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Taking the Regents Exam

There is a strategy to successfully taking the Physics Regents.

1. Get a good night's sleep the night before the exam.
2. Eat a good breakfast the morning of the exam.
3. Come prepared to the exam with sharpened pencils, a ruler, a protractor and your calculator.
4. Take the exam backwards! Do the free response first and the multiple choice second. Why? Because free response questions generally require more brain power than multiple choice, so you want to complete them while your brain is fresh. Furthermore, if you run out of time, you can guess at incomplete multiple choice, but not incomplete free response.
5. Use the time given to you. If you finish early, double check your work.
6. Most importantly, stay calm and do your best!

Problem Solving Strategy

Successful problem solving requires the meticulous use of good problem solving strategy. The basic steps of good problem solving strategy are:

1. Read the problem carefully. Do it twice! Picture the situation described in the problem.

2. Draw any necessary diagrams to help yourself visualize the problem. (E.g. sketch the situation or draw a free body diagram.)

3. Write down all the given values, including their units.

4. Write down what you need to find.

5. Choose the formula(s) that are needed to get from what you are given to what you need to find.

6. Solve the formula(s) algebraically for what you need to find.

7. Plug the given values into your rearranged formula to find the answer. Be sure to include appropriate units!

8. Make sure that your answer makes physical sense. This is the most important step. If your answer does not make sense, you know that you made a mistake somewhere along the line.

Topic 1: The Mathematical Toolbox

In order to be successful at solving physics problems, one must possess the proper set of mathematical tools. These tools include:

1. The proper use of a ruler and protractor to draw scale diagrams.
2. The use of scientific notation and significant figures.
3. The ability to calculate percent error and percent difference.
4. The ability to estimate values.
5. The ability to graph data and draw a proper line of best fit.
6. The ability to use sine, cosine and tangent functions to determine the sides and angles of a right triangle.
7. The ability to solve basic algebraic equations.

Special notes on lines of best fit:

There are often misconceptions on how a line of best-fit should be drawn. Here are some easy guidelines for lines of best fit.

- A line of best fit *does not* have to go through the point (0, 0).
- A line of best fit *does not* have to go through the first and last data point. (In fact, lines of best fit do not have to go through ANY data points.)
- There should be approximately the same number of data points above a line of best fit as below it.
- The average distance of the points above the line of best fit and the line itself should be the same as the average distance of the points below the line of best fit and itself.
- A line of best fit is just what its name implies: a line that shows the trend of ALL of the data.

Practice Problems:

1. Draw a right triangle whose two shorter sides are 5 centimeters and 12 centimeters. Determine the length of the hypotenuse. Determine the acute angles in the triangle.

2. How many significant figures are in the measurement 5,060 meters?

3. What is the approximate thickness of a piece of paper?

(1) 10^{-4} [m] (2) 10^{-3} [m] (3) 10^{-2} [m] (4) 10^{-1} [m]

4. While conducting a photoelectric effect experiment, a student measures the following data.

K_{max} [eV]	f [x10^{14} Hz]
0.65	7.50
0.45	7.06
0.30	6.67
0.15	6.32

a. Graph the K_{max} vs. f.
b. Draw a line of best fit on your graph.
c. Use the equation for your line of best fit to determine the slope of the graph. This slope represents Planck's constant.
d. The accepted value for Planck's constant is $4.14\times10^{-15}\left[\text{eV}\cdot\text{s}\right]$. What is the percent error for this experiment?

<u>Topic 2: One-Dimensional Kinematics</u>

Distance and Displacement:

- <u>*Distance*</u> is how far an object moves.
    - Distance is always cumulative (adds up).
    - Distance only has magnitude (size). It is a scalar.
- <u>*Displacement*</u> is how much an object has changed its position.
    - Displacement has both magnitude and direction. It is a vector.
- Both distance and displacement are measured in meters ([m]).
- It is possible for an object to travel some distance, but have zero displacement. E.g. A car completing a lap on a circular track.

Speed and Velocity:

- <u>*Speed*</u> is how fast an object is moving.
    - $\text{average speed} = \frac{\text{distance}}{\text{time}}$
    - Speed is a scalar.
- <u>*Velocity*</u> is the rate at which the position of an object changes.
    - $\text{average velocity} = \frac{\text{displacement}}{\text{time}}$
    - Velocity is a vector.
- Both speed and velocity are measured in meters per second $\left(\left[\frac{\text{m}}{\text{s}}\right]\right)$.

Acceleration:

- <u>*Acceleration*</u> is the rate at which the velocity of an object changes.
- An object is accelerating if its velocity changes *magnitude* <u>**OR**</u> *direction*.
- $\text{Average Acceleration} = \frac{\text{Change in Velocity}}{\text{Time}} = \frac{\text{Final Velocity - Initial Velocity}}{\text{Time}}$
- Acceleration is measured in units of $\left[\frac{\frac{m}{s}}{s}\right]$ or $\left[\frac{\text{m}}{\text{s}^{\text{s}}}\right]$.
- Acceleration is a vector.
- The direction of acceleration depends on two factors:
    - Is the object speeding up or slowing down?
    - Is the object moving in the positive or negative direction?
- As a general Rule of Thumb:
    - If an object is speeding up, the direction of its acceleration is in the same direction as its velocity.
    - If an object is slowing down, the direction of its acceleration is in the opposite direction of its velocity.

Describing Motion with Graphs:

- Three types of graphs are used to describe an object's motion: displacement-time, velocity-time and acceleration-time.
- The three types of graphs for an object's motion are related to one another mathematically.
  - Acceleration is the slope of a velocity-time graph.
  - Velocity is the slope of a displacement-time graph.
  - Displacement is the area under a velocity-time graph.
  - Velocity is the area under an acceleration-time graph.

Describing Motion with Equations:

- There are three kinematic equations used to describe an object moving with a constant acceleration.
- $v_f = v_i + at$
- $d = v_i t + \frac{1}{2}at^2$ This is often referred to as the "great distance formula."
- $v_f^2 = v_i^2 + 2ad$

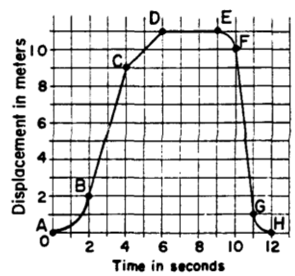
Freefall:

- An object is said to be in free fall when it is only acted upon by gravity.
- The acceleration due to gravity at the surface of Earth is $9.8\left[\frac{\text{m}}{\text{s}^2}\right]$.

Practice Problems:

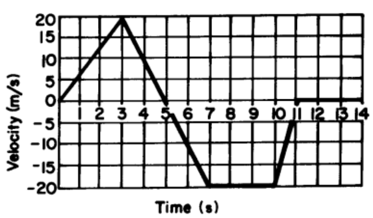
1. A person walks 3 meters East and then 12 meters at 30.° North of East. What distance did the person travel? What was the person's displacement?

2. The graph below shows an object's displacement as a function of time.



   a. What is the object's displacement at t=6[s]?
   b. What is the average velocity of the object from point B to point C?
   c. During what time interval(s) is the object at rest?
   d. What distance does the object travel over its entire path?
   e. Over what interval(s) is the object accelerating?

3. The graph below shows an object's velocity as a function of time.



   a. What is the object's average velocity from t=3[s] to t=5[s]?
   b. At what time does the object return to its starting position?
   c. What is the acceleration of the object from t=10[s] to t=11[s]?
   d. What is the total distance traveled by the object?

4. How far will an object near Earth's surface fall in 4 seconds?

5. A woman is coming up to a traffic light while traveling at a speed of 20 meters per second. She sees the light change while she is still 40 meters away. It takes her 0.3 seconds to react and apply the brakes. What average acceleration must be applied by the brakes if she is going to stop before entering the intersection?

Topic 3: Projectile Motion

Projectile motion problems are easiest when thought of as two separate one-dimensional motion problems: one problem for the vertical motion and one problem for the horizontal motion. Problems should be started by making a table for the given information, such as the one shown below. Remember, that the information in the "Horizontal" column can only be used to describe horizontal motion and the information in the "Vertical" column can only be used to describe vertical motion. The only value that can lie in both columns is time! Note that for Regents level projectile problems, the horizontal acceleration will always be 0 (meaning that the horizontal velocity is constant) and the vertical acceleration is due to gravity (-9.8 [m/s/s].

Horizontal	Vertical
a_x = 0 [m/s/s]	a_y = -9.8 [m/s/s]
v_x =	v_{iy} =
	v_{fy} =
d_x =	d_y =
t =	t =

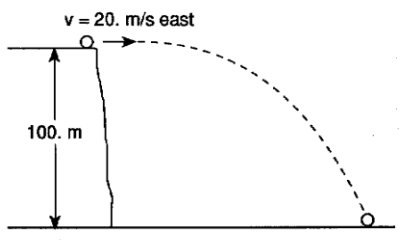
Remember that all projectiles follow parabolic paths.

Projectiles Fired Horizontally:
- The initial vertical velocity is zero.
- The vertical displacement is negative (the object is moving downward).

Projectiles Fired at an Angle:
- If the initial velocity is given, it must be resolved into horizontal and vertical components before making your table.
- The initial vertical velocity will be positive (the object is traveling upward).
- The vertical displacement of the object over the entire path is 0.
- The time to peak will be half the total time of flight. This can be used to your advantage to find total time of flight or maximum height.

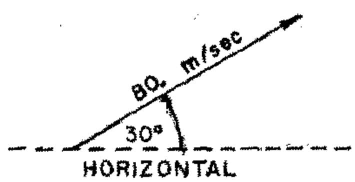
Practice Problems:

1. The image below shows a projectile being fired horizontally.



    a. What is the time of fight of the projectile?
    b. What is the range of the projectile?
    c. What is the projectile's final velocity?

2. The image below shows a projectile being fired at an angle.



    a. Sketch the path of the projectile.
    b. What is the time of flight of the projectile?
    c. What is the range of the projectile?
    d. What is the maximum height reached by the projectile?

Topic 4: Force and Motion

To understand why objects move, one must understand forces. A force can be defined as a push or a pull.

Newton's First Law of Motion (the Law of Inertia):

- An object at rest will rest will remain at rest *unless* acted upon by an outside force. An object in motion with a constant velocity will remain in motion with that same constant velocity *unless* acted upon by an outside force.
    - Note that constant velocity means both constant magnitude AND constant direction. This means that for an object to travel along any path that is not straight, an outside force must act on it.
- Objects resist changes in their state of motion. We call this resistance *inertia*.
    - Inertia is measured by mass.
    - more mass = more inertia = requires more force to change an object's state of motion

Newton's Second Law of Motion:

- If an unbalanced force is applied to an object, that object will accelerate.
- $a = \frac{F_{net}}{m}$
    - From this, we can see that the unit of force is $\left[\frac{\text{kg} \cdot \text{m}}{\text{s}^2}\right]$, also known as a newton ([N]).
- The following four statements are equivalent. If one is true, all are true. If one is false, all are false.
    - The forces acting on an object are balanced.
    - The net force acting on the object is zero.
    - The acceleration of the object is zero.
    - The object is in equilibrium.
- Force problems are solved by drawing free body diagrams and applying Newton's Second Law.

Drawing Free Body Diagrams:

The steps to successfully drawing a free body diagram are:

1. Draw a box representing the object.
2. Place a dot in the center of the box.
3. Draw in all forces you can envision physically pushing or pulling on the object (NO NET FORCES). Include arrowheads for all force vectors and be conscious of the relative length of different force arrows.

Common forces which appear on free body diagrams include force due to gravity, friction, normal force, spring force, electrostatic force and tension.

Newton's Third Law of Motion (Law of Action / Reaction):

- When one object applies a force on a second object, the second object applies an equal and opposite force on the first.
- Action / reaction pairs must follow certain rules.
  - They must be like forces (i.e. both electrostatic, both gravitational, etc.)
  - One force acts on each object. Both forces *do not* act on a single object.
  - They must both have the same magnitude.

Uniform Circular Motion:

- The velocity of an object in circular motion is tangent to the object's path.
  - $v = \frac{2\pi r}{T}$
- Objects in circular motion always experience acceleration towards the center of their path. This is known as centripetal acceleration.
  - $a_c = \frac{v^2}{r}$
- The net force acting on an object in circular motion is known as a centripetal force.
- When drawing free body diagrams for circular motion problems, it is helpful to note where the center of the object's path is located.

Newton's Law of Universal Gravitation:

- All masses in the universe exert mutual forces of gravitation on one another.
- $F_G = \frac{Gm_1m_2}{r^2}$
  - $G = 6.67 \times 10^{-11} \left[\frac{\mathrm{N} \cdot \mathrm{m}^2}{\mathrm{kg}^2}\right]$ and is known as the universal gravitational constant.
- Every mass in the universe generates a gravitational field. This field acts on other masses, causing the gravitational force that affects them.
  - $g = \frac{F_g}{m}$
- An object has the same mass no matter where it is located in the universe. An object's weight, however, depends on location.

Spring Forces:

The force due to a spring is given by the formula F=kx.

- k is known as the spring constant and depends on the particular spring being used.
- x is how much the spring has been stretched or compressed.
- The force due to a spring is always in the opposite direction of its displacement.

Friction:

Friction is a generic term referring to forces which oppose the motion of an object. Types include static friction, kinetic friction, rolling friction and fluid friction (this includes air resistance). For the Regents exam, you need to primarily understand static and kinetic friction.

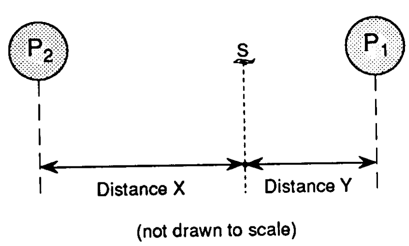
- Static friction opposes the start of motion. It provides just enough force to keep an object from moving, up to a maximum.
- Kinetic friction opposes the motion that an object is already experiencing. Kinetic friction is a constant value for a given system.
- $F_f = \mu F_N$ can be used to calculate the maximum force of static friction between an object and a surface or the kinetic friction between the object and the surface.
- μ is the coefficient of friction.
    - It is different for static and kinetic friction and depends on the two surfaces in contact.
    - For a given system, the coefficient of static friction is always greater than the coefficient of kinetic friction.
    - Coefficient of friction is unitless.
    - Coefficient of friction *does not* depend upon the surface area of the object in contact with the surface.

Practice Problems:

1. Which of the following objects has more inertia?
    (1) An 800 [kg] car at rest
    (2) A 70 [kg] student running at 5 meters per second
    (3) A 100 [kg] student walking at 1 meter per second
    (4) A 10 [kg] book at rest

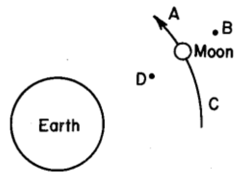
2. A block has a mass of 10 [kg] when it is on the surface of the Earth. If it is moved to two Earth radii above the surface of Earth, what is its mass? What is the weight of the ball at the surface of Earth and two Earth radii above the surface of Earth?

3. Spaceship, S, experiences equal forces of gravity from both planet P_1 and planet P_2. If distance X is greater than distance Y, then the mass of planet P_1 is



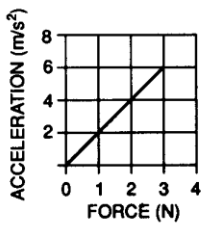
    (1) less than the mass of planet P_2.
    (2) greater than the mass of planet P_2.
    (3) the same as the mass of planet P_2.

4. The figure below shows the Moon in orbit around Earth. Towards which point is the acceleration experienced by the Moon? Towards which point is the Moon's velocity vector directed?

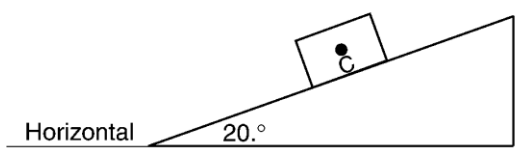


(1) A (2) B (3) C (4) D

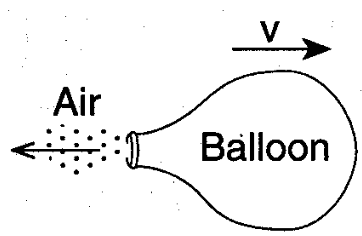
5. The figure below shows the acceleration experienced by an object plotted as a function of the net force exerted on the object. What is the object's mass?



6. The figure below shows a 10 [kg] block at rest on a 20° incline. Draw a free body diagram for the object. Calculate the coefficient of static friction between the block and the incline.



7. The figure below shows a balloon moving to the right as it releases the air inside. Explain why this occurs.



Topic 5: Impulse and Momentum

What is Momentum?:

The biggest misconception involving momentum is that it is the same as inertia. This is not true! Momentum is the product of an object's mass and velocity. An object always has inertia. It must be moving to possess momentum.

- $p = mv$
- Momentum is a vector.

Conservation of Momentum:

Momentum is conserved within isolated systems.

- An isolated system is two or more objects where no outside forces act on the objects within the system.
- The total momentum of the system before something happens equals the total momentum of the system after something happens.
- The momentum lost by objects in the system is equal to the momentum gained by other objects in the system.
- An object cannot change its own momentum.

Collisions and Explosions:

Usually conservation of momentum is considered when solving collision and explosion problems.

- An elastic ("bouncy") collision is when two or more objects collide and "bounce" off one another.
- An inelastic ("sticky") collision is when two or more objects collide and "stick" to one another.
- An explosion is when a single object "explodes" into two or more objects.

Impulse-Momentum Theorem:

Sometimes it is difficult to define a system as isolated. When this is the case, problems can be solved by using impulse-momentum theorem.

- The impulse applied to an object is equal to the change in momentum experienced by the object.
- Impulse is also the outside for exerted on an object multiplied by the time during which the force acts.
- $J = \Delta p$
  $Ft = m\Delta v$

Practice Problems:

1. If a huge truck and a motorcycle have a head on collision, which vehicle will experience the greater force of impact? The greater impulse? The greater change in momentum? The greater acceleration and, hence, the greater damage?

2. A car of mass 110 kilograms moves at 24 meters per second. What braking force is needed to bring it to a halt in 20. seconds?

3. A 40 kilogram football player moving at 4 meters per second tackles a 60 kilogram player who is headed toward him at 3 meters per second. What is the speed and direction of the tangled mess?

4. A lunar vehicle on Earth moves at 10 kilometers per hour. If it travels on the Moon at the same speed, is its momentum less, more or the same?

5. A jet engine gets its thrust by taking in air, heating and compressing it and then ejecting it at high speed. If a particular engine takes in 20 kilograms of air per second at 100 meters per second and ejects it at 500 meters per second, calculate the thrust of the engine.

<u>Topic 6: Work, Energy and Power</u>

Energy:
Energy can be categorized in a number of ways. Two very important categories of energy are potential energy and kinetic energy. Energy is a scalar and is measured in joules ([J]).

- Potential energy is energy that an object possesses due to its position or state. Examples include gravitational potential energy, elastic potential energy (such as that stored in a spring) and electrostatic potential energy.
  - $\Delta PE_G = mg\Delta h$
  - $\Delta PE_S = \frac{1}{2}kx^2$
- Kinetic energy is energy that an object possesses due to its motion. If an object is not moving, it cannot possess kinetic energy.
  - $KE = \frac{1}{2}mv^2$

Work:
Work is the transfer of energy to an object that moves as a result of a force acting upon it.

- For a constant force, $W = Fd = \Delta E_T$, where F is the force in the direction of the object's motion. If the force varies, work is the area under a force-displacement graph.
- As you can see from the above equation, the unit of work can be shown as a newton-meter ([N-m]) or a joule ([J]). These units are equivalent. Furthermore, it can be shown that one joule is equal to one $\left[\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}\right]$. Work is a scalar.

Power:
Power is the rate at which work is done or the rate at which energy is transferred.

- $P = \dfrac{W}{t} = F\overline{v}$
- Power is measured in watts ([W]) and is a scalar.

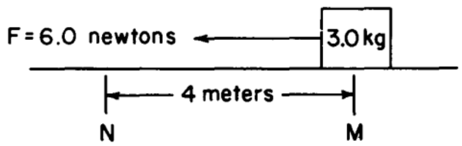
Conservation of Energy:
In an isolated system, energy can be transferred from one form to another, but the total amount of energy in the system must remain constant.

Work-Energy Theorem:

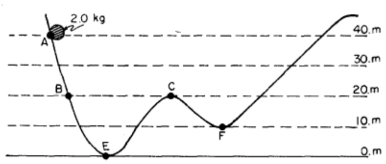
- Some forces do not change the total mechanical energy of an object when they do work on it. They merely change potential energy to kinetic energy or vice-versa. These are known as conservative forces.
- Some forces change the total mechanical energy of an object when they do work on it. These are known as nonconservative forces.
- All types of friction are a special case of nonconservative force. When they do work on an object, they decrease its total mechanical energy, transforming it into thermal energy.

Practice Problems:

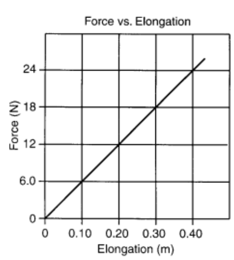
1. The figure below shows a 3.0 kilogram block being pushed 4 meters along a tabletop by a force of 6.0 newtons. How much work is done on the block by the force? If the block's motion took 3 seconds, what was the average power exerted by the force? If the coefficient of friction between the block and the surface is 0.30, by how much did the thermal energy of the block and the surface increase during the block's motion?



2. The figure below shows a 2.0 kilogram ball rolling down and then back up an incline. If the ball started from rest, what is its kinetic energy at point C?



3. The figure below shows the force exerted by a spring as a function of its elongation. What is the spring constant of the spring? How much work is done in stretching the spring from 0 [m] to 0.30 [m]? What is the potential energy stored in the spring when it is stretched 0.30 [m]?



Topic 7: Electrostatics

Charge and Charge Transfer:

- All matter contains charged particles in the form of electrons and protons. The charge on an electron is a negative *elementary charge* ([e]) and the charge on a proton is a positive *elementary charge*.
- Objects become charged because they either have an excess (making them negatively charged) or deficit (making them positively charged) of electrons.
  - ONLY ELECTRONS MOVE WHEN CHARGE IS EXCHANGED!
  - The amount of charge transferred to or from an object must be a whole number of elementary charges. In other words, charge is quantized.
- Charge is conserved. If charge is exchanged between two objects, the amount of charge gained by one object is equal to the amount of charge lost by the other object.
- The SI unit of charge is the coulomb ([C]). The elementary charge is equivalent to 1.6×10^{-19} coulomb.
- When an object is charged by direct contact with a charged object, the process is known as *conduction*. Charge is transferred directly from the charged object to the object being charged. At the end off the process both objects will have the same type of charge (positive or negative).
- When an object is charged by being grounded after a charged object is placed near, but not in contact, with it the process is known as *induction*. Charge IS NOT transferred directly from the charged object to the object being charged. The object being charged will have the opposite charge of the initial charged object.

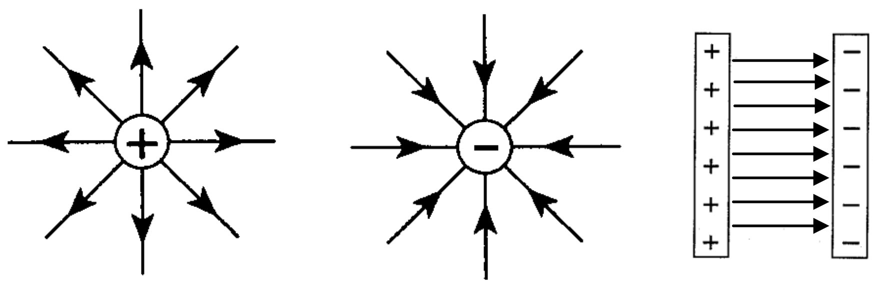
Coulomb's Law:

The force between two charged particles is given by Coulomb's Law, $F_e = \frac{kq_1q_2}{r^2}$

- k is the electrostatic constant and is equal to $9\times10^9\left[\frac{\mathrm{N\cdot m^2}}{\mathrm{C^2}}\right]$.
- The force between like charges is repulsive. The force between opposite charges is attractive.

Electric Field:
Every charged particle generates an electric field. This field acts on other charged particles, causing the electrostatic force that affects them.

- $E = \frac{F}{q}$
- Electric field is visualized by drawing electric field lines. Electric field lines point out of positive charges and into negative charges.
- Positive charges experience force in the same direction as the electric field, negative charges experience force in the direction opposite the electric field.
- The electric field around a point charge follows an inverse square law. The electric field between two parallel plates is uniform.



Electric Potential Difference:
Otherwise known as *voltage*, electric potential difference between two points is the work done (or change in electric potential energy) per unit charge as a charged particle is moved from one point to the other.

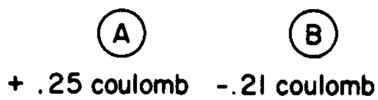
- $V = \frac{W}{q}$ and is measured in volts ([V]).
- ANY TIME THAT A CHARGED PARTICLE MOVES THROUGH A POTENTIAL DIFFERENCE, WORK IS DONE ON IT!
- The relationship between potential difference and work leads to a new unit of energy known as the *electronvolt* ([eV]). One electronvolt is the amount of energy required to move one elementary charge through a potential difference of one volt and is equivalent to 1.6×10^{-19} joules.

Practice Problems:

1. The distance between the proton and the electron in a hydrogen atom is 5.29×10^{-11} [m]. Calculate the electrostatic force that the proton exerts on the electron. Calculate the gravitation force that the proton exerts on the electron. Based on these answers, which of these forces do you think is responsible for holding the atom together? Why?

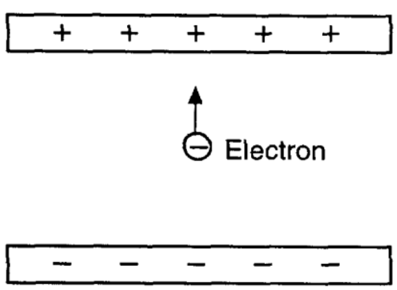
2. Which of the following cannot be the charge on an object?
   (1) 3.2 [μC] (2) 8 [μC] (3) 10 [μC] (4) 64 [μC]

3. The figure below shows two identical objects, A and B, and their respective charges. If A and B are brought into contact with one another and then separated, what will the charge on each object?



4. An electron is accelerated by a potential difference of 5000 [V]. How much work is done on the electron as it passes through the region of potential difference? What is the electron's kinetic energy after this work is done? How fast will the electron be traveling after it passes through the region of potential difference?

5. The figure below shows an electron between two parallel plates. In what direction is the force acting on the electron? If the electric field between the plates is 2000 newtons per coulomb, what is the magnitude of the force acting on the electron?



Topic 8: Electric Circuits

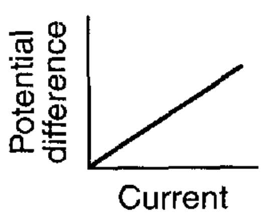
Electric Current:
Electric current is the rate at which charge flows past a given point.

- $I = \frac{\Delta q}{t}$ and is measured in amperes ([A]). One ampere is equal to one coulomb per second.
- Two conditions must be met in order for current to flow. Fulfilling these conditions makes an *electric circuit*.
  - There must be a potential difference acting across the wire.
  - There must be a closed path for charge to flow through.
- Conservation of charge dictates that the total current flowing into any junction be equal to the total current flowing out of any junction.

Resistance:
Resistance is opposition to the flow of charge.

- For a give potential difference, higher resistances result in lower currents.
- Resistance is measured in ohms ([Ω]).
- The resistance of a wire is given by the formula $R = \frac{\rho L}{A}$.
  - ρ is the *resistivity* of the material that the wire is made of. Resistivity depends on material and temperature. Higher temperatures lead to higher resistivities, causing higher resistance for the wire.

Ohm's Law:
Potential difference, current and resistance are related for any circuit. The relationship is known as Ohm's Law, V=IR.



The slope is resistance!

Series Circuits:
In series circuits, there is only one path for the charge to follow.

- $I_T = I_1 = I_2 = I_3 = \cdots$
- $V_T = V_1 + V_2 + V_3 + \cdots$
- $R_{eq} = R_1 + R_2 + R_3 + \cdots$

Parallel Circuits:
In parallel circuits, there are multiple paths for charge to follow.

- $I_T = I_1 + I_2 + I_3 + \cdots$
- $V_T = V_1 = V_2 = V_3 = \cdots$
- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

Meters:
Ammeters are wired in series with the resistor they are intended to measure the current through. Voltmeters are wired in parallel with what they are intended to measure the potential difference across.

Electric Power:

- $P = IV = I^2 R = \frac{V^2}{R}$
- The power dissipated by a resistor leaves in the form of thermal energy.

Practice Problems:

1. A wire is carrying 0.07 amperes of current. How many electrons flow through the wire in one second?

2. A 5 ohm, a 10 ohm and a 20 ohm resistor are wired in series with a 12 volt battery. Draw a circuit diagram for this circuit. What is the equivalent resistance of the circuit? What is the total current drawn from the battery? What is the potential drop across each resistor? How much thermal energy is dissipated by the circuit in one minute?

3. A 5 ohm, a 10 ohm and a 20 ohm resistor are wired in parallel with a 12 volt battery. Draw a circuit diagram for this circuit. What is the equivalent resistance of the circuit? What is the total current drawn from the battery? What is the potential drop across each resistor? How much thermal energy is dissipated by the circuit in one minute? Based on your answer to problems 2 and 3, what type of circuit uses more energy?

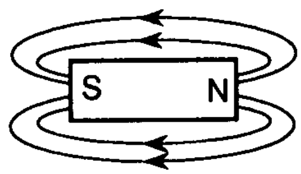
4. Why do you think houses are wired in parallel?

5. A 30 centimeter piece of aluminum wire has a diameter of 4 millimeters. What is the resistance of the wire?

Topic 9: Magnetism

Magnetic Dipoles and Magnetic Field:

- Magnets have two poles: north and south. You will never have a north pole by itself or a south pole by itself. Because you must always have both poles together, magnets are generally referred to as *dipoles*.
- As with the other forces that act at a distance (e.g. gravity and electrostatic force), we describe magnetism by using magnetic fields. The magnetic field outside a dipole points from the north pole to the south pole.



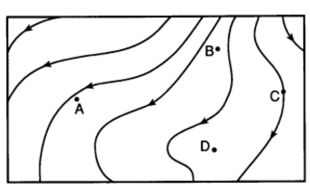
- All magnetic fields are the result of moving electrons.
- Due to spinning molten iron in its core, Earth behaves like a magnetic dipole. The north geographic pole is a south magnetic pole and the south geographic pole is a north magnetic pole.

Magnetic Field Strength:

- The more closely spaced the field lines are, the higher the strength of a magnetic field.
- Magnetic field strength is measured in tesla ([T]).

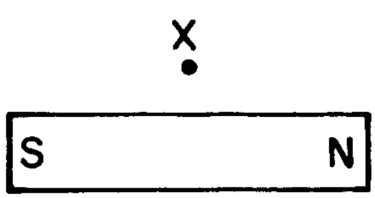
Practice Problems:

1. The figure below shows magnetic field lines in a region of space. At which point is the magnetic field strength the greatest?



(1) A (2) B (3) C (4) D

2. The figure below illustrates a bar magnet. Draw and label the points of a compass needle as it would appear when the compass is placed at point X.



Topic 10: Mechanical Waves

Only energy is transferred in wave motion. This contrasts with particle motion in which both matter and energy are transferred.

Wave Types:

- A *pulse* is a single vibratory disturbance that propagates through a medium.
- A *continuous wave* is a repeated vibratory disturbance that propagates through a medium.
- In a *transverse wave* the particles oscillate perpendicular to the direction in which the wave propagates.
  - Moving a slinky side to side will create a transverse wave.
- In a *longitudinal wave* the particles oscillate parallel to the direction in which the wave propagates.
  - Sound is a good example of a longitudinal wave.

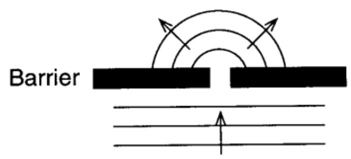
Wave Properties:

- *Wavelength* is the distance a wave travels during one complete cycle.
- *Amplitude* is the maximum displacement from the equilibrium position experienced by a particle.
- *Frequency* is the number of cycles that pass a given point per unit time.
- *Period* is the amount of time that it takes one complete cycle to pass a given point.
- The speed of wave can be calculated using the formula $v = f\lambda$.
  - The speed depends on the medium through which the wave is traveling.
  - The frequency depends on the source of the wave.

Wave Phenomena:

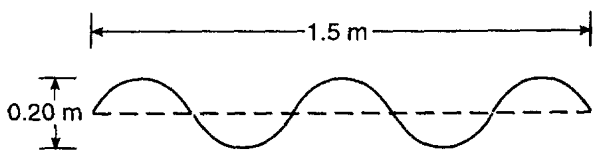
- The *Doppler Effect* occurs when the source of a wave and an observer are moving relative to one another.
  - When the relative motion is towards one another, the observer detects a frequency that is higher than that produced by the source.
  - When the relative motion is away from one another, the observer detects a frequency that is lower than that produced by the source.
- *Interference* occurs when two or more waves act at the same place in a medium at the same time.
  - *Constructive interference* occurs when the displacements of two waves interfering with one another are in the same direction.
  - *Destructive interference* occurs when the displacements of two waves interfering with one another are in opposite directions.
  - The pattern that results from interference can be determined using the *principle of superposition*, which states that the resultant displacement at any point is the vector sum of the displacements caused by each wave.

- *Standing waves* occur when two waves with the same amplitude and frequency travel in opposite directions through a medium and interfere with one another.
    - The points on a standing wave that never move experience *total destructive interference* and are known as *nodes*.
    - The points on a standing wave that oscillate from one maximum value to the other experience *maximum constructive interference* and are known as *antinodes*.
- *Resonance* occurs when an object is forced to oscillate at its *natural frequency*, causing a standing wave in the object.
- *Diffraction* is the bending of a wave around a barrier. The amount of bending increases as the size of the barrier decreases.

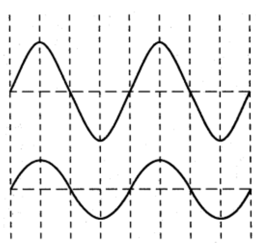


Practice Problems:

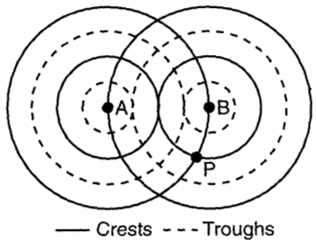
1. The figure below shows a portion of a transverse wave. What are the wavelength and amplitude of the wave? If it takes 5 seconds of the portion of the wave shown to pass a given point, what are the period and speed of the wave?



2. The figure below shows two waves that interfere with one another. Use the principle of superposition to determine the resulting wave pattern.



3. The figure below shows two groups of circular wavefronts interfering with one another. What kind of interference will occur at point P?



Topic 11: Electromagnetic Waves

Electromagnetic waves require no physical medium through which to travel. Rather than particles in a medium oscillating, electromagnetic waves consist of oscillating electric and magnetic fields that are always perpendicular to one another.

- Electromagnetic waves are transverse waves.
- Electromagnetic waves can very greatly in wavelength and frequency, going from radio waves with wavelengths the size of buildings to gamma rays with wavelengths smaller than the nucleus of an atom.
- Visible light is a very small portion of the *electromagnetic spectrum*, spanning roughly 400-800 [nm].
- All electromagnetic waves travel at the speed of light in vacuum, which is 300,000,000 meters per second.

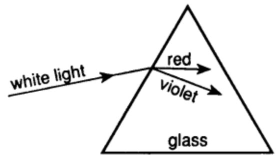
Light at a Boundary:

When light (or any wave) is incident on a boundary, three things occur: reflection, transmission and absorption.

- When light reflects off of a boundary, the angle of incidence is equal to the angle of reflection. These angles are measured from the normal line.
- When light is incident on a boundary at an angle relative to the normal line, *refraction* occurs. When the light is transmitted through the boundary, its speed changes, causing the path of the light to change direction.
  - Refraction is governed by Snell's Law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$.
    - n is known as the index of refraction of the medium. It is a measure of the speed of light in the mediuim
    - $n = \frac{c}{v}$. n is always greater than 1, because light travels slower in any medium that is not vacuum.
  - When light travels from a medium with high index of refraction to one with a lower index of refraction, it bends away from the normal.
  - When light travels from a medium with low index of refraction to one with a higher index of refraction, it bends towards the normal.

Refraction Phenomena:

- In a *dispersive medium*, the index of refraction depends on wavelength. This causes polychromatic light to split into its component colors when it refracts. The higher the frequency of the color, the more it will bend in a dispersive medium. Almost all media are dispersive.



- When light refracts from a medium with a high index of refraction to one with a lower index of refraction at an angle of incidence greater than the *critical angle*, *total internal reflection* occurs.
    - All of the light will be reflected back into the original medium.
    - The critical angle is the angle of incidence for which the angle of refraction is 90°.
        - $\sin\theta_c = \frac{n_{low}}{n_{high}}$

Practice Problems:

1. Light is incident from lucite to diamond at an angle of 30°. What is the angle of refraction? Sketch the ray diagram, showing both reflected and refracted rays.

2. A ray of light goes through multiple boundaries from air to lucite to diamond to lucite to air. Sketch the path of the ray if it is incident on the first boundary at an angle of 50°.

3. A ray of light is incident from fused quartz to air at an angle of 45°. Sketch the path of the ray.

4. A radio wave with a wavelength of 21 centimeters is detected by a telescope. What is the frequency of this wave? How long would it take the radio wave to travel $7.5\times10^{11}\,[\text{m}]$?

Topic 12: Modern Physics

Wave Particle Duality:

- In 1905, Albert Einstein showed that light could behave like a particle as well as a wave. He called these light particles *photons*.
  - A photon is a "packet" of light energy.
  - $E_{photon} = hf = \frac{hc}{\lambda}$
- In 1916, Arthur Compton extended Einstein's photon idea by showing that photons could transfer momentum as well as energy.
  - $p_{photon} = \frac{h}{\lambda}$
- In 1923, Louis DeBroglie suggested that if waves could behave like particles, then particles should behave like waves. He proposed that particles should have wavelengths. He was proved right when Davisson and Germer were able to make electrons diffract.
  - $\lambda_{dB} = \frac{h}{mv}$
- We now view both light and subatomic particles as exhibiting *wave-particle duality*.

Atomic Models:

- In 1897, J.J. Thomson discovered the electron, proving that the atom was made up of smaller particles. His new model of the atom was known as the plum pudding model.
- In 1909, Ernest Rutherford found that most of the mass of an atom and all of its positive charge are located in the nucleus.
- In 1913, Niels Bohr proposed a comprehensive model for the hydrogen atom.
  - The energy levels in the atom are quantized. The electron can only occupy orbits that correspond to those energy levels.
  - The electron can jump to a higher energy level by absorbing a photon whose energy is equal to the difference in energy between the two energy levels.
  - If an electron falls from a higher energy level to a lower energy level, it will emit a photon whose energy is equal to the difference in energy between the two energy levels.
- The Bohr model successfully explains the spectra of elements.
- The most recent view of the atom is the *electron cloud model*. This is based upon the statistical nature of the behavior of subatomic particles. The electron is not guaranteed to be at Bohr's radii, but is most probable to be there.

Mass-Energy Relationship:

Einstein showed that mass and energy are two facets of the same concept and are, therefore, equivalent. This idea led to what is probably the most famous equation in physics, $E = mc^2$.

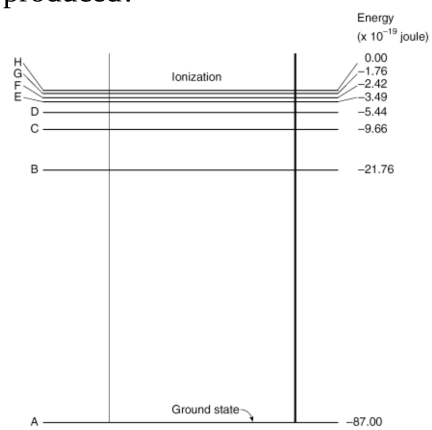
The Standard Model:

Physicists attempt to understand nature by narrowing down various theories into fundamental ideas. The standard model is one such attempt. It narrows down all forces to one of four fundamental forces and describes how matter is structured on the subatomic level.

- The four fundamental forces of nature are gravity, electromagnetic, weak nuclear and strong nuclear.
- Matter can be broken down into two main categories of particles: hadrons and leptons.
    - Leptons are fundamental particles. They can not be broken down further.
    - The possible leptons include: electron, muon, tau, electron neutrino, mu neutrino and tau neutrino.
- Hadrons can be further broken down into baryons and mesons.
    - Baryons consist of three quarks.
    - Mesons consist of a quark and an antiquark.
    - Quarks are fundamental particles, but never exist by themselves in nature. They are always contained in baryons or mesons.
    - The possible quarks include up, down, charm, strange, top and bottom.
    - The proton and neutron are examples of baryons.
    - The strong nuclear force is what binds quarks together to make baryons and mesons and also what binds protons and neutrons to each other to form nuclei.

Practice Problems:

1. The diagram below shows the energy level diagram for an unknown element. How much energy is required to ionize an electron when it is in the C energy state? If an electron is in the D energy state and returns to the ground state, how many different colors of photons can be produced? If an electron falls from the B energy state to the ground state, what are the wavelength and color of the photon produced?



2. The data table below lists the masses of several nuclei in atomic mass units. Find the energy released from the fusion reaction listed.

$${}^{3}_{1}H + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + \text{energy}$$

The masses of the nuclei are:

${}^{1}_{1}H$ = 1.00813 u (amu)

${}^{3}_{1}H$ = 3.01695 u (amu)

${}^{4}_{2}He$ = 4.00388 u (amu)