Things You Should Know About Physics **HONORS**

Measurement and Mathematics

Sig Figs: 260 = 2 sf 260. = 3 sf 0.026 = 2 sf 0.0260 = 3 sf

Estimation: 1 kg = 2.2 lbs 1 apple = 1 N 1 quarter = 5 g = 0.005 kg

Order of magnitude: power of ten (thickness of paper = 10^{-4} m)

Addition/Subtraction Rule: match decimal places

Multiplication/Division Rule: match significant figures

Fundamental Units: There are only 7 (see table). All other units are **derived units**.

Fundamental units

Quantity	Units	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount	mole	mol
Luminous intensity	candela	cd

Factor-Label Conversions: "1 goes with the prefix, exponent goes with the base."

$$\%\text{error} = \frac{|\text{experimental - actual}|}{\text{actual}} \times 100$$

Mean = average Range = highest value – lowest value

Measured Uncertainties: use 1 sig fig and match decimal place of measurement eg.- 2.0 cm ±0.1 cm
(exception: extreme variability)

Calculated Uncertainties for multiple trials: use greatest residual of data and match decimal place of measurement

Parallax: uncertainty in measurement due to perspective of person reading instrument

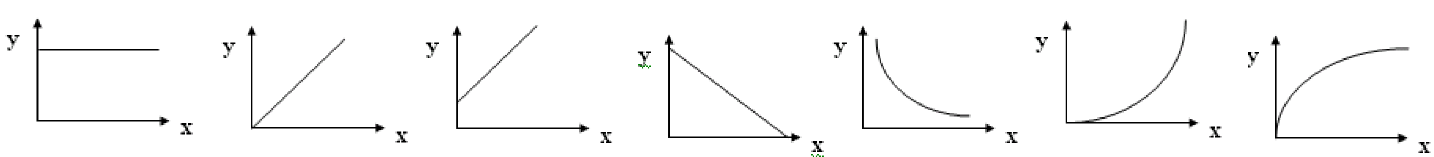
Accuracy: how close a measurement is to the accepted value (a measure of correctness)

Precision: agreement among a number of measurements made in the same way (a measure of exactness)

Systematic Error: all measurements off by same amount – non-zero y-intercept – can be eliminated – measure of accuracy

Random Uncertainty: unpredictable variations in data – the reason for error bars on graph – can be reduced by multiple trials but never eliminated – measure of precision

General Relationships:



Constant y = c | Direct y = mx Slope = Δy/Δx | Linear y = mx + b | Linear (Indirect) y = mx + b | Inverse y = c/x Inverse Quadratic $y = c/x^2$ | Quadratic $y = cx^2$ | Square Root y = c√x

Scalars (magnitude only)	**Vectors** (magnitude and direction) – only 9!
Distance Speed Anything else!	Displacement Velocity Acceleration Force (weight, normal force, etc.) Momentum Impulse Fields (gravitational, electric, magnetic)

$$\sin\theta = \frac{opp}{hyp}$$

$$\cos\theta = \frac{adj}{hyp}$$

$$\tan\theta = \frac{opp}{adj}$$

Things You Should Know About Physics

Mechanics

Equilibrium: no net force, no acceleration, constant velocity or at rest, forces form a closed figure

Concurrent vectors: placed tail-to-tail
Component vectors: must be head-to-tail to find resultant

Resultant force = F_{net} : head-to-head and tail-to-tail with components

Range of possible resultants:
Maximum = sum of vectors Minimum = difference of vectors

Equilibrant: equal and opposite to resultant

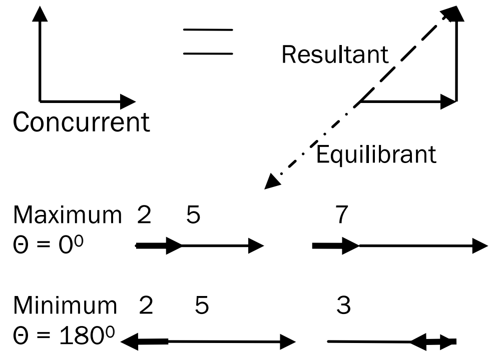
Box on a Hill in Equilibrium: $mg\sin\theta = F_f$ or F_A or F_T and $mg\cos\theta = F_N$

Mass (m): = **inertia**, amount of matter, constant from place to place, units: kg

Weight (F_g): = force of gravity, changes from place to place, units: N
Formula: $F_g = mg$

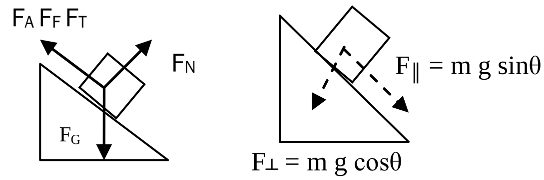
Two names for little "g":
1) acceleration due to gravity, units: m/s^2, formula: $g = GM/r^2$ 2) gravitational field strength, units: N/kg, formula: $g = F_g/m$

Vectors

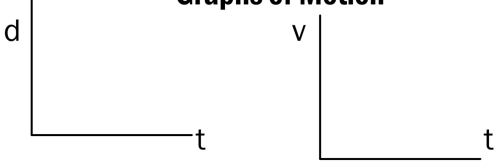


Triangle rule → sum of any 2 sides ≥ third side for forces to be in equilibrium

Inclined Plane



Graphs of Motion



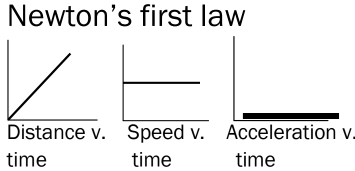
Slope = velocity

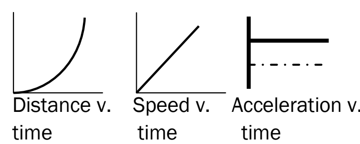
Slope = acceleration
Area = displacement

Conservation Laws: electric charge, momentum, mass and energy

Two Types of Motion

Constant Velocity	Constant Acceleration
Forces are balanced	Forces are unbalanced
$F_{net} = 0$, $a = 0$	$F_{net} \neq 0$, $a \neq 0$
In equilibrium	not in equilibrium
Newton's first law	Newton's second law



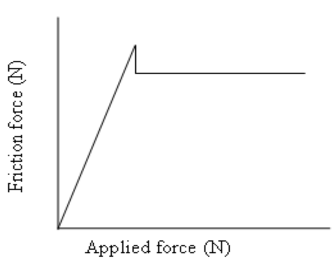


Friction

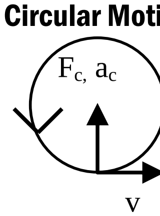
Static friction (at rest) = applied force until motion starts

Kinetic friction (in motion) is constant

Maximum static friction is greater than kinetic friction



Circular Motion



$$v = \frac{d}{t} = \frac{circumference}{period} = \frac{2\pi r}{T}$$

$$a_c = \frac{v^2}{r} \qquad F_c = ma_c = \frac{mv^2}{r}$$

Newton's Third Law: Whenever A exerts force on B, B exerts equal/opposite force on A. (Action/reaction pairs: bat and ball, Earth and Moon, hammer and nail)

Forces are the same but the **effects** of the forces are not: mA = Ma

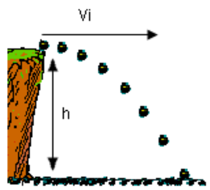
Things You Should Know About Physics

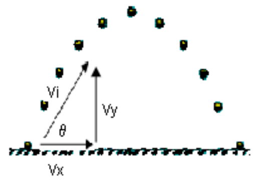
Projectiles

Horizontal – constant speed
Vertical – constant acceleration

Horizontal Launch

	x	Y
d		h
t	The	same
a	0	9.81
v_i	v_i	0
v_f	v_i	
v_{avg}	v_i	





Angle Launch

	x	Y
d		
t	Whole	half
a	0	9.81
v_i	V_x	V_y
v_f	V_x	0 (top)
v_{avg}	V_x	

Energy

Work: force and displacement must be parallel

Mechanical Energy: $PE_g + PE_s + KE$

Total Energy: $PE_g + PE_s + KE + Q$

Internal Energy = Q: thermal energy, heat due to friction/air resistance

Power: rate of change of energy, rate of dong work (units: Watts (W) = J/s)

Efficiency: useful out/total in

PE_g increases if height increases. KE increases if speed increases. PE_s increases if spring is stretched or compressed.

Formulas for springs: $PE_s = \frac{1}{2} kx^2$ $F_s = kx$

k = spring constant (units: N/m)

Conservation of Energy: $E_T = E_T$
$PE_g + PE_s + KE + Q = PE_g + PE_s + KE + Q$

Work-Energy Theorem: $W = \Delta E_T$

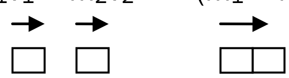
Collisions

Conservation of Momentum: $p_{before} = p_{after}$

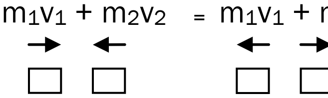
Isolated System: no external forces

Elastic Collision: total KE is conserved

Sticky $m_1v_1 + m_2v_2 = (m_1 + m_2) \cdot v_f$

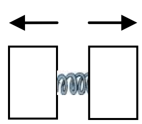


Bouncy $m_1v_1 + m_2v_2 = m_1v_1 + m_2v_2$



Remember – Moving to the left gets a NEGATIVE sign!

Explosion



Equal and opposite forces, impulses, changes in momentum, and contact times

Different speed based on mass

$ma = Ma$

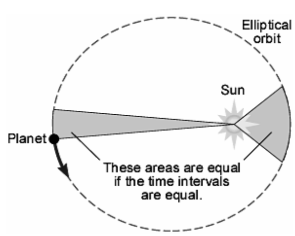
$mV = Mv$

Kepler's Laws

#1: orbits are ellipses, Sun at one focus

#2: equal areas in equal times (planet moves faster when closer to Sun)

#3: $$\frac{T^2}{r^3} = \frac{T^2}{r^3}$$

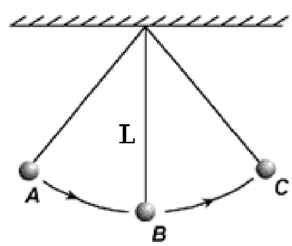


Newton's Law of Universal Gravitation

$$F_g = \frac{Gm_1m_2}{r^2}$$

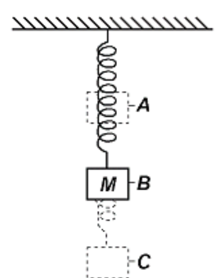
Simple Harmonic Motion

1) Pendulum



$$T = 2\pi\sqrt{\frac{L}{g}}$$

2) Mass on Spring



$$T = 2\pi\sqrt{\frac{M}{k}}$$

Things You Should Know About Physics

Electricity

Conductors (metals) have free electrons, insulators do not.

Objects become charged by losing or gaining electrons (not protons).

Elementary Charge: proton or electron

1 Coulomb of charge = 6.25×10^{18} elementary charges

Charge of Electron: $q = -1e$ OR $q = -1.60 \times 10^{-19}$ C
Mass of Electron: $m = 9.11 \times 10^{-31}$ kg

Charge of Proton: $q = +1e$ OR $q = +1.60 \times 10^{-19}$ C
Mass of Proton: $m = 1.67 \times 10^{-27}$ kg

If two or more identical charged spheres touch, the final charge on each is the **average** charge (total charge / # of spheres). The total charge is conserved.

A neutral object will be attracted (never repelled) by any charged object. If two objects attract, they could have opposite charges or one could be neutral. If two objects repel, they must have the same type of charge.

Charging by conduction: direct contact - electroscope gets same charge as rod
Charging by induction: no direct contact - electroscope gets charge opposite of rod

Electric potential difference (voltage): work done per unit charge ($V = W/q$)

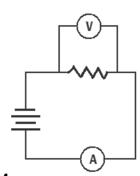
Resistance of a wire: $R = \rho L/A$ where $A = \pi r^2$

Least resistance (best conductor): short, fat, cold

Most resistance (worst conductor): long, hot, skinny

Voltmeter: connect in parallel, infinite internal resistance

Ammeter: connect in series, zero internal resistance



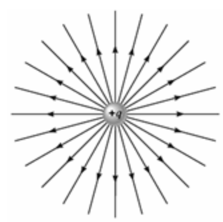
Coulomb's Law (electric force, electrostatic force)

$$F_e = \frac{kq_1q_2}{r^2}$$

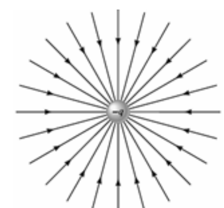
Electric Field (units: N/C or V/m)

$$E = \frac{F_e}{q}$$

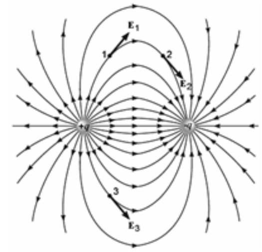
Lines go from + to -.
Lines never cross.
Lines show direction of force on small positive test charge.
Field is most intense where field lines are most dense.



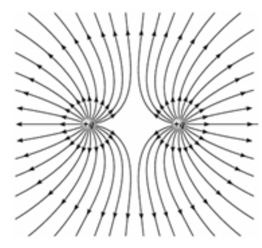
Single Positive (Point) Charge



Single Negative (Point) Charge

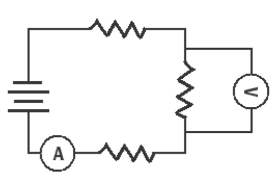


Two Unlike Equal Charges



Two Like Equal Charges

Series Circuit



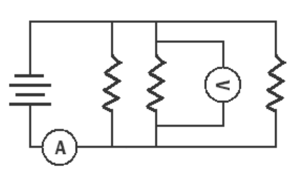
$$\frac{R_1}{R_2} = \frac{V_1}{V_2} = \frac{P_1}{P_2}$$

Control: current

Resistance adds up (greater than greatest)

Adding extra resistor increases total resistance and decreases total current.

Parallel Circuit



$$\frac{R_1}{R_2} = \frac{I_2}{I_1} = \frac{P_2}{P_1}$$

Control: voltage

Resistance adds down (less than least)

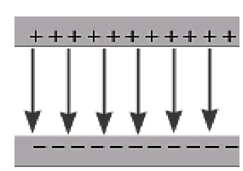
Adding extra resistor decreases total resistance and increases total current.

Two Parallel Plates (Capacitor)

Uniform electric field between plates = same E everywhere and same F everywhere

Used to store electric charge

$$E = \frac{V}{d}$$



Capacitance (C): ability to store charge

Units: farads (F)

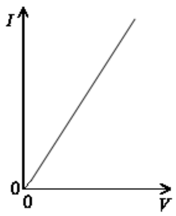
$$C = \frac{Q}{V}$$

Things You Should Know About Physics

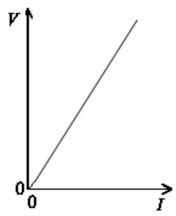
Resistance: $R = V/I$

Ohmic Device: follows Ohm's law ($V \alpha I$ at constant T) = constant resistance

Non-Ohmic Device: resistance not constant (eg. filament lamp)



Slope = 1/R



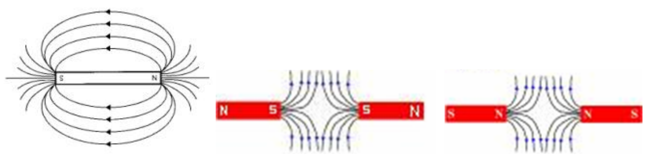
Slope = R

Potential difference	V	Volt	V = J/C
Current	I	Amps	A = C/s
Resistance	R	Ohms	Ω = V/A
Power	P	Watts	W = J/s
Charge	q	Coulombs	C
Energy	W	Joules	J = N·m

Magnetic Fields

From N to S, density = strength (intensity)

Direction of lines = direction of compass needle



Mechanical Power: $P = W/t = Fd/t = Fv$

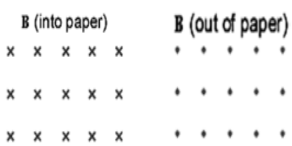
Electrical Power: $P = VI = I^2R = V^2/R$

1 electronvolt (eV) = 1.60×10^{-19} J

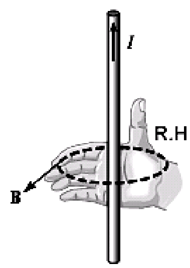
1 kilowatt hour = (1000 W)(1 hr) = 3.6×10^6J

Three units of energy: joules, electronvolts, kilowatt hours

B = Magnetic Flux Density (Intensity, Field Strength) Units: Tesla (T)

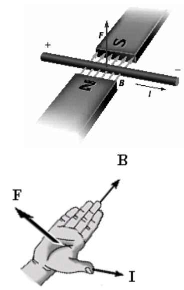


Magnetic Field around a Wire



Magnetic Force on a Wire

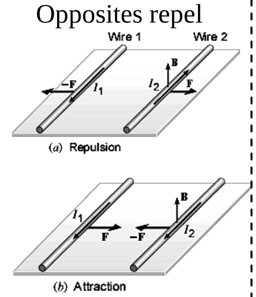
$F_B = BIL$



Magnetic Force between 2 Wires

Likes attract

Opposites repel

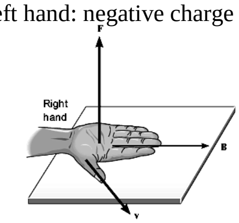


Magnetic Force on a Charged Particle

$F_B = qvB$

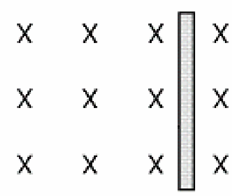
Right hand: positive charge & current

Left hand: negative charge



Two Principles of Electromagnetism:

1) An electric current (or moving charged particle) generates a magnetic field.
2) A changing/moving magnetic field induces an electric current (electromagnetic induction).



Electromagnetic induction:

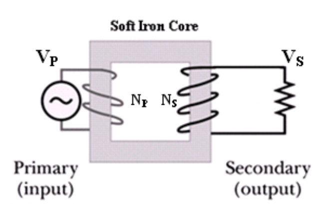
emf = V = BLv

(move wire perpendicular to field lines for maximum induced potential difference)

Motor: converts electrical to mechanical energy (using principle #1)

Generator: converts mechanical to electrical energy (using principle #2)

Transformer: used to increase or decrease AC voltage (using principle #2)



All transformers

$$V_P / V_S = N_P / N_S$$

Ideal transformers

$$P_P = P_S$$
$$V_P I_P = V_S I_S$$

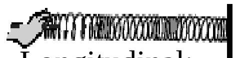
Step-up: $N_s > N_P$, $V_s > V_P$, $I_s < I_P$

Step-down: $N_s < N_P$, $V_s < V_P$, $I_s > I_P$

Things You Should Know About Physics

Waves

Mechanical: needs medium
Electromagnetic: no medium



Transverse: perpendicular

Longitudinal: parallel

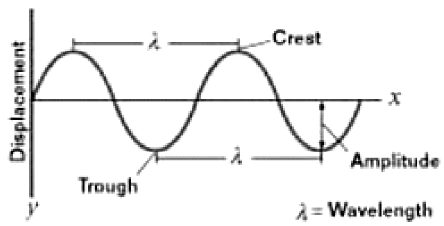
Radio Wave: electromagnetic wave – speed = 3.00×10^8 m/s

Sound	Light
Longitudinal, mechanical	Transverse, electromagnetic
Speed = 331 m/s (STP) 340 m/s (room temp)	Speed = c = 3.00×10^8 m/s (vacuum)
Amplitude = loudness (volume)	Amplitude α brightness (intensity)
Frequency = pitch	Frequency α energy (E =hf)
Energy α amplitude	Slows down when going from air to water
Speeds up when going from air to water	Can be polarized
Can't be polarized	**Red**: long wavelength, low frequency
	Blue: short wavelength, high frequency

Period (T): seconds/cycle

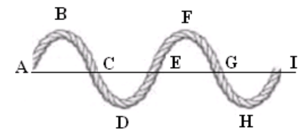
Frequency (f): cycles/second

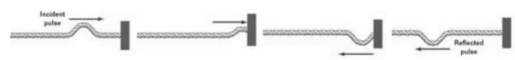
Wave equation: $v = f\lambda$



In Phase: A, E, I

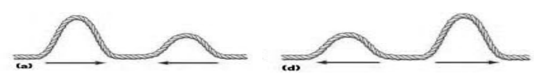
Out of Phase by 180^0 or $\lambda/2$: A, C



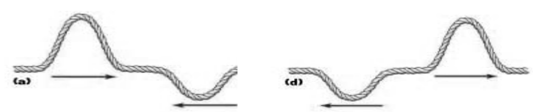


Hard reflection: out of phase

Soft reflection: in phase



Constructive interference: in phase



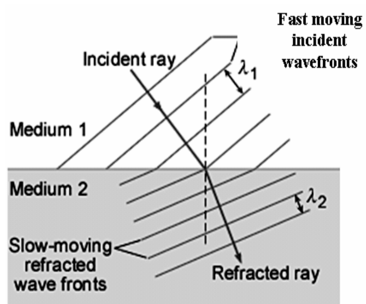
Destructive interference: out of phase

In one medium : $f \alpha 1/\lambda$

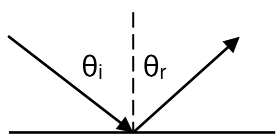
Control: speed - you can only change the speed of the wave by changing the properties of the medium)

Crossing a boundary: $v \alpha \lambda$

Control: frequency stays the same, so does period and phase

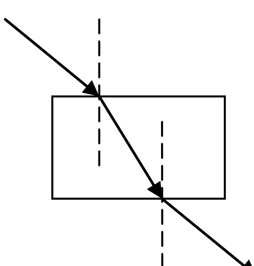


Law of Reflection: $\theta_i = \theta_r$



Refraction: changing direction when changing speed when crossing a boundary

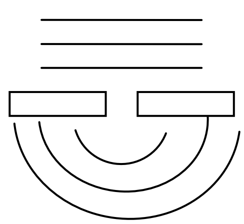
FAST:
into fast, bend away from normal (high n to low n)
into slow, bend towards normal (low n to high n)



Light slows down, bends towards the normal, and has a shorter wavelength when it enters a medium with a higher index. The frequency stays the same.

Diffraction: bending around obstacle or spreading through opening

Noticeable diffraction: when size of opening approx. equal to size of wavelength – as opening gets smaller, more diffraction effects

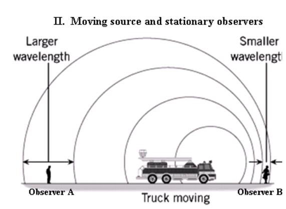


Resonance: energy is transferred to a system by making it vibrate at its natural frequency resulting in large amplitude standing waves

Examples: guitar strings, bridges, swings, wine glasses

Doppler Effect: apparent change in frequency due to relative motion

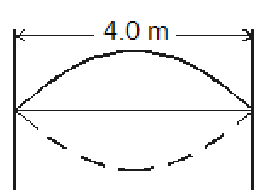
Constant low frequency, Decreasing amplitude

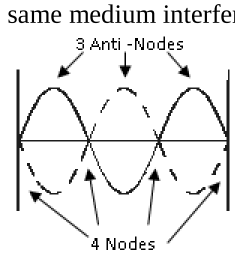


Constant high frequency, Increasing amplitude

Doppler Shift for Light:
"blue shift" = object moving towards
"red shift" = object moving away

Standing Wave: Two identical waves traveling in opposite directions in the same medium interfere





Fundamental Wave: lowest frequency (f_1), $\lambda_1 = 8.0$ m

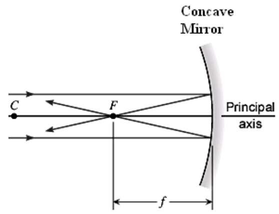
Third Harmonic: $f_3 = 3f_1$ $\lambda_3 = 1/3\ \lambda_1$

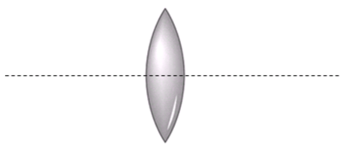
Order of Electromagnetic Spectrum: Source – accelerating charged particles
Radioactive **M**onkeys **I**n **V**irginia **U**se **X**-ray **G**uns –
lowest to highest frequency and energy

Visible Light: 400 nm (violet) – 700 nm (red)

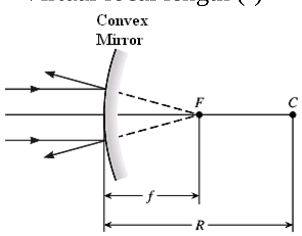
Things You Should Know About Physics

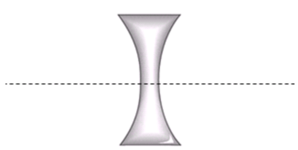
- Converging mirror = concave
- Converging lens = convex
- Real/inverted (all sizes) and virtual/upright (larger) images
- Real focal length (+)





- Diverging mirror = convex
- Diverging lens = concave
- Virtual/upright (smaller) images only
- Virtual focal length (-)





Lens/Mirror Equations

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

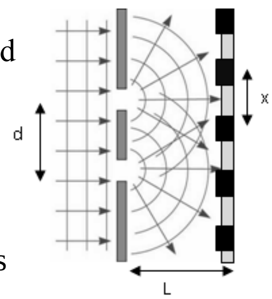
$$m = \frac{h_i}{h_o} = -\frac{q}{p}$$

Focal length = ½ radius of curvature

Double Slit Diffraction and Interference: equally spaced bright and dark bands

$x = \lambda L/d$

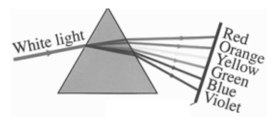
Red Spreads



Single Slit Diffraction: wide and bright central maximum

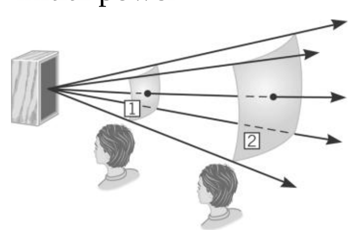
Dispersion: spreading out of light into components due to refraction – each color has slightly different index and speed

Blue **B**ends **B**est - slowest
Red **R**esists **R**efraction - fastest



Intensity = Power per unit area

$I = P/A = P/(4\pi r^2)$
$I \; \alpha \; r^2$ so doubling distance from source means power is ¼ initial power



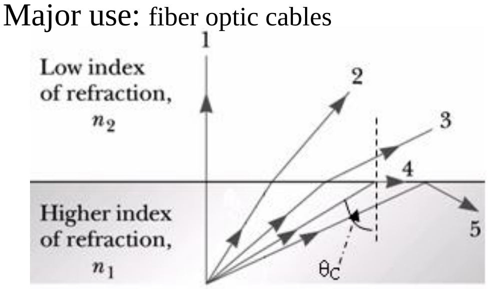
Total Internal Reflection

Critical Angle (θ_C): incident angle for which the refracted angle is 90^0

Formula: $\sin \theta_C = n_2/n_1$

Total Internal Reflection: all light is reflected at surface, none is refracted – only occurs when light travels from high to low index and incident angle is greater than θ_C

Major use: fiber optic cables



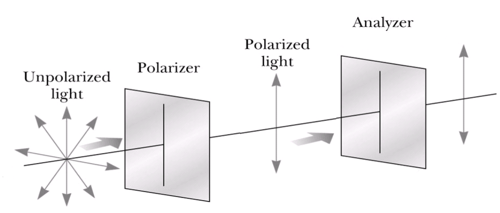
Polarization

Only transverse waves can be polarized – light = yes, sound = no.

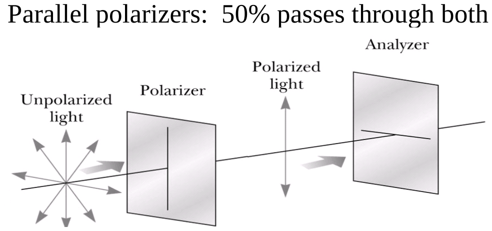
Polarized Light: vibrates in only one direction

Natural Polarization: light is partially polarized when it reflects off a surface

50% of unpolarized light transmits through a single polarizer.

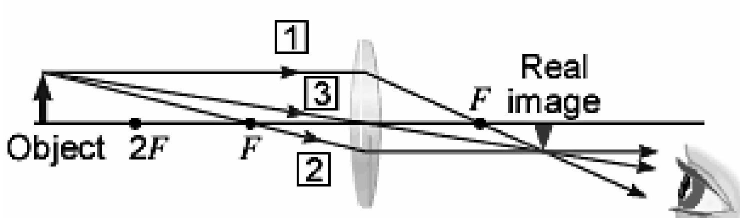


Parallel polarizers: 50% passes through both

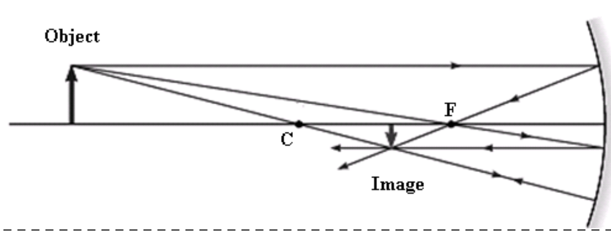


Perpendicular polarizers: 0% passes through second

Ray diagramming



Magnifying glass: object inside F, image is virtual upright and large behind object



Things You Should Know About Physics

Thermodynamics

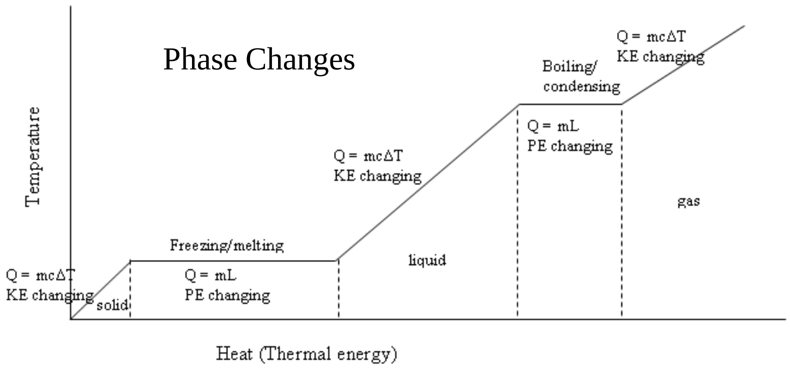
Internal Energy (U): total internal PE and KE of all particles of substance
Temperature (T): proportional to average KE of particles of a substance
Thermal Energy (Heat) (Q): energy transferred due to a temperature difference
Work (W): product of force and displacement in direction of force
Thermal Equilibrium: objects are at same temperature
Methods of thermal energy transfer: conduction, convection, radiation

Specific Heat Capacity (c): $Q = mc\Delta T$

Specific Latent Heat (L): $Q = mL$

L_f = heat of fusion (melting, freezing)
L_v = heat of vaporization (boiling, condensing)

Calorimetry: $Q_c = -Q_H$
$mc\Delta T = -mc\Delta T$



First Law: Internal energy of a substance changes due to heat and work. ($\Delta U = Q + W$)

Heat Engine: device that uses heat to do work

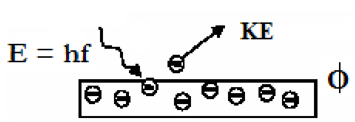
Efficiency: eff = work done/total heat supplied

Second Law: Total entropy of universe is always increasing. (entropy = disorder of system)

Modern Physics

Photoelectric Effect

Incoming photon (if high enough energy = frequency above threshold frequency) ejects electron – some energy needed to release electron (work function) – remaining energy is kinetic energy



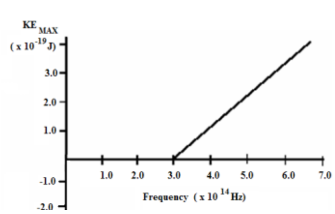
$$E_{photon} = \phi + KE_{max}$$

$$\phi = hf_o$$

Increasing frequency of light = increasing KE of electrons

Increasing intensity of light = increasing number of electrons

Photoelectric effect graphs:
Slope = Planck's constant
Y- intercept = -work function
X-intercept = threshold frequency



Wave-Particle Duality

	Wave Nature	Particle Nature
Light (Energy)	- Diffraction - Interference - Doppler Effect	Photo-electric Effect
Matter	- Electron Diffraction - Matter Waves	Collisions (e.g. Alpha particle scattering)

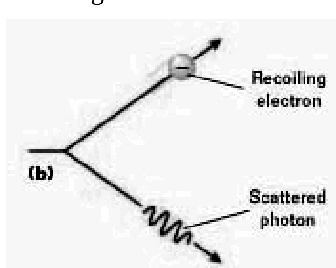
Photon – quantum (particle) of light

Higher frequency = higher energy ($E = hf$)

Higher intensity = more photons

Compton Scattering (Photon Collisions)

After collision, photon's energy decreases, momentum decreases, frequency decreases, wavelength increases



Matter Waves (de Broglie wavelength):

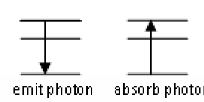
not noticed since too small for everyday objects

$$\lambda = \frac{h}{mv}$$

Atomic Spectra

Ground state: lowest energy level
Excited state: higher energy level
Ionization: zero energy level

$E_{photon} = |\Delta E_n|$



Photon Momentum:

$$p = \frac{h}{\lambda}$$

Mass defect: m + Δm = m (nuclei weigh less than sum of their parts)

$E = mc^2$ (only use if E is in Joules and m is in kg)

1 u = 9.31×10^2 MeV

Antimatter = same mass, opposite charge
Alpha particle = helium nucleus (2 protons and 2 neutrons)
Positron = positive electron
Proton = uud
Neutron = udd

Fundamental forces

EM and gravity – long-range

Strong and weak – short-range