Introduction to Physics

Physics:

Study of the physical world. Science of energy.

Metric System

The metric system is based on prefixes that indicate a power of 10 with base units.

Metric Prefixes commonly used in physics		
Prefix	**Symbol**	**Multiple**
Kilo	k	1000
Deci	d	0.1
Centi	c	0.01
Milli	m	0.001
Micro	m	0.000001
Nano	n	0.000000001

SI system

The International System of units gives a standard unit for each type of measurement.

SI Units commonly used in physics		
Measurement	**Unit**	**Symbol**
Mass	Kilogram	kg
Volume	Liter	L
Temperature	Kelvin	K
Length	Meters	m
Time	Seconds	s

Amount of substance	Mole	Mol
Energy	Joule	J
Charge	Coulomb	C

Dimensional analysis:

To work dimensional analysis problems:

- Write your known down on the left side
- Write down "=_____ [desired unit]" at the rightside
- Identify equalities that will get you from the known information to the desired unit. If there is no equality that involves both the known and unknown, you'll have to find more than one to more than one step.
- Arrange the equalities into a fractional form so that the known unit will cancel out and the desired unit will be left.
- Multiply across the top of the expression and divide numbers on the bottom.

Measurements and uncertainty:

Measurements must be taken accurately. Always write down one more decimal place than the instrument tells for certain—a "0" if it's "one the line" and a "5" if it's "between the lines."

Significant figures:

The significant figure rules are to allow people to read data or calculations and know with what precision the data was taken. The significant rules can be summarized in two rules: (1) If a decimal point is not present, count digits starting with the first the first non-zero number and ending with the last non-zeronumber; (2) If a decimal point is present anywhere in thenumber, start counting with the first non-zero number and continue until the end of the number.

Scientific process:

There are many paths to follow when undertaking "science"—there is no one scientific method. Science involves observing, posing questions, forming possible explanations (hypothesis), experimenting, processing/analyzing data, looking for trends, more formation of possible explanations or question posing. Scientific processes form theories (which attempt to explain observed behavior) and laws (which describe or predictbehavior, and are usually mathematical). A theory cannot become a law—one explains why and one describes what. A hypothesis is a proposed explanation for why something will occur (that may become a theory

with enough evidence), while a prediction is simply a guess at what will happen—it does not attempt to say "why" it will happen.

Basic Math for Physics

Algebraic operations:

• **If a # is … to avariable,**	• **then … the # to solve for thevariable**	• **Example**
• Added	• Subtract	• 5 = x + 2 • **-2 -2** • **5-2 = x**
• Subtracted	• Add	• 3 = x – 6 • **+6 +6** • **3-6 = x**
• Multiplied	• Divide	• &2 = 4x • **4** • **2/4 = x**
• Divided	• Multiply	• **2 · 6 = x · 2** • 2 • **2 · 6 = x**

- **Adding & Subtracting with significant figures:**
    1. Perform the calculation
    2. Determine the least # of decimal places in problem
    3. Round answer to that # of decimal places
- **Multiplying & Dividing with significant figures:**
    1. Perform the calculation

2. Determine the least # of sig figures in problem
3. Round answer to that # of sig figures

- **Scientific Notation**—a short hand method of writing numbers using powers of 10.
- **Writing scientific notation:**
  1. The decimal point is always moved to after the 1st non-zero number.
  2. Count the number of times the decimal point is moved and use this as the power of 10.
  3. "Big" numbers (>1) have positive exponents. "Small" numbers (<1) have negative exponents.
- **Trigonometry review:**
  Trig functions are often used to find resultants and components. The most useful relationships are:

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

- **Quadratic formula:**
  The quadratic formula is sometimes useful for squared functions:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- **Graphing**:
  Data is often graphed in physics. Theses relationships are often analyzed to fit mathematical models.

Problem Solving in Physics

5 step problem solving strategy:

Step 1:

Identify what's being given

Step 2:

Clarify what's being asked.
If necessary, rephrase the question

Step 3:

Select a strategy
Trial & error, search, deductive reasoning, knowledge-based, working backwards

Step 4:

Solve using the strategy

Step 5:

Review the answer

KUDOS method for solving work problems:

- K = Known
- U = Unknown
- D = Definition
- O = Output
- S = Substantiation

Physics exam prep tips:

- Stay ahead of the game
- Make a cheat-sheet
- Know the format of the test and information that's fair game
- Make a mock exam
- Attend the review session
- Get help early

Exam taking tips:

- Arrive early and prepared
- Listen & Read instructions carefully
- Memory dump first
- Skim the test and form a plan

- Answer questions sequentially
- Apply the guessing rule

Multiple-choice tips:

- Scan all the choices
- Avoid word confusion
- Beware of absolutes

Essay tips:

- Understand the question
- Answer the whole question and only the question
- Watch your time

Free-Response tips:

- Show partial work
- Don’t forget units
- Don’t be fooled by blank space

Mechanics

Describing Motion – Kinematics in One Dimension

Kinematics:

The mathematical description of motion without any reference to the cause.The cause of this motion will be described in a later tutorial.

Vector:

A quantity that has magnitude, size, and direction. Velocity and displacement are examples.

Scalar:

A quantity that has only magnitude, or size.Speed, distance, and time are examples.

Instantaneous velocity:

The speed of an object at any particular instant.

Average velocity:

The total distance traveled divided by the total time of travel.

Acceleration:

The rate of change of velocity. Acceleration describes how fast an objects speed is changing per amount of time.

Kinematic Equations:

Formulas that relate the variables of motion.
v=d/t
a = Δv/Δt=(vf-vi)/t
d=vit+at2/2
vf2=vi2+2ad
acceleration due to gravity = -9.8 m/s2

Free Fall:

Motion where gravity is the only force acting on an object.Gravity will accelerate an object at -9.8 meters per second per second.

Kinematics in Two Dimensions; Vectors

Vector:Â

A quantity that has magnitude, size, and direction. Velocity and displacement are examples.

Scalar:Â

A quantity that has only magnitude, or size.Â Speed, distance, and time are examples.

Vector Addition:

When vectors are graphically added, they are drawn head to tail.Â This may also be described as placing the arrowhead of one vector next to the tail end of another vector.

Resultant:

- The result of adding two or more vectors; vector sum.Â It is drawn from the tail of the first vector to the tip ofthe last vector.

Phythagorean Theorem:

- c2=a2+b2

Vector Component:

- The parts into which a vector can be separated and that act in different directions from the vector.

Horizontal Motion of a Projectile:

Since gravity acts only vertically, there is 0 acceleration.
Horizontally, the projectile moves with a constant speed.
We can use one of the previous kinematic formulasÂ v=d/t

Vertical Motion of a Projectile:

Use previous kinematic formulas in the vertical direction.
a = Î”v/Î”t=(vf-vi)/t
d=vit+at2/2
vf2=vi2+2ad
acceleration due to gravity = -9.8 m/s2

Work, Power and Energy

Work:

The work, W, done by a constant force on an object is defined as the product of the component of the force along the direction of displacement and the magnitude of the displacement.

Calculation of Work:

When calculating work, only the force that is applied in the direction of motion is considered.
W=Fdcosθ

Postive Work:

If the force and displacement are in the same direction, that would be considered positive work.

Power:

Power is a measure of how quickly work is done.

Kinetic Energy:

Kinetic energy is energy of motion. All moving object possess kinetic energy.

Gravitational Potential Energy:

Gravitational Potential energy is the energy an object possessed due to its position.

Base Level:

The point that height is measured from. Any point can be used as a base level because the energy amount you calculate will be relative.

Conservation of Energy:

Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.

Momentum and Collisions

Momentum:

Momemtum may be described as inertia in motion. It is the product of mass times velocity. P = mv

Impulse:

A change in the momentum of an object. It is the product of force times time. J=Ft The impulse may occur over a long or short time period, and with a large or small force applied to make the change in momentum.

Conservation of momentum:

Momentum isn't created or destroyed in a given system. It may be transferred from one object to another. Only an outside or external force will change the total momentum.

- When comparing a bouncing collision to a collision where an object is brought to a halt, the bouncing object experiences a much larger impulse.
- A hit and stick collision is when one object impacts another, then they stay as one.
- A hit and rebound collision is when one object hits another and they both remain separate.
- An explosion collision is when an object breaks apart. It may not necessarily be an explosion.

Elastic collision:

An elastic collision is one where:

- Momentum is conserved.
- The objects colliding aren't deformed or smashed

- Thus no kinetic energy is lost; kinetic energy is conserved also.
- *Ex:* billiard ball collisions

Inelastic collisions:

An inelastic collsion is one where:

- Momentum is still conserved, but kinetic energy is lost.
- The lost kinetic energy will be transformed into other types.
- The objects often interlock and stick together, they may also be deformed and mangled.
- Ex: car crash

Rotational Motion and Equilibrium

Radian:

A unit of rotational displacement; one revolution equals 2 ∏ radians.

Angular Velocity:

- Also called rotational speed, the number of rotations orrevolutions per unit of time, often measured in rpm,revolutions per minute.

Table of rotational motion formulas, and the related linear motion formulas:

Linear motion formula	**Rotational motion formula**
$v = \frac{d}{t}$	
	$\omega = \frac{\Delta\theta}{\Delta t}$
$a = \frac{\Delta v}{\Delta t}$	$\alpha = \frac{\Delta \omega}{\Delta t}$
$d = v_i t + at^2/2$	$\theta = \omega_i t + \alpha t^2/2$

$v_f^2 = v_i^2 + 2ad$	$\omega_f^2 = \omega_i^2 + 2\alpha\theta$

Torque:

The rotational quantity that causes rotation; the product of force times lever arm.

Moment of inertia:

- Also called rotational inertia, The rotational equivalent of linear inertia; a measure of the ease of rotating some object.

Newton's second law for rotational motion:

- $\Sigma T = I \alpha$ The sum of the torques is equal to the rotational inertia times the angular acceleration.

Rotational Equilibrium:

- The situation when the net torque on an object equals zero.

Angular momentum:

- The rotational equivalent of linear momentum that describes the tendency of an object to continue rotating.

Fluid Mechanics and Thermal Physics

Solids and Fluids

Matter:

Anything that has mass and takes up space.

Crystalline:

Solids with ordered atom-structure and fixed melting point.

Amorphous:

Solids with in ordered atom-structure and without melting point.

Young's modulus:

Ratio of stress to strain when solids is under tension.

Shear modulus:

Ratio of stress to strain when solids is under shear.

Bulk modulus:

Ratio of stress to strain when solids is under hydraulicpressure.

Buoyancy:

The force caused by pressure variation with depth to lift immersed objects.

Surface tension:

The force to attract surfaced molecular to make the surface area of fluid as small as possible.

Capillary action:

The phenomena of fluids automatically raising in open-ended tubes.

Continuity:

The net rate of flow of mass inward across any closed surface is equal to the rate of increase of the mass within the surface.

Viscosity:

The inter-friction mechanism in fluid to dissipate energy.

Laminar flow:

Every particle passing a particular point moves exactly along the smooth path followed by particles passing that point early.

Turbulent flow:

The irregular flow when the velocity of the flow is high.

Temperature and Kinetic Theory of Gases

Kinetic Molecular Theory (KMT):

An attempt to explain gas behavior.

Kelvin (K):

Temperature scale used in gas calculations. Has an absolute zero. °C + 273 = K

Pressure:

Force of gas molecules colliding with surfaces

Atmospheric pressure:

Pressure due to the layers of air in the atmosphere

Standard Temperature and pressure:

1 atm (or anything it's equal to) and 0°C (273 K)

Ideal Gas:

All assumptions of the kinetic molecular theory are true.

Molar Mass (Molecular Mass):

Grams per mole for a molecule.

Density:

Mass per volume of a sample

Average Translational Kinetic Energy (KEave):

Average kinetic energy (energy due to motion) of eachparticle.

Root-Mean-Square Speed (Vrms):

One measure of average particle speed in a gas

Maxwell's Probability Distribution:

Probability function that indicates the probability that a particlein a gas will be moving at a certain speed.

Real Gas:

Real gases have significant particle volume and significant attractions/repulsions

Diffusion:

The rate at which a gas travels through a container

Effusion:

The rate at which a gas escapes through a tiny hole

Kenectic Theory of Gases

Heat and Thermodynamics

Thermodynamics:

Study of heat changes.

Temperature (T):

Proportional to the average kinetic energy of the particles. The higher the temperature the faster the molecules move.

Linear Expansion Coefficient (α):

Linear expansion of a material per °C increase in temperature.

Volume Expansion Coefficient (ß):

Volume expansion of a material per °C increase in temperature.

Endothermic reaction:

Energy is absorbed into the system from the surroundings.

Exothermic reaction:

Energy is released from the system into the surroundings.

Specific Heat Capacity (Cp):

Amount of energy that 1 gram of material can absorb before increasing in temperature. Cp for water: 4.18 J or 1.00 cal

Enthalpy of fusion (Lfus):

Energy needed to break enough intermolecular forces to change a solid into a liquid

Enthalpy of vaporization (Lvap):

Energy needed to break the intermolecular forces to change a liquid into a gas.

Thermal Equilibrium:

Two objects at different temperatures will come to the same temperature when placed together.

Zeroth Law of Thermodynamics:

Objects in thermal equilibrium are at the same temperature. Objects in contact will eventually come to thermal equilibrium.

1st Law of Thermodynamics (Law of Conservation of Energy):

Energy cannot be created nor destroyed in a chemical or physical process.

Calorimetry:

Energy lost/gained from the system is equal & opposite to that lost/gaines from the surroundings

Entropy (S):

Disorder or random-ness

2nd Law of Thermodynamics:

The total entropy of the universe can never decrease.

Electricity and Magnetism

Electrostatics

Electric Charge:

A fundamental intrinsic property of matter that gives rise to theattractions and repulsions between electrons and protons.

Coulomb:

The typical unit for measuring charge; a set number ofelectrons. 1 Coulomb = 6.25x1018 electrons

Charging by Contact:

The transfer of electric charge from one object to another by simple contact or conduction.

Charging by Induction:

Redistribution or charging of an object by bringing a charged item in close proximity to, but not touching, an uncharged object.

Coulomb's Law:

Mathematical relationship between electric force, charge, and distance. The electric force varies directly with the product of the charges, and inversedly to the square of the distance between the charges.

Polarization:

Separation or alignment of the charges in a neutral body so that like charges are grouped together, resulting in a positive and a negative region.

Electric Field:

A force field that fills the space near any charge.

Electric Potential:

The ratio of electric potential energy to electric charge at a particular spot in an electric field. It is often referred to as voltage since it is measured in volts.

Equipotential Line:

A line where all points have an equal electric potential, or voltage.

Conductors, Capacitors and Dielectrics

Conductor:

Material where electrons are loosely bound and are able to flow throughout due to the free electrons.

Insulator:

Materials where electrons are bound and don't flow easily.

Semiconductor:

Materials in between insulator and conductor.

Superconductor:

A material where electrons flow without any resistance. Generally, superconductivity only occurs at very low temperatures.

Resistivity:

An intrinsic property of a material that partially determines the resistance of a wire.

Capacitor:

A device used to store or accumulate electric energy. This is done by oppositely charging two nearby conductive surfacesthat are not in contact with each other.

Dielectric:

An insulating material is inserted between the plates of a capacitor.

Dielectric Constant:

The factor that describes the additional capacitance gained by adding a dielectric material between the plates of a capacitor

Electric Circuits

Current:

- Electrical charge flow past a given point per unit of time.

Direct current:

- Electrical current that flows in only one direction.

Alternating current:

- Electrical current that oscillates forward and backwards.

Voltage:

- The ratio of electric potential energy to electric charge at a particular spot in an electric field. It is often referred to as voltage since it is measured in volts.

Ohm's law:

- Basic law that describe current electricity; Voltage equals current times resistance.

Internal resistance:

- Resistance from the processes inside a voltage source; reistance due to the battery itself.

Series circuit:

- A circuit where the components form one continuous loop. The current is constant throughout.

Parallel circuit:

- A circuit where each component is connected to form its own separate independent branch. The voltage is constant throughout.

Fuse/Circuit breaker:

- A safety device designed to melt or disconnect a circuit after a predetermined amount of current is exceeded.

Junction rule:

- A restatement of conservation of charge; the current going into a junction must equal the current going out of the junction.

Loop rule:

- A restatement of conservation of energy; the sum of all voltages in the elements of a loop is zero.

Magnetic Fields

Magnetic Domain:

- Microscopic areas of atoms where the magnetic fieldsare aligned.

Ferromagnetic:

- A naturally magnetic class of materials where themagnetic domains are ordered and do not cancel out.

Magnetic Field:

- Lines showing the shape and exent of a magnetic field around a permanent magnet or a moving charged object. To signify a field coming directly out of the plane of a page, dots are used. To signify a field going directly into the page, an X is used.

Right Hand Rule. RHR:

1. The fingers extend or curl in the direction of the magnetic field.
2. The outstretched thumb points in the direction of conventional current, or the direction of a positively charged moving particle.
3. A line perpendicular to the palm indicates the direction of the magnetic force.

Mass Spectrometer:

- A device that magnetically separates charged ions according to their mass.
  A magnetic field is used toaccomplish this separation.

Electromagnetism

Magnetic flux:

- A measurement of the number of magnetic field lines passing through a particular area or surface.

Faraday's law:

- The voltage induced is directly proportionoal to thenumber of loops and the change in the magnetic flux. It is inversely proportional to the time that this change occurs throughout.

Lenz's law:

- The induced emf always gives rise to a current whosemagnetic flux opposed the original change in magneticflux. Thus, the induced current tries to maintain the level of magnetic flux.

Electromotive force:

- A voltage that gives rise to a current flow. This voltagecan be induced or created by a changing magnetic field.

Right hand rule, RHR:

- The fingers extend or curl in the direction of themagnetic field. The outstretched thumb points in the direction of conventional current.

Generator:

- A machine that produces electricity by a rotating coil of wire immersed in a stationary magnetic field. This rotating motion could be obtained from a variety of sources.

Waves, Sound and Optics

Vibrations and Waves

Amplitude:

- The maximum displacement of the body in vibration.

Period:

- The time taken by a body to complete one vibration.

Frequency:

- Frequency is the number of oscillations completed in a unit time
- $(f = 1/T)$.

Resonance:

- The natural frequency of a body executing forcedvibrations is equal to the input frequency. The body vibrates with maximum amplitude. The frequency is called resonant frequency

Mechanical Wave:

- A mechanical wave is just a disturbance that propagates through a medium

Electromagnetic Wave:

- An electromagnetic wave is simply light of a visible or invisible wavelength. Oscillating intertwined electric and magnetic fields comprise light. Light can travel without medium

Transverse Wave:

- In a transverse wave the particles in the medium move perpendicular to the direction of the wave. Eg. Light waves, waves on strings.

Longitudinal Wave:

- The particles in the medium move parallel to the direction of the wave. Eg. Sound waves

Interference:

- The superposition of two waves of the same frequencyand wavelength traveling with a phase difference which remains constant with time. This phenomenon is called interference. The pattern so formed is called interference pattern.

Sound

Audible sounds:

- The audio spectrum extends from approximately 20Hz to 20,000 Hz.Sounds of frequency between 20Hz and 20,000Hz can be heard by human ear

Infrasonic sounds:

- Sounds of frequency less than 20Hz are called “infrasonics”.

Ultrasonic sounds:

- Sounds of frequency greater than 20,000Hz are called“ultrasonics”.
- Ex: Sound produced by bats.

Nodes:

- The points of no displacement when standing waves are formed.

Antinodes:

- The points along the medium which vibrate back andforth with maximum displacement.

Sound Intensity:

- The loudness of sound is directly proportional to the square of the amplitude or intensity (I). It is convenient to use a logarithmic scale to determine the intensitylevel b = 10 log (I/I0)

Pitch:

- Pitch is the highest or lowest sound an object makes.

Beats:

- Beats are the periodic and repeating fluctuations heard in the intensity of a sound. Two sound waves of nearly same frequencies interfere with one another to produce beats
- The intensity of the resultant wave at a given point in the medium becomes maximum (waxes) and minimum (wanes) periodically.

Doppler Effect:

- The apparent change in the frequency of sound due torelative motion between the sound source and observer is called Doppler Effect.

Echoes:

- The sound obtained by reflection at a wall, cliff or a mountain is called an echo.

Diffraction:

- When waves encounter an obstacle with an edge, some of the wave energy bends around the edge behind the obstacle. This bending is called diffraction.

Physical Optics

Electromagnetic spectrum:

A diagram that illustrates all the varieties of electromagneticwaves based on their relative frequency/wavelengths. Our eyes observe only a small amount of this spectrum.

Speed of light:

In a vacuum 3x108 m/s. It was first calculated by Olaus Roemer. Albert Michelson also performed an experiment to refine the value.

Principle of superposition:

When two or more waves occupy the same region of space simultaneously, the resulting wave disturbance is the sum of separate waves.

Constructive interference:

Two or more waves superimposing to create a resulting wave that has a larger amplitude.

Destructive interference:

Two or more waves superimposing to create a resulting wave that has a smaller amplitude.

Thin film interference:

The principle that creates colors on thin layers of transparent substances. The light reflecting off the interior of the substance interferes with light reflecting off the exterior.

Coherent light:

Light wave that are all in phase or in step.

Monochromatic light:

Light waves that possess the same frequency, color, or wavelength.

Diffraction:

The bending of waves around obstacles, corners, or openings.

Polarized light:

Light where the electric field fluctuates in only one direction.

Geometric Optics

Law of reflection:

- The angle of incidence equals the angle of reflection.

Diffuse reflection:

- Reflection from a rough surface where variations in the direction of the surface cause light to reflect in differentdirections.

Convex mirror:

- Also called a diverging mirror, a surface that diverges light as if it originates from a point behind the mirror, a focal point.

Concave mirror:

- Also, called a converging mirror, a surface that converges light to a single point, focal point.

Real image:

- An image where the rays of light actually meet at a location. It can be projected onto a screen.

Virtual image:

- An image that cannot be projected onto a screen. The rays of light don't actually converge there, they just seem to originate from that location.

Refraction:

- The bending of light due to its change in velocity in various media.

Index of refraction:

- The ratio between the speed of light in a vacuum and a particular medium.

Snell's law:

- The formula that describes the amount of refraction of light based on the two different media and the angle ofthe light ray: $n1\sin\theta1=n2\sin\theta2$

Total internal reflection:

- The complete reflection of light when it strikes the boundary between two media at greater than a critical angle.

Convex lens:

- A converging lens that gathers incoming light to a single focal point.

Concave lens:

- A diverging lens that diverges light as if it originates from a point behing the lens, the focal point.

Spherical aberration:

- A lens defect where light is imperfectly focused near the focal point.

Chromatic aberration:

- A lens defect where various color focus at different locations.

Atomic and Nuclear Physics

Atomic and Quantum Physics

Atomic Physics

Electron:

- Electron was discovered during experiments on the discharge of electricity through rarified gases. The magnitude of electric charge (e) was determined by Millikan. Charge of the electron = 1.602 X10 -19 coulomb

Bohr Model of the Atom:

- Proposed by Neil Bohr in 1913. Bohr applied the Planck's quantum theory to the Rutherford nuclear atom with remarkable success.

First postulate:

- An atom consists of a positively charged nucleus at the centre. The electrons move round the nucleus in certain stationary orbits of definite radii and not all possible radii.

Second postulate:

- The radius of the orbit is such that the angular momentum of the electron is an integral multiple of h/2p.

Third postulate:

- Electron may jump from one orbit to the other, in which case the difference in energy between the two states of motion is radiated in the form of a light quantum.

X-Rays :

- Invisible electromagnetic radiations, Wavelengths range form 0.010A – 100A. These are discovered by Roentgen. When a fast moving electron is suddenly stopped a part of its kinetic energyis converted into X-ray photon the rest of the energy is converted into heat.

Wave Particle Duality:

- To understand any given experiment, we must use either the wave or the photon theory, but not both. Light sometimes behaves like a wave and some times like aparticle

de Broglie Hypothesis:

- Photons are treated as "packets of light" behaving like a particle. Momentum of a photon: p = E / c = h/l Energy of a photon: E = hc/l

Heisenberg Uncertainty Principle:

- If position is identified the momentum cannot be measured. If momentum is measured the position is lost. Dx X Dp ³ h / 4π

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