^3 =10^{-9} km^3

Exam 1, Fall 2015

______1. According to Newton's First Law of motion

a) all objects have inertia
b) force is inversely proportional to mass
c) force is directly proportional to mass
d) for every action force there is an equal & opposite reaction force
e) a body in Uniform motion remains in uniform motion unless acted upon

______2. According to Newton's Second Law of motion

a) all objects have inertia
b) force is inversely proportional to mass
c) force is directly proportional to mass
d) for every action force there is an equal & opposite reaction force
e) a body in Uniform motion remains in uniform motion unless acted upon

______3. The acceleration of a 500 g object under the influence of a 200 N force is ________m/s2

a) 0.4 b) 105 c) 2.5 d) 400 e) 40

F=ma → a=F/m 200/0.5 = 400

______4. A ball is thrown straight upward at an initial speed of 80 m/s. The speed of the object after 11 seconds is _________.

a) 11m/s, upward b) 11 m/s downward c) 30 m/s upward d) 30 m/s downward e) 50 m/s downward

A = Δv/t → at = Δv -10*11 = -110 m/s. 80-110 = 30m/s down

______5. A 60 g object occupying a 0.25 cm3 volume has a density of _________g/cm3.

a) 240 b) 15 c) 4.2 x10-3 d) 80 e) 0.0004

d=m/v 60/0.25 = 240

______6. A rock is thrown straight downward with an initial speed of 30 m/s. After 4 seconds, its speed is __________ m/s.

a) 10 b) 30 c) 40 d) 70 e) 120

$V_f = V_0 + a*t = 30+10*4 = 70$

______7. A 6°C change in temperature corresponds to a _______ °F change.

a) 6 b) 10.8 c) 1.8 d) 18 e) 3.33

1°C = 1.8°F 6*1.8 = 10.8

______8. A ball is dropped and fall 400m. Approximately how long does it take?

a) 4.6 s b) 5.8 s c) 6.4 s d) 8.9 s e) 10.6 s

$d = at^2/2 \rightarrow \sqrt{(2d/a)} = t \rightarrow \sqrt{2*400/10)} \rightarrow \sqrt{80} = 8.9$

______9. An object fall for 4 seconds when dropped from a window. How high is the window?
a) 40 m b) 60 m c) 80 m d) 160 m e) 240 m
$d = at^2/2 \rightarrow 10*4^2/2 = 80$

______10. 0.000200 contains _______ significant figures.
a) 2 b) 3 c) 4 d) 5 e) 6
Leading 0's are insignificant, trailing zeros after a decimal are significant

______11. 2 x 75.33333 = _____________ (significant figures).
a) 150.6666 b) 150.66 c) 150.6 d) 151 e) 200
Keep lowest number of SF when multiplying, want answer w/ 1 SF

______12. An example of an inverse square law is
a) Boyles' Law b) Guy-Lussac Law c) Newton's Law of Gravity
d) Charles' Law e) mancini's Law
Inverse square laws have the form $X = n/y^2$

______13. When the speed of an object is quadrupled, its kinetic energy is
a) doubled b) quadrupled c) increased by 16x
d) decreased in half e) decreased by 4x
$KE=½*mv^2 \rightarrow (4v)^2 = 16x$

______14. What is the speed of a 500 g object with momentum 1000 kg m/s ?
a) 2 m/s b) 4 m/s c) 500 m/s d) 1000 m/s e) 2000 m/s
$P = m*v \rightarrow P/m = v$ 1000/0.5 = 2000

______15. A 4 kg object has a kinetic energy of 50 Joules. What is the speed of the object?
a) 5 m/s b) 10 m/s c) 50 m/s d) 200 m/s e) 18 m/s
$KE=½*mv^2 \rightarrow \sqrt{(2KE/m)} = v \rightarrow \sqrt{25} = v$

______16. An ideal gas is held at constant temperature. The initial pressure & volume are 6 atm and 200 mL, respectively. If the pressure is increased to 30 atm, then the new volume is __________ mL.
a) 30 b) 6 c) 200 d) 40 e) 1000
$P_1V_1 = P_2V_2 \rightarrow P_1V_1/P_2 = V_2 \rightarrow 6*200/30 = 40$

______17. The average kinetic energy of the particles of a system is measured by its
a) PE b) inertia c) entropy d) absolute temperature
e) specific heat capacity

______18. A box measures 2 cm x 2 cm x 3 cm. Its volume is then
a) 7 cm3 b) 12 m3 c) 12 nm3 d) 1.2 x 10-8 m3 e) 12 x 10-6 m3
$2x10^{-2}m*2x10^{-2}m*3x10^{-2}m \rightarrow 12x10^{-2+-2+-2} \rightarrow 12x10^{-6}$

______19. When a body has a change in velocity with time, we call this
a) speed b) momentum c) acceleration d) displacement e) inertia

______20. 10^-16/ 10^-22 = __________.
a) 10^-38 b) 10^6 c) 10^+38 d) 10^-6 e) 10^12
$10^{-16}/10^{-22} = 10^{-16 - -22} \rightarrow 10^{6}$

______21. In the Law of Gay- Lussac, ____________ is held constant.
a) temperature b) pressure c) volume d) entropy e) specific heat

______22. When both the mass and the speed of an object are doubled, the momentum is
a) doubled b) quadrupled c) increased by 16x d) halved e) decreased by 4x
p=mv 2m*2v = 4p

______23. 10^{8} mm^2 = __________km^2
a) 100 b) 10^{4} c) 10^{-4} d) 10^{6} e) 10^{-6}
$1km = 10^{6}$ mm $\rightarrow 1km^{2} = 10^{6}*10^{6} \rightarrow 10^{12}mm^{2}$. $10^{8}/10^{12} = 10^{8-12} \rightarrow 10^{-4}$

______24. An object whose velocity does not change with time has zero ___________.
a) inertia b) speed c) acceleration d) KE e) PE

______25. The disorder of the Universe is
a) increasing b) decreasing c) constant d) exponential e) unmeasurable

______26. A phase transition from a solid to a liquid is called
a) condensation b) melting c) evaporation d) deposition e) sublimation

______27. A phase transition from a gas to a solid is called
a) sublimation b) condensation c) deposition d) evaporation e) melting

______28. The buoyant force is equal to the ____________ of the displaced fluid.
a) mass b) weight c) density d) specific heat capacity e) entropy

______29. An ideal gas is held at constant temperature. The initial pressure and volume are 200 atm and 60 mL, respectively. If the pressure is increased to 10^3 atm, what is the new volume?
a) 100 mL b) 300 mL c) 5 mL d) 12 mL e) 40 mL
$P_1V_1 = P_2V_2 \rightarrow P_1V_1/P_2 = V_2 \rightarrow 200*60/10^{3} = 12$

______30. An ideal gas is held at constant volume. The initial pressure and temperature are 140 Pa and 127°C. If the pressure is changed to 420 Pa, what is the new temperature in °C ?
a) 40 b) 1200 c) 927 d) 627 e) 1027
$P_1/T_1 = P_2/T_2 \rightarrow T_1* P_2/P_1 = T_2 \rightarrow$ 400K*420/140 = 1200K, 1200-273 = 927C

______31. An ideal gas is held at constant pressure. The initial volume and temperature are 80 mL and 327 °C, respectively. If the volume is decreased to 20 mL, what is the new temperature in °C ?

a) 123 b) 981 c) 823 d) -981 e) -123

$V_1/T_1 = V_2/T_2 \rightarrow T_1*V_2/V_1 = T_2 \rightarrow$ 600K*20/80 = 150K -273 = -123C

______32. A car traveling at a speed of 60 m/s then decelerates at a rate of 8m/s2 for 6 seconds. The new speed of the car is

a) 108 m/s b) 48 m/s c) 360 m/s d) 480 m/s e) 12 m/s

$V_f = V_0 + a*t \rightarrow$ 60 * -8*6 = 12

______33. A 50 kg diver stands on top of a cliff with a total energy of 80,000 J. What is the height of the cliff?

a) 1600 m b) 1200 m c) 160 m d) 120 m e) 16 m

PE = mgh → PE/mg = h → 80000/50*10 = 160

______34. From the previous problem, what is the approximate speed of the diver when she is ¾ of the way down?

a) 15 m/s b) 27 m/s c) 33 m/s d) 48m/s e) 57 m/s

¾ of the way down, ¾ of PE has converted to KE = 60kJ KE.

$KE = ½ mv^2 \rightarrow \sqrt{(2KE/m)}=v \rightarrow \sqrt{(120000/50)} \rightarrow \sqrt{2400} = 48$

______35. The mass of a 60 N object is

a) 60 kg b) 600 kg c) 6 kg d) 0.6 kg

e) need to know the weight of the object.

W = m*g → m = W/g → 60/10 = 6

______36. An egg is thrown straight downward at an initial speed of 40 m/s. Its acceleration after 4 seconds is

a) 40 m/s2 b) 400 m/s c) 80 m/s2 d) 10 m/s2 e) 120 m/s2

Acceleration is due to gravity, which doesn't change

______37. The number of significant figures in 0000203.0 is

a) 3 b) 5 c) 8 d) 9 e) 4

______38. An example of a Law that exhibits a direct relationship is ____________ Law.

a) Boyle's b) Newton's c) Archimedes' d) Einstein's

e) Charles'

______39. A thermodynamic version of the Law of conservation of energy was proposed by

a) Coulomb b) Lord Kelvin c) Archimedes d) Newton

e) Claussius

______40. If the masses are each doubled while the separation is halved, then the gravitational force between the two masses is

a) halved b) doubled c) quadrupled d) increased 16 x e) increased 64 x

$F = m_1 * m_2 / d^2 \rightarrow 2*2/(0.5)^2 = 2*2*4 = 16$

______41. When evaporation occurs, the liquid that remains is cooler because

a) the pressure on the liquid decreases
b) the pressure on the liquid increases
c) the volume of the liquid decreases
d) the slowest molecules remain behind
e) the fastest molecules remain behind

______42 . In the city of Denver which is one mile above sea level, water boils at a ___________ pressure and ___________ temperature compared to at sea level.

a) greater, higher b) greater, lower c) lower, lower d) lower, greater
e) same, lower

As altitude increases, pressure decreases, and temp is directly proportional to pressure

______43. When the speed is quadrupled while the radius is halved, then the centripetal acceleration is

a) doubled b) quadrupled c) increased 32x d) increased 64x
e) decreased by 8x

$F=mv^2/r \rightarrow 4^2/0.5 = 16*2 = 32$

______44. When the mass is quadrupled while the radius is decreased by 8x, the the centripetal force is

a) doubled b) quadrupled c) increased 32x d) increased 64x
e) decreased by 8x

$F=mv^2/r \rightarrow 4/\frac{1}{8} = 4*8 = 32$

______45. A 10 N force acts due North on a 2 kg object while a 15 N force acts due East on the object. The acceleration of the object is then _________m/s2.

a) 9 b) 12 c) 225 d) 24 e) 4

Net force = $\sqrt{(F_1^2+F_2^2)} = \sqrt{(100+225)}$ = 18N. $F=m*a \rightarrow F/m = a$ 18/2 = 9

______46. A 4kg object is lifted to a height of 2 m. in 5 seconds. How much power was expended?

a) 12 W b) 80 W c) 16 W d) 160 W e) 800 W

$F = m*a$, Work $F*d$, Power = $W/t \rightarrow P = m*g*d/t \rightarrow (4*10*2)/5 = 16$

______47. Which of the following is not equal to atmospheric pressure at sea level?

a) 760 mm of Hg b) 1 atm c) 101 Pa d) 14.7 psi
e) all of these are correct

______48. When evaporation occurs, the liquid that remains is cooler because
a) the pressure on the liquid decreases
b) the pressure on the liquid increases
c) the volume of the liquid decreases
d) the slowest molecules remain behind
e) the fastest molecules remain behind

______49. Neglecting air resistance, the rate at which an object falls
a) depends on the height
b) depends on the weight of the object
c) is continually increasing
d) is continually decreasing
e) is a constant

______50. The following forces act on a 2 kg mass:
80 Newtons due north
60 Newtons due north
70 Newtons due south
62 Newtons due South

The acceleration of the body is ________ m/s2 due ___________.

o

a) 60, north b) 60, south c) 140, north d) 8, north e) 8, south
This problem is actually incorrect. Net force is 140N-132S = 8N.
a=F/m → 8/2 = $4 m/s^2$ north

Exam 2, Fall 2018

______1. In. a series circuit, all devices have the same
a) current b) voltage c) power d) resistance e) energy

______2. In. a parallel circuit, all devices have the same
a)current b) voltage c) power d) resistance e) energy

______3. After refraction, the _________ of a wave remains unchanged.
a)amplitude b) energy c) wavelength d) speed e) frequency

______4. Which of the following waves may not be polarized?
a) radio b) x ray c) gamma d) sound e) UV

______5. As the frequency of an EM wave doubles, its speed
a)doubles b) halves c) quadruples d) decreases by 4x e) unchanged

______6. The visible part of the EM spectrum lies between
a)UV & x ray b) IR & UV c) radio & microwave d) x ray & gamma
e) microwave & IR

______7. The energy gap of ________________ is very large.
a)tin b) copper c) aluminum d) plastic e) iron

______8. A solar cell uses visible light to excite electrons in materials known as
a)metals b) non-metals c) insulators d) conductors e) semiconductors

______9. Atoms are mostly
a) empty space b) positively charged c) negatively charged d) ionically bound
e) radioactive

______10. Most of the mass of an atom resides in the
a) electrons b) positrons c) alpha particles d) nucleus e) orbitals

______11. A 45 μW device has a current of 9 nA. What is the potential difference?
a) 5 V b) 5 nV c) 50 μV d) 5 kV e) 500 mV
$P = V*I$, $P/I = V$ $45*10^{-6}/9*10^{-9} \rightarrow 45/9 *10^{-6-9} = 5*10^{3}$V

______12. A 300 nV device has a resistance of 50 mΩ. What is the current?
a)6 μA b) 600 nA c) 60 nA d) 60 mA e) 6 kA
$V = I*R \rightarrow V/R = I$ $300*10^{-9}/50*10^{-3} = 300/50*10^{-9-3} = 6*10^{-6}$A

______13. Twenty identical resistors R are placed in series & have an equivalent resistance of 20 Ω. What is the value of R?

a) 1 Ω b) 100 Ω c) 10 kΩ d) 400 Ω e) 4 kΩ

R_{eq}= R+R+R+...R → R_{eq} = 20*R → R_{eq}/20 = R 20/20 = 1

______14. The color with the greatest frequency is

a) blue b) yellow c) violet d) green e) orange

______15. The color with the greatest energy is

a) blue b) yellow c) violet d) green e) orange

______16. The color with the smallest period is

a)blue b) yellow c) violet d) green e) orange

______17. All nuclei are

a) radioactive b) electrically neutral c) electrically positive d) electrically negative e) unstable

______18. A certain EM wave has a frequency of 200 kHz. What is the wavelength?

a) 1.5 m b) 1.5 km c) 150 nm d) 1500 μm e) 1.5 mm

λ = c/f → $3*10^8/200*10^3 = 3/200*10^{8-3} = 0.015*10^5$ → $1.5*10^3$

______19. Con Edison utilizes transformers in order to minimize the dissipation of ___________ to the environment.

a) voltage b) current c) heat d) charge e) ohms

______20. What is the unit of Volts2/ohms?

a) amperes b) watts c) joules d) Newtons e) Coulombs

______21. As the magnitude of two electric charges doubles as their separation also doubles, the electric force

a) doubles b) quadruples c) halves d) decreases by 4 x e) unchanged

F = $q*q/d^2$ → $2*2/2^2$ = 1

_____22. ____________ refers to the change in frequency of a wave due to the relative motion between source & observer.

a)diffraction b) refraction c) constructive interference
d) destructive interference e) Doppler Effect

______23. Radio station WKCC broadcasts at 2000 on the AM dial. What is the period?

a) 150 s b) 15 s c) .5 μs d) 1.5 ns e) 0.15 ms

AM = KHz, P = 1/f → $1/2000*10^3$ = 1/2000 * 10^{0-3} = $0.0005*10^3$ = $0.5*10^6$

_____24. Electrons do not fall into the nucleus because they are actually
a) positrons b) alpha particles c) moving too fast d) standing waves
e)moving too slowly

_____25. Balance the following nuclear reaction:
$_{40}{}^{88}X + 4\ _2^4\alpha$ --> $6\ _{-1}^{0}\beta$ + _-- Y
a) $_{42}{}^{88}$ Y b) $_{54}{}^{92}$ Y c) $_{54}{}^{88}$ Y d) $_{54}{}^{104}$Y e) $_{42}{}^{104}$Y
Nucleons = 88+4*4 = y = 104 Protons = 40+4*2 = -6+y → 40+8+6 = y = 54

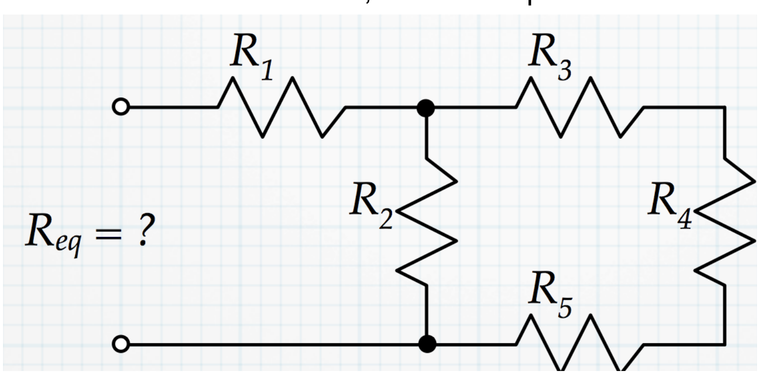
_____26. Balance the following nuclear reaction:
$_{92}{}^{220}X + 8\ _{+1}^{0}\beta$ --> $5\ _2^4\alpha$ + _-- Y
a) $_{92}{}^{228}$ Y b) $_{93}{}^{220}$ Y c) $_{100}{}^{228}$ Y d) $_{90}{}^{200}$Y e) $_{90}{}^{240}$Y
Nucleons = 220 = 5*4+y → 220-20 = y = 200 Protons = 92+8 = 5*2+y → 92+8-10 = 90

_____27. The half life of element A is 8 hours and changes into element B. How much element B is produced after 2 days if the original amount of A is 1.28 kg?
a) 20 g b) 1.26 kg c) 25 g d) 1.25 kg e) none of these
$current = original * \frac{1}{2^{t/HL}}$ 1.28*1/2$^{48/8}$ → 1.28/2^6 = 0.2 A remains. 1.28-0.02 = 1.26B

_____28. A converging lens has a focal length of 8 cm. If an object is placed 24 cm away, then the image is formed _________ from the lens.
a) 1/12 cm b) 3 cm c) 12 cm d) 1/3 cm e) 192 cm
$\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$ ⅛ = 1/24 + 1/d_i → ⅛-1/24 = 1/d_i → 2/24 = 1/d_i → 24/2 = d_i = 12

____29. As the period of an EM wave doubles, the wavelength
a) doubles b) halves c) quadruples d) decreases by 4x e) unchanged

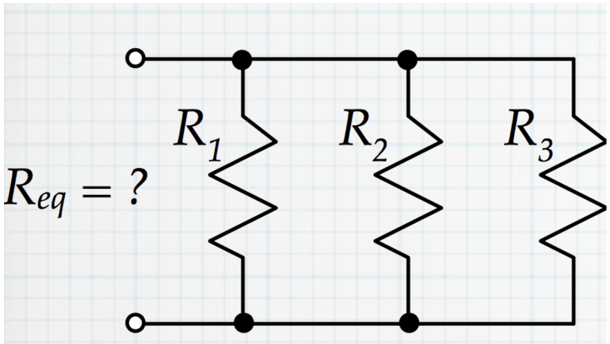
____30. If the value of each resistor is 2 ohms, what is Req ?



4/6 Ω. b) 6/4 Ω. c) 3.5 Ω. d) 10 Ω. e) 12/5 Ω.

R3/4/5 are in series with each other and parallel to R2, R1 is series with those two.
R1+1/(1/R2 + 1/(R3+4+5) → 2+1/(½+ ⅙) → 2+6/4 = 3.5

____31. If R1= 2 Ω., R2= 4 Ω., R3= 6 Ω., what is Req ?



a) 12 Ω. b) 11/12 Ω. c) 12/11 Ω. c) 3 Ω. d) 1/12 Ω. e) 8 Ω.

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ ½+¼+⅙ = 11/12 → 1/11/12 = 12/11

_____32. A water wave traveling at a speed of 40 cm/s has a wavelength of 2 m. What is the this period of this wave?

a) 0.5 s b) 2 s c) 0.8 s d) 20 s e) 8 s

The answer to this question should be 5s. Speed = λ*f, f = 1/p → λ/speed = p

_____33. After 64 days, only 1/16 of a radioactive sample remains. What is the half-life of this Sample?

a) 16 days b) 8 days c) 4 days d) 2 days e) 32 days

1/16 remains = $1/2^4$, meaning 4 half lives occurred. 64/4 = 16 days

______34. An example of anti-matter is

a) negative beta b) positive beta c) alpha d) positron e) both (b) & (d)

_____35. Another name for a Helium-4 nucleus is

a) negative beta b) positive beta c) alpha d) gamma e) deuterium

_____36. An example of an isotope of hydrogen is

a) tritium b) positron c) Helium-3 d) deuterium e) both (a) & (d)

_____37. As the period of an EM wave doubles, its energy

a) doubles b) halves c) quadruples d) decreases by 4x
e) unchanged

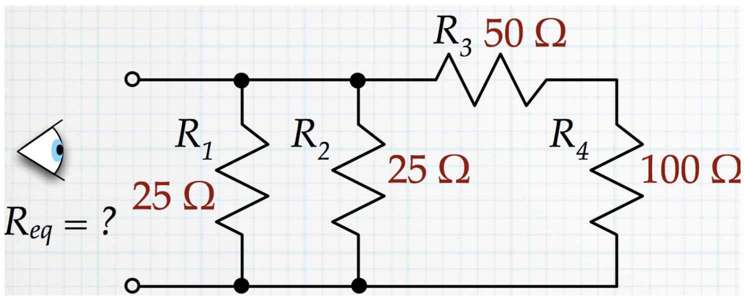
If period doubles, frequency doubles. Energy is inversely proportional to frequency

______38. Which of the following waves cannot travel through the vacuum of outer space?
a) sound b) radio c) gamma d) infrared e) microwave

______39. Which of the following waves may not be polarized?
a) x rays b) microwave c) visible d) UV e) all of these are polarizable

_____40. The fuel being bred in a breeder reactor is
a) U-235 b) U-238 c) Pu-239 d) deuterium e) tritium

______41. What is the value of Req ?



a) 40.29 Ω. b) 0.829 Ω. c) 11.5 Ω. d) 91.17 Ω. e) 141.54 Ω.
R1 and R2 are parallel with each other, and with R3+R4.
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_1} + \frac{1}{R_{3+4}}$ → 1/25+1/25+1/150 = 13/150 → 1/13/150 = 11.5

______42. Balance the following nuclear reaction:
$_{54}^{118}X + 9\ _{-1}^{0}\beta$ --> $11\ _{2}^{4}\alpha$ + _-- Y
a) $_{45}^{74}$ Y b) $_{23}^{118}$ Y c) $_{54}^{227}$ Y d) $_{23}^{74}$Y e) $_{54}^{74}$Y
Nucleons = 118 = 11*4+y → 118-44 = y = 74.
Protons = 54-9 = 11*2 = y → 54-9-22 = y = 23.

______43. In all nuclear reactions
a) mass is gained b) mass is lost c) charge is lost d) charge is gained
e) both (b) & (d) are correct

______44. The bending of a wave around an obstacle is called
a) refraction b) reflection c) diffraction d) constructive interference
e) destructive interference

______45. The nuclear process that fuels the stars is
a) fusion b) fission c) beta decay d) alpha decay e) ionic transport

______46. What characteristic of sound determines the "pitch" of a musical note?
a) amplitude b) wavelength c) frequency. d) phase e) intensity

______47. When a nucleus with atomic number 57 emits two alpha particles, its atomic number is then

a) 53 b) 55 c) 59 d) 59 e) 51

Alpha emission loses 2 protons, 57 - 2*2 = 53

______48. The current passing through a 20 mΩ resistor when connected to a 600V outlet is

a) 3mA b) 30mA c) 3 A d) 300 A e) 3 kA

$V=IR \rightarrow I = V/R = 600/20\times10^{-3} = 30\times10^{3} = 30kA$

______49. After 2 days has elapsed, 1/16 of the original quantity of a certain radionuclide remains un-decayed. The half-life of this sample is

a) 24 hours b) 12 hours c) 16 hours d) 32 hours e) 40 hours

$1/16 = 1/2^4$ = 4 HL. 48h/4 = 12h

______50. Element 43 undergoes 12 β+, 16 β-, 22γ and 4 α decays. The resulting nucleus is

a) 39 b) 17 c) 51 d) 43 e) 33

β- adds 1 to protons, β+ subtracts 1 from protons, α subtracts 2 from protons.

43-12+16-8 = 39

Exam 3 Spring 2019

______1. The name of K_3PO_4 is
a) phosphoric acid b) tripotassium mono phosphorus tetraoxide
c)potassium phosphide d) potassium phosphate e) potassium phosphoric acid

______2. All acids have
a) pH=0 b) pH=7 c) pH<7 d) pH>7 e) pH=10-7

______3. What Is the name of $(H_3O)^{+1}$?
a) positronium b) harmonium c) ionized water d) distilled water
e) hydronium

______4. The correct formula when magnesium & sulfur combine is
a) MgS b) Mg_2S c) MgS_2 d) M_2S_3 e) M_3S_2

______5. The best way to increase the solubility of a solid in a liquid is
a) Increase surface area b) stir c) increase temperature
d) increase pressure e) both (a) & (b)

______6. The solvent in a tincture is
a) water b) alcohol c) NaOH d) glycerine e) peroxide

______7. The correct formula for chalk is
a) NaOH b) Ca_2CO_3 c) H_2SO_4 d) $CaCO_3$ e) MgF_2
$Ca^{2+} + CO_3^{2-}$

______8. The formula for strontium nitride is
a) $Sr(NO_3)_2$ b) $Sr(NO_2)_2$ c) $Sr_3(NO_3)_2$ d)SrN_2 e)$Sr_3\ N_2$
$Sr_3^{2-} + N_2^{3+}$

______9. How many molecules of water are present in 54g of water?
a) NA b) 2NA c)54 NA d)3 NA e) 18 NA
Water has molecular mass 18g/mole. 54/18 = 3 moles, 3 moles have $3N_A$ molecules.

______10. In all combustion reactions of an organic substance, a byproduct is
a) water b) CO_2 c) H_3O+ d) O_3 e) both (a) & (b)

______11. The name of C_2H_2 is
a) methane b) ethane c) ethyl d) ethyne e) ethene
2 carbon = eth. H = 2C-2 is the pattern of alkynes.

______12. The formula for benzene is
a) C_6H_6 b) C_6H_{12} c) C_6H_{13} d) C_6H_{14} e) C_6H_{10}

______13. The formula for heptyl is

a) C_7H_{15} b) C_7H_{14} c) C_7H_{12} d) C_7H_{16} e) C_7H_7

Alkyls are H=2C+1

______14. Salts are produced in all ________________ reactions.

a) single replacement b) combustion c) ionization

d) neutralization e) catalytic

______15. A cup of tea was found to have a $[H_3O+] = 10^{-8}$. The pH of this tea is

a) -8 b) +8 c) -6 d) +6 e) 10^{-18}

$pH = -\log[H_3O+] \rightarrow -\log 10^{-8} = 8$

______16. Balance the following

____ NaBr + ____ H_3PO_4 ____ Na_3PO_4 + ____ HBr

a) (2,1,2,1) b) (1,2,1,2) c) (1,3,3,1) d) (3,1,1,3) e) (2,3,3,2)

______17. Balance the following

____ $Ca(OH)_2$ + ____ $Al_2(SO_4)_3$ ____ $CaSO_4$ + ____ $Al(OH)_3$

a) (2,1,1,3) b) (1,2,2,1) c) (3,1,3,2) d) (3,2,3,2) e) (2,3,2,3)

______18. Balance the following

____ H_2SO_4 + ____ NH_4OH ____ H_2O + ____ $(NH_4)_2SO_4$

a) (1,2,2,1) b) (2,2,2,1) c) (2,1,2,1) d) (1,1,2,2) e) (2,3,3,1)

______19. Name the following: $CH_3CH_2CH_2CH_2CH_3$

a) methyl benzene b) methyl butane c) dimethyl propane

d) pentane e) pentene

______20. Another name for methyl benzene is

a) aniline b) salicylic acid c) methanol d) toluene

e) chalk

______21. The correct formula for hexyne is

a) C_6H_6 b) C_6H_{13} c) C_6H_{10} d) C_6H_{12} e) C_6H_{11}

Alkynes use H = 2C-2, hex = 6C, 12-2 = 10H

______22. The functional group for alcohol is

a) -O- b)C=O c) OH d) H_3O e) O-C=O

______23. The correct formula for ammonium carbonate is

a) NH_4CO_3 b) $(NH_4)_2CO_3$ c) $(NH_4)_3(CO_3)_2$ d) $(NH_4)_2(CO_3)_3$

e) $(NH_4)_3(CO_2)_2$

$NH_4^+ + CO_3^{2-} \rightarrow 2NH_4^+ + CO_3^{2-}$

______24. When a metal combines with a non-metal, a(n) ____________ bond is formed.
a) hydrogen bond b) metallic c) nonmetallic d) ionic
e) covalent

______25. The correct name of F_3Br_6 is
a) fluorine bromide b) trifluorine hexabromide c) trifluorine heptabromide
d) trifluoride hexabromide e) trifluorine hexabromine

_____26. In 0.2 moles of aluminum sulfite, how many oxygen atoms are there?
a) 0.2 NA b) 9 NA c) 1.8 NA d) 2.4 NA e)12 NA
aluminum sulfite = $Al_2(SO_3)_3$ 1 mole has 9 O, 0.2mole*9O/mole = 1.8O

______27. The name of C_4H_9 is
a) butyl b) butyne c) butene d) propyl e) propene
But = 4C, alkyl are H=2C+1

______28. Which of the following would be found in gasoline?
a) CH_4 b) C_8H_{16} c) C_8H_{18} d) C_8H_{17} e) C_7H_{12}
C_8H_{18} = octane

______29. Which of the following would be found in a gas grill?
a) C_3H_8 b) C_3H_6 c) C_3H_4 d) C_2H_4 e) C_8H_{16}
C_3H_8 = propane

______30. Which of the following would be found in a cigarette lighter?
a) C_4H_9 b) C_3H_6 c) C_4H_8 d) C_4H_{10} e) C_4H_6
C_4H_{10} = butane

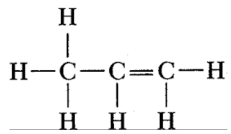
______31. Which of the following would be found in drain cleaner?
a) HCl b) NaOH c) $CaCO_3$ d) NaCl e) H_2SO_4

______32. An example of a triprotic acid is
a) acetic b) phosphoric c) nitricd) carbonic e) sulfuric
H_3PO_4

______33. An acid that one would find on a salad is
a) acetic b) phosphoric c) nitricd) carbonic e) sulfuric
Acetic acid = vinegar

______34. All aromatic compounds have __________ as a building block.
a) toluene b) aniline c) salicylic acid d) nitrogen e) C_6H_6

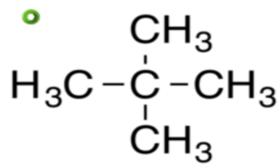
______35. What is the name of the following?



a)butane b) butene c) propene d) propyl e) 1-propyne

3 carbon, 1 double bond

___36. What is the name of the following?

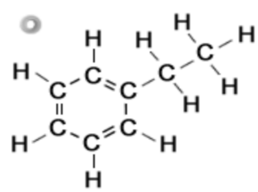


a) tetra methyl methane b) tetra ethyl methane c) 2,2 dimethyl propane

d) hydronium trimethyl methane e) trimethyl butane

3 carbon, single bonds, 2 methyl attached to carbon 2

___37. What is the name of the following?

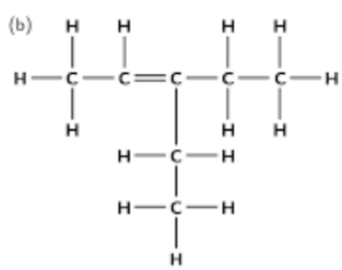


a) ethyl benzene b) toluene c) dimethyl benzene d) methyl benzene

e) propyl benzene

Benzene ring + ethyl (C_2H_5)

___38. What is the name of the following?

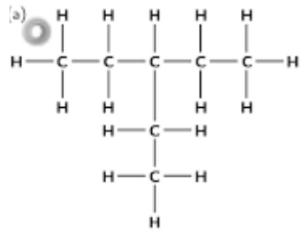


a) pentane b) pentene c) 3 ethyl, 2-pentene d) 2 ethyl, 2 pentane

e) 3 ethyl, 2-pentyne

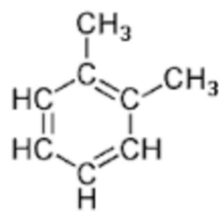
Longest chain is 5, double bond = pentene. Ethyl attached at carbon 3.

___39. What is the name of the following?



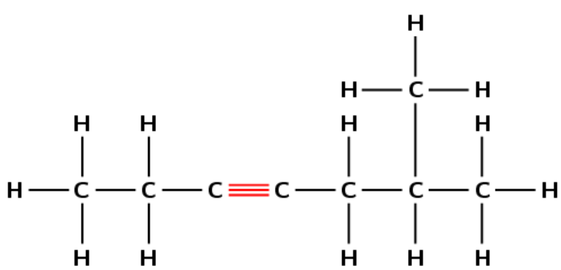
a) pentane b) hexane c) butane d) diethyl pentane e) 3 ethyl pentane
Longest chain is 5, single bonds = pentane. Ethyl attached to carbon 3

___40. What is the name of the following?



a) 1,2 dimethyl benzene b) ortho methyl toluene c) ethyl, methyl benzene
d) diethyl toluene e) both (a) & (b) are correct
Ortho means methyl is adjacent to each other

___41. What is the name of the following?



a) heptane b) 5 methyl 3-heptane c) 5 methyl 3-heptyne d) 5 methyl 3-heptene
e) 6 methyl 3-heptyne
7 carbon, triple bond = heptyne w/ bond at c3, methyl attached to c5

___42. What is the name of the following: $CH_3CH_2CCl_2CBr_2CH_2CH_3$
a) 2,2 dibromo 3 chloro hexane b) 3,3 dibromo, 4,4 dichloro, hexane
c)4,4 dibromo, 3 chloro, 2-hexyne d) 4,4 dibromo, 3 chloro, 2-hexyl
e) 2,2 dibromo 3 chloro 2-hexyne
6 Carbon, single bonds = hexane. 2 bromine at C3, 2 chlorine at C4

___43. What is the name of the following: $CHCC_6H_{13}$
a) octane b) 1-octene c) 1-octyne d) octyl e) 2-octene
8 carbon, 14 hydrogen = 2n-2 = octyne

___44. What is the name of the following: C_9H_{18}
a) nonane b) nonene c) nonyne d) nonyl e) noway
9 carbon = non, H = 2C = alkene

___45. What is the name of the following: $CBr_3CH_2CCCH_3$
a) 1,1,1 tribromo, 2-pentyne b) 5,5,5 tribromo, 2-pentyne
c)1,2,3 tribromo, 2-pentyne d) 1,1,1 tribromo, 2-pentene
e) 5,5,5 tribromo, 2-pentene
CCC indicates triple bond at C2, 5 carbon = pentyne. 3 bromine at carbon 5

___46. What column of the periodic table represents the halogens?
a) VIA b) VIIIA c) VIIA d) VIIB e) IIA

___47. How many sulfur atoms are in 3.6 x10^{24} aluminum sulfate molecules?
a) 6 NA b)18 NA c) 4 NA d)6 e) 7.2 x1024
Aluminum sulfate = $Al_2(SO_4)_3$ = 3 sulfur per molecule. 3.6*10^{24}*3/N_A = 18

___48. Approximately how many grams of lithium oxide are needed to make 400 mL of a 0.6 M solution?
a) 30 g b) 12 g c) 7.2 g d) 12,000 g e) 18 g
Lithium oxide = Li_2O, 30g/mole. M = mole/L → M*L = mole → 0.6M*0.4L*30g/mol = 7.2g

___49. Elements in the same group in the periodic table have the same
a) chemical properties b) boiling point c) melting point
d)number of valence electrons e) both (a) & (d)

___50. A sample of aluminum contains 2.91 × 10^{22} atoms of aluminum. What is the mass of this sample? [Molar mass: Al= 26.98 g/mol]
a) 0.767 g b) 1.30 g c) 558 g d) 1.08 × 10^{21} g e) 7.85 × 10^{23}g
2.91x10^{22}/6*10^{23} = 0.485 moles. 26.98*0.485 = 1.30g