College Physics

UNITS (SI)
Mass (kg) Length (m) Time (s)

VECTORS
Have magnitude and direction (scalars only have magnitude)

x and y components ($x = r\cos\theta$; $y = r\sin\theta$; $\tan\theta = \frac{y}{x}$)

adding and subtracting vectors

KINEMATICS
Displacement = Δx (change in position) or d (Difference from **Distance**)

Velocity $v = \frac{\Delta x}{\Delta t}$ $v_{avg} = \frac{\Delta x_{total}}{\Delta t_{total}}$ (Difference from **Speed;** $speed = \frac{distance}{time}$)

Acceleration $a = \frac{\Delta v}{\Delta t}$

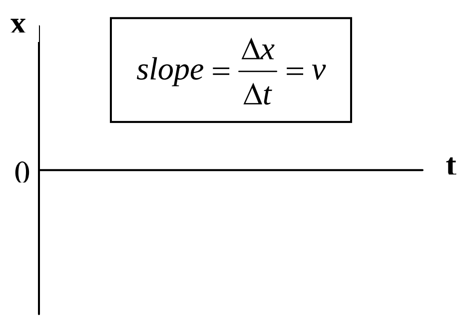
-signs (±) are important when displacement, velocity, and acceleration don't all point in the same direction

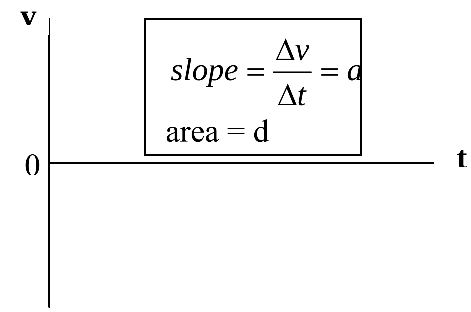
1. A car accelerates from 40mph to 60 mph in 4 seconds. What is its acceleration?

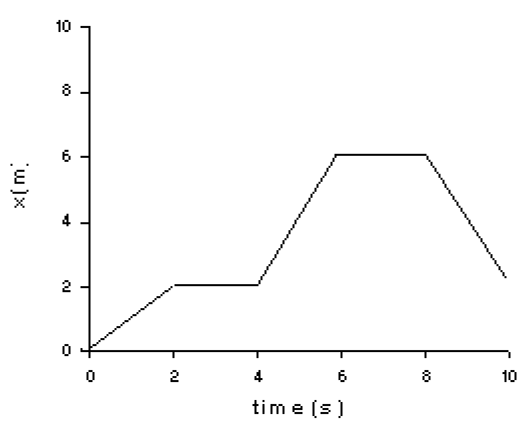
2. A car travels north at 60mph for 5 hours. What is its total displacement?

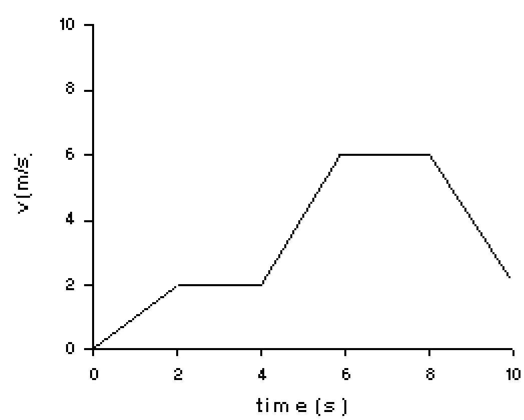
3. From rest a car accelerates at $3 m/s^2$. What is the car's velocity after 6s? How far has it traveled?

Graphs









Kinematics Equations

$v = v_i + at$

$d = vt$ (no acceleration)

$d = v_{avg}t$ (constant acceleration)

$d = v_i t + \frac{1}{2}at^2$ (constant acceleration) $d = \frac{1}{2}at^2$ when starting from rest

$v_f^2 = v_i^2 + 2ad$ (constant acceleration) used when no time information is available

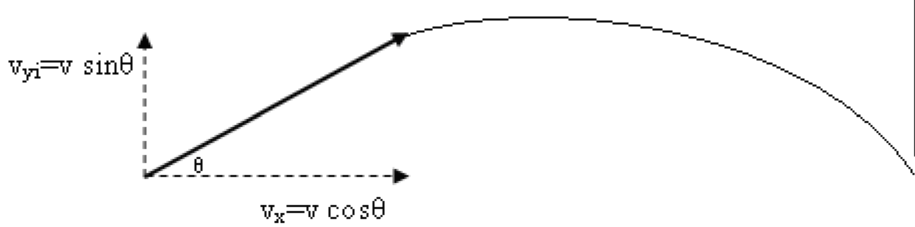
Gravity (near the surface of the earth)
$g = 9.80 m/s^2$ (always toward the center of the earth)

4. A penny is dropped from the roof of a building and takes 4s to reach the ground. From what height was the penny dropped? (Ignore air resistance)

5. A penny is dropped from the roof of a 100m tall building. How long does it take for the penny to reach the ground? (Ignore air resistance)

6. A penny is dropped from a building. It's final velocity just before it reaches the ground is 40m/s. From what height was the penny dropped?

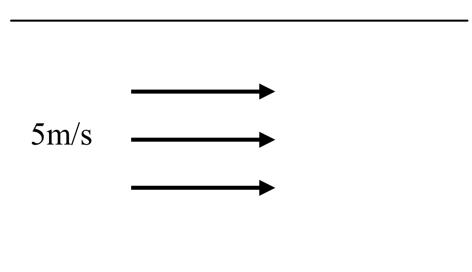
Projectile Motion



time to max height (use y-direction)
max height (use y direction)
total time (use y-direction)
horizontal displacement or range (x-dir)

7. A potato is fired from a potato gun with an initial velocity of 100m/s 30° above the horizontal. What is the time of flight of the potato? What is its maximum height during flight? What is the distance between where it was fired and where it lands?

Relative motion (like in a river)



MECHANICS

Newton's Laws

1st Law – An object's velocity remains constant unless a net force is acting upon it.

If ΣF = 0, then v = constant.

2nd Law – ΣF = ma

3rd Law – For every force exerted by one object on a second object, there is an equal but opposite force by the second object on the first. $F_{1\to 2} = -F_{2\to 1}$

1. A baseball player hits a ball off of a tee starting from rest accelerating it to a velocity of 25m/s during the time the bat is in contact with the ball (0.10s). If the mass of a baseball is 145g, then what average force does the bat exert on the ball?

2. Two astronauts of masses 100.0kg and 150.0kg are at rest floating in space. The larger pushes the smaller so that they are moving away from each other. During the time he is pushed, the 100 kg astronaut experiences an acceleration of 2.0m/s^2. What was the force of the larger astronaut on the smaller astronaut? What was the resulting acceleration of the larger astronaut during the time they were in contact?

Fundamental Forces
1. Strong Nuclear
2. Electromagnetic
3. Weak Nuclear
4. Gravity

Forces

Gravity

$F_g = G\dfrac{m_1 m_2}{r^2}$ $\quad G = 6.67x10^{-11}\dfrac{N\cdot m^2}{kg^2}$ $\quad$ W = mg (near the Earth's surface)

For an object on the surface of the earth, $F_g = G\dfrac{mM_E}{r_E^2} = mg$, so $g = G\dfrac{M_E}{r_E^2} = 9.8\dfrac{m}{s^2}$

Normal Force – Perpendicular component of the contact force that a surface exerts on an object.

Friction

$F_f = \mu_k F_N$ kinetic

$F_{f\max} = \mu_s F_N$ static

Tension – The tension in a rope is everywhere the same.

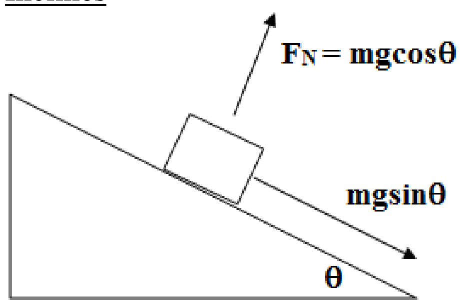
Problem Solving
1) Draw a free-body diagram.
2) If in equilibrium, ΣF = 0.
3) If not in equilibrium, ΣF = ma.

3. A new planet with twice the mass and a radius that is three times greater than that of earth has been discovered. How will its gravitational acceleration compare to that of earth?

4. A 100.0kg man is on an elevator that is accelerating upward 2.0m/s^2. What is his apparent weight?

5. A 10.0 kg object is being pulled horizontally along a surface with a force of 200.0N resulting in a net acceleration of 18m/s^2. What is the coefficient of kinetic friction between the object and the surface?

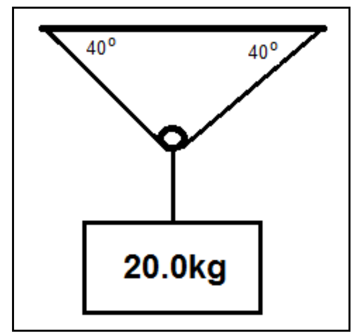
Inclines



6. A 10.0kg object slides down a frictionless plane inclined 29° above the horizontal. What is its acceleration?

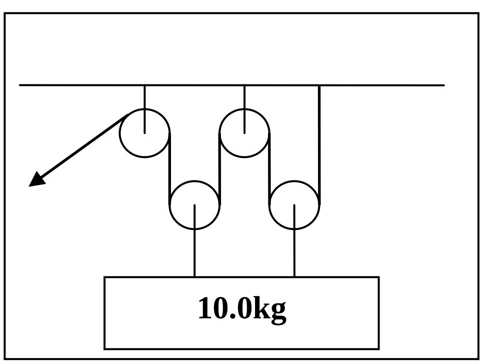
7. An object slides down a 45.0° incline at constant velocity? What is the coefficient of kinetic friction between the object and the incline?

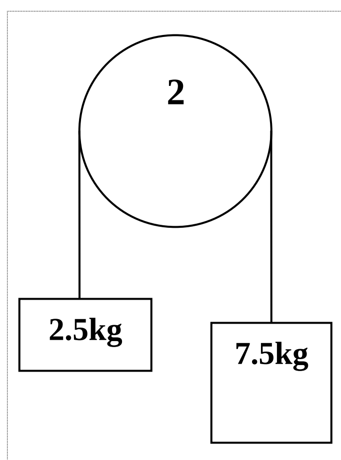
8. What is the tension in the rope supporting the 20.0kg mass in the following diagram?

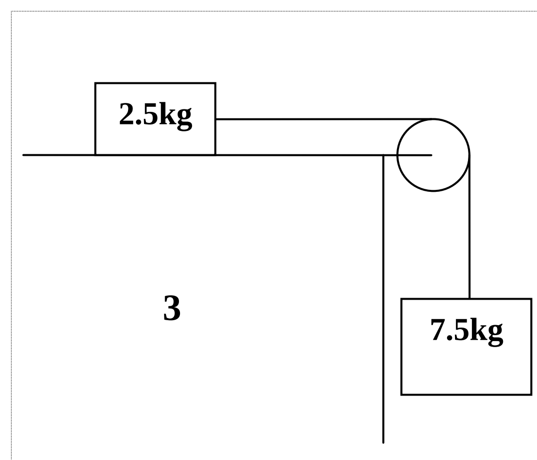


Pulleys

1







9. For pulley **1**, what is the tension in the rope if the mass is suspended at rest?

10. For pulley **2**, what is the acceleration of the 7.5kg mass? What is the tension in the rope?

11. For pulley **3**, what is the acceleration of the 7.5kg mass? What is the tension in the rope (Assume no friction)?

WORK AND ENERGY

$W = (F\cos\theta)d$ (only the force component in the direction of motion)

12. How much work is performed by an Alaskan husky pulling a dog sled 10.0m across the snow with a pulling force of 290N.

Mechanical Energy

$E = KE + PE$ $KE = \frac{1}{2}mv^2$ $PE = mgh$ (gravitational)

Conservation of Mechanical Energy ($\Delta E = 0$ when no nonconservative forces are present)

$KE_i + PE_i = KE_f + PE_f$ $\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$ (if no work is done by nonconservative forces)

13. A ball is dropped from a 45m cliff. What is the velocity of the ball just before it reaches the ground (ignore air resistance)?

14. A 1.5m long pendulum is released from an angle of 60.0° from the vertical. What is the maximum velocity achieved by the pendulum?

Work-Kinetic Energy Theorem

$W = \Delta KE$

$W_{nc} = \Delta E$ (work performed by nonconservative forces)

15. A 1.0kg ball is dropped from a 45m cliff. Its velocity just before it reaches the ground is 20.0m/s. How much work is done by air resistance on the ball?

Springs

$F = -kx$ (Hooke's Law) k = spring constant x = displacement from equilibrium position

$P.E. = \frac{1}{2}kx^2$ (Elastic Potential Energy)

16. If a 50.0N force displaces a spring 2.0cm from its equilibrium position, what displacement would a 10.0N force result in?

17. A spring with a spring constant of 800.0N/m and a 2.0kg mass on the end is stretched 10.0cm from its equilibrium position. What is the velocity of the mass on the end of the spring as it passes through the equilibrium position?

Power $P = \frac{W}{\Delta t} = Fv$

18. The worlds fastest elevator achieves speeds of 1010 meters per minute. How much power is generated by a motor that lifts an 800.0kg elevator traveling at this speed?

Momentum and Impulse

Momentum $p = mv$

Collisions

Elastic Collisions	**Perfectly Inelastic Collisions (objects stick together)**
Momentum Conserved $m_1v_{1i} + m_2v_{2i} + ... = m_1v_{2f} + m_2v_{2f} + ...$	Momentum Conserved $m_1v_{1i} + m_2v_{2i} + .. = (m_1 + m_2 + ...)v_f$
KE Conserved $\frac{1}{2}m_1v_{1i}^2 + \frac{1}{2}m_2v_{2i}^2 + ... = \frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2v_{2f}^2 + ...$	KE Not Conserved

19. A 2.0kg ball heading west at 5.0m/s across a frictionless surface collides head-on with a 4.0kg ball that had also been moving. After the collision, the two balls are stuck together and are moving with a velocity of 5.0m/s directly east. What was the original velocity of the 4.0kg ball?

20. A stationery bomb explodes into 3 fragments. The 1st fragment weighing 2.0kg is moving directly north with a velocity of 100.0m/s after the explosion. The 2nd fragment weighing 4.0kg is moving directly west with a velocity of 50.0m/s after the explosion. What is the velocity of the 3rd fragment (weighing 2.0kg) immediately after the explosion?

Impulse-Momentum Theorem $\overbrace{F\Delta t}^{\text{Impulse}} = \Delta mv$

21. A 1.0kg baseball traveling at 40.0m/s towards home is sent in the opposite direction at 30.0m/s after being hit with a baseball bat. If the bat is in contact with the ball for 0.050s, with what force was the ball struck by the bat?

ROTATIONAL DYNAMICS

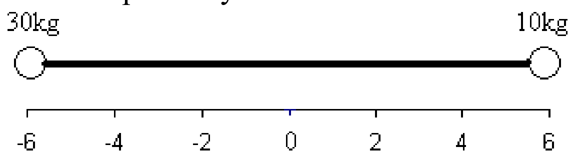
Rotational/ Angular	Translational
$\Delta\theta$	d
ω	v
α	a
I	m
τ	F
$KE = \frac{1}{2}I\omega^2$	$KE = \frac{1}{2}mv^2$
$W = \tau\theta$	$W = Fd$
$L = I\omega$	$p = mv$

Center of Mass $x_{CM} = \dfrac{m_1 x_1 + m_2 x_2 + ...}{m_1 + m_2 + ...}$

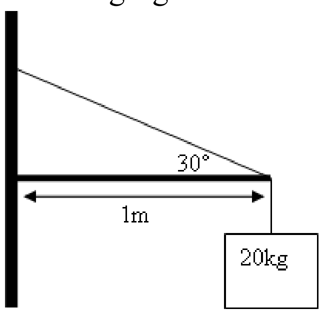
Torque $\tau = F_{\perp}\ell$ ℓ = lever arm

$\tau = I\alpha$ (just like F=ma)

5. Where would a fulcrum need to be placed for the following bar to be balanced perfectly?



6. A 20kg sign is hanging on the end of a 50kg boom that is suspended by a wire attached to the wall as in the following figure. What is the tension in the cable?



Inertia $I = \Sigma mr^2$ (for point masses about an axis)

Angular Momentum $L = I\omega$

Rotational KE $= \frac{1}{2}I\omega^2$

7. A solid cylinder and a hollow cylinder of equal mass and radius roll down an incline. Which one reaches the bottom first?

8. A wheel with a moment of inertia of $100\text{kg}\cdot\text{m}^2$ is accelerated from rest by a motor to an angular velocity of 80rad/s. How much work is performed by the motor?

<u>ROTATIONAL KINEMATICS</u>

Angular Displacement = Δθ or θ $d = r\theta$

Angular Velocity $\omega = \frac{\Delta\theta}{\Delta t}$ $v = r\omega$

Angular Acceleration $\alpha = \frac{\Delta\omega}{\Delta t}$ $a = r\alpha$

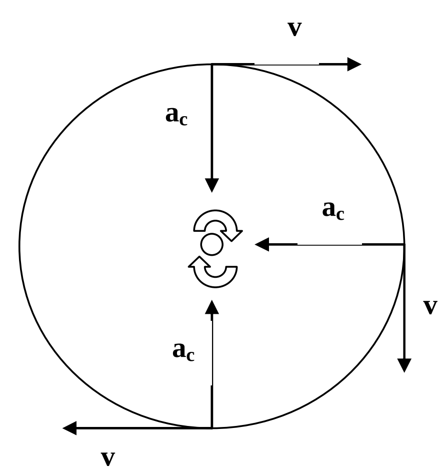
Rotational Kinematics Eqns	**Analagous Translational Kinematics Eqns**
$\Delta\theta = \omega t$	$d = vt$ (no acceleration)
$\Delta\theta = \omega_{avg} t$	$d = v_{avg} t$ (constant acceleration)
$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$	$d = v_i t + \frac{1}{2}at^2$ (constant acceleration)
$\omega_f^{\ 2} = \omega_i^{\ 2} + 2\alpha\Delta\theta$	$v_f^{\ 2} = v_i^{\ 2} + 2ad$ (constant acceleration)

1. A fly is sitting on the edge of a record with a radius of 0.2m spinning at constant velocity. If the fly completes 6 revolutions in 30s, what is the angular velocity of the record? What is the translational velocity of the fly?

2. A boy is riding a horse on a carousel located 2m from its center, while his father is sitting on a bench on the carousel located 5m from its center. How much greater is the angular velocity of the boy compared to his father? How much greater is the translational velocity of the boy compared to his father?

<u>Centripetal Force/Acceleration</u>

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



3. Give an expression for the radius of a satellite in a stable orbit around the Earth in terms of the gravitational constant **G**, the mass of the Earth $\mathbf{M_E}$, and the velocity **v** of the satellite.

4. A roller coaster car completes a loop-d-loop on it's track. Is the normal force acting on the car by the track greater at the top or bottom of the loop-d-loop? By how much (answer in terms of **m**, **v**, **r**, and **g**)?

ELASTICITY OF SOLIDS

Stress = Modulus x Strain

	Stress	Modulus	Strain
Young's Modulus Stretching/Compression	$\frac{F}{A}=$	Y	$\frac{\Delta L}{L_0}$
Shear Modulus Shear Deformation	$\frac{F}{A}=$	S	$\frac{\Delta x}{h}$
Bulk Modulus Volume Deformation	$\Delta P=$	$-B$	$\frac{\Delta V}{V_0}$

Stretching/Compression

$$\frac{F}{A}=Y\frac{\Delta L}{L_0}$$

Ultimate Strength – largest force that can be applied bef

Breaking Point – the point at which the object breaks--just beyond the ultimate strength for a brittle material

Shear Deformation

$$\frac{F}{A}=S\frac{\Delta x}{h}$$

A component of the force is parallel to one of the objects faces.

Volume Deformation

$$\Delta P=-B\frac{\Delta V}{V_0}$$

1. A stretching force of 100.0N is applied to a 100.0cm length of wire of radius 1.0mm resulting in an elongation of 5.0mm. What is the Young's modulus of the wire?

2. A solid piece of metal with a bulk modulus of $1.0\text{x}10^{11}$ is dropped to a depth of 1000.0m. What is the fractional change in the volume of this piece of metal?

FLUIDS
Hydrostatics

Density: $\rho = \frac{m}{V}$ Specific Gravity $= \frac{\rho}{\rho_{H_2O}}$ $\rho_{H_2O} = 1000\frac{kg}{m^3}$

Pressure

$P = \frac{F}{A}$ 1atm = 760torr = 760mmHg = **101,325Pa** (Pa is the SI unit and 1Pa = 1N/m^2)

3. The applied force is tripled and the area over which it is applied is cut in half. What is the affect on the pressure?

Hydrostatic Pressure (Gauge Pressure)

$P = \rho_{fluid} gh$ where h = depth

Every 10m depth in H_2O is ~1 atm pressure

Absolute Pressure

$P = P_0 + \rho_{fluid} gh$

4. A snorkeler dives to a depth of 25m in a freshwater lake. What is the absolute pressure at this depth? What is the gauge pressure?

Manometers and Barometers

Buoyancy Force (Archimedes Principle)

$F_B = W_{fluid\_displaced} = \rho_{fluid} V_{submerged} g$

$F_B = W_{object}$ (if the object is floating)

% submerged $= \frac{\rho_{object}}{\rho_{fluid}} \times 100$

5. A large piece of Styrofoam with a mass of 2.0kg and a specific gravity of 0.050 is floating in a pool of water. What volume of the piece of Styrofoam is submerged below the surface?

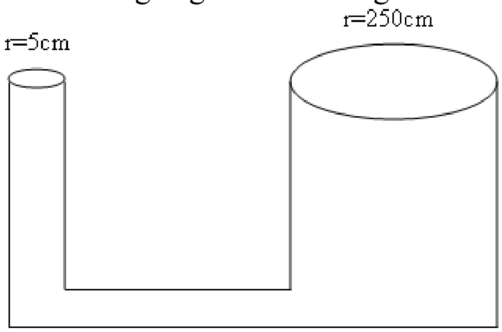
6. If an object normally weighs 500.0N and while submerged in water it has an apparent weight of 300.0N, what is the density of the object?

7. A block of wood having a specific gravity of 0.60 is floating in a pool of water. What percentage of the block of wood is above the surface?

Hydraulic Jack

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$ (Pascal's Principle) $A_1 d_1 = A_2 d_2$

8. For the following hydraulic jack, how much force must be applied to the small side of the jack in order to lift a 250kg engine on the large side?



Hydrodynamics

Laminar or streamline flow vs turbulent flow

Ideal Fluid – non-viscous, incompressible, steady flow without turbulence

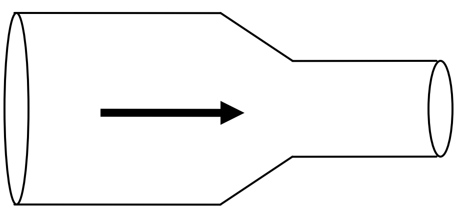
Flow Rate: $f = Av$ A = cross-sectional area $v = velocity$

$A_1 v_1 = A_2 v_2$ (Equation of Continuity)

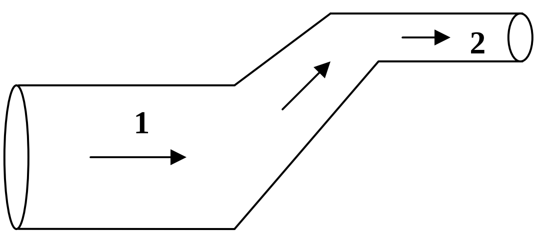
Bernoulli's Equation

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

9. If the radius of the larger end of the pipe is 3 times larger than the radius of the smaller end of the pipe, in which region of the pipe is the velocity of an ideal fluid undergoing laminar flow higher and how much higher? Where is the pressure higher?



10. For an ideal fluid undergoing steady flow, in which region of the pipe is the pressure higher? Region 1? Region 2? Not enough information given to determine?



SIMPLE HARMONIC MOTION

$x = A\cos\omega t$ A=Amplitude ω=frequency factor

$v = -A\omega\sin\omega t$ $v_{\max} = A\omega$

$a = -A\omega^2\cos\omega t$ $a_{\max} = A\omega^2$

$\omega = 2\pi f = \frac{2\pi}{T}$ $f = \frac{1}{T}$ f = frequency T = period

Spring

$\omega = \sqrt{\frac{k}{m}}$

Pendulum

$\omega = \sqrt{\frac{g}{L}}$ (for small angles)

Springs

$F = -kx$ k=spring constant x=displacement from equilibrium position

$P.E. = \frac{1}{2}kx^2$

Conservation of Mechanical Energy

11. A spring with a 1kg mass attached obeying simple harmonic motion follows the following equation of motion: $x = (100cm)\cos 5t$. What is the velocity of the mass as it passes through the equilibrium position? What are the frequency and period of oscillation?

12. A mass on a spring undergoing simple harmonic motion has another mass glued to the original mass while in motion effectively quadrupling the mass. What is the effect on the period of oscillation?

13. If the length of a pendulum is increased by a factor of 10 and the mass of the bob is doubled, what will be the effect on the frequency of oscillation?

Waves

Transverse vs longitudinal

Speed of a wave: $\lambda f = v$

$y(x,t) = A\cos(\omega t \pm kx)$ $\omega = 2\pi f$ $k = \frac{2\pi}{\lambda}$

14. The motion of a wave on a string follows the following equation: $y = (100cm)(\cos 5t - 3x)$. What direction is the wave moving? What is its wavelength?

Standing Waves

$$\lambda_n = \frac{2L}{n}$$ (string fixed at one end)

$$v = \sqrt{\frac{F}{\mu}}$$ $$\mu = \frac{m}{L}$$ = linear mass density

$$\lambda_n = \frac{2L}{n}$$ (pipe open at both ends)

$$\lambda_n = \frac{4L}{n} \qquad n = odd\#$$ (pipe open at one end)

n = 1 is first harmonic or fundamental frequency

15. What is the fundamental wavelength of a 0.25m long string that is fixed at one end?

GASES

Pressure = Force / Area (P = F/A)

1atm = 760torr = 760mmHg = 1.01325bar = 101,325Pa = 101.325kPa

Gas Constant

$R = 8.31447\ J\ K^{-1}\ mol^{-1}$

$R = 8.31447\ dm^3\ kPa\ K^{-1}\ mol^{-1}$

$R = 0.0820574\ dm^3\ atm\ K^{-1}\ mol^{-1}$

$R = 62.364\ dm^3\ torr\ K^{-1}\ mol^{-1}$

Boyle's Law pV = constant or $p_1V_1 = p_2V_2$

Charles' Law $\frac{V}{T}$ = constant

Avogadro's Principle $\frac{V}{n}$ = constant

Combined Gas Law $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$

Better Combined Gas Law $\frac{p_1V_1}{n_1T_1} = \frac{p_2V_2}{n_2T_2}$

Dalton's Law of Partial Pressures $p_{total} = p_A + p_B + p_C + \ldots$

$p_A = \chi_A p_{Total}$ χ_A = mole fraction A

Kinetic Model of Gases

Assumptions: 1) Gas molecules are in constant random motion.
2) Gas molecules don't have volume (negligible volume anyway).
3) Gas molecules don't experience any attractive forces between each other. (All collisions are elastic.)

Perfect Gas Behavior

1) Gases behave more 'perfectly' at low pressures and high temperatures.
2) Gases with lower intermolecular forces tend to behave more 'perfectly.'

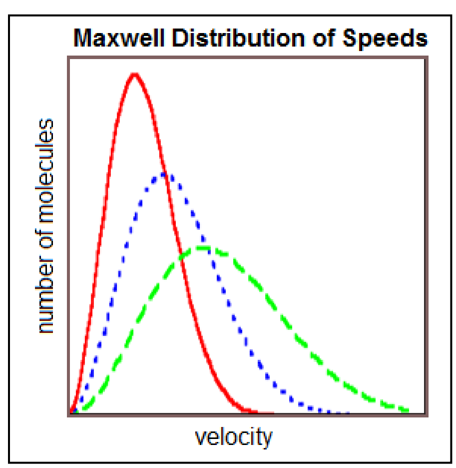
Perfect Gas Equation of State pV = nRT

$p = \frac{nMc^2}{3V}$ M = molar mass c = rms speed

$$c = \left(\frac{3RT}{M}\right)^{\frac{1}{2}}$$

Maxwell Distribution of Speeds

$f = F(s)\Delta s$ $F(s) = 4\pi\left(\frac{M}{2\pi RT}\right)^{3/2} s^2 e^{-\frac{Ms^2}{2RT}}$



THERMODYNAMICS

1st Law of Thermodynamics

"Conservation of Energy"

open system - energy and matter can be exchanged with the surroundings
closed system - energy but not matter can be exchanged with the surroundings
isolated system – neither energy nor matter can be exchanged with the surroundings
diathermic vs adiabatic

Heat Capacity $C = \frac{q}{\Delta T}$

specific heat capacity $C_s = \frac{C}{m}$

molar heat capacity $C_m = \frac{C}{n}$

Isothermal ($\Delta T = 0$)	($\Delta U = 0$)
Adiabatic	($q = 0$)
Constant Volume	($w = 0$)

$C_V = \left(\frac{\delta U}{\delta T}\right)_V$ or $C_V = \frac{\Delta U}{\Delta T}$ constant volume heat capacity $\Delta U = C_v \Delta T$

$C_P = \left(\frac{\delta H}{\delta T}\right)_P$ or $C_P = \frac{\Delta H}{\Delta T}$ constant pressure heat capacity $\Delta H = Cp\Delta T$

Internal Energy

$\Delta U = q + w$ $\delta U = C_V dT$

Heat

$q = \int C_V dT$	Constant V
$q = \int C_P dT$	Constant P
$q = -w$	Constant T

Enthalpy

$H = U + pV$ $\delta H = C_P dT$

$\Delta H = q_p$

$C_P - C_V = nR$ (for a perfect gas)

Work

$w = \int -p_{ex} dV$	Always
$w = -p_{ex}\Delta V$	constant p_{ex}
$w = -nRT \ln\frac{V_f}{V_i}$	Reversible, Isothermal

Entropy and the 2nd and 3rd Laws of Thermodynamics

Three laws of thermodynamics
1) Conservation of energy (Energy can't be created or destroyed).
2) For a spontaneous process, the entropy of the universe increases.
3) A perfectly ordered crystal at 0K has zero entropy.

Entropy

$$\Delta S = \frac{q_{rev}}{T}$$

$$\Delta S = nR\ln\frac{V_f}{V_i} \qquad \Delta S = nR\ln\frac{P_i}{P_f}$$ (Entropy Change during Expansion/Compression)

$$\Delta S = C\ln\frac{T_f}{T_i}$$ (Entropy Change during heating; constant heat capacity)

Calculate the entropy change when 0.5 mol of a perfect gas expands from 12L to 24L and is simultaneously cooled from 298K to 200K. ($C_{v,m}$ = 12.5 $JK^{-1}mol^{-1}$

SOUND
Longitudinal waves, not transverse waves
Alternating compressions and rarefactions

$\lambda f = v$ $\qquad$ $v_{sound} \sim 343 m/s$

Sound travels faster in solids and liquids than in air.

$v = \sqrt{\frac{Y}{\rho}}$ $\qquad$ Y=Young's modulus $\qquad$ (speed of sound in a metal rod)

$v = 331 m/s \sqrt{\frac{T}{273K}}$ $\qquad$ (speed of sound in air)

1. The wavelength of a sound wave in air is 1.70m. What is its frequency? (v_{sound}=340m/s)

Intensity

$I = \frac{P}{A} = \frac{P}{4\pi r^2}$

$\beta = 10 \log \frac{I}{I_0}$ $\qquad$ $I_0 = 10^{-12} \frac{W}{m^2}$

2. If the intensity level of a siren is 80dB at a distance of 10m from a fire truck, what is the intensity level at a distance of 100m?

Doppler Effect

$f_O = f_S \frac{v \pm v_O}{v \mp v_S}$ $\qquad$ f_O = frequency observed $\qquad$ f_S = frequency of source

$f_o > f_s$ if, relatively, object and source are moving towards each other
$f_o < f_s$ if, relatively, object and source are moving away from each other

3. You are moving in a car toward a stationery ambulance with a velocity of 34m/s. Is the frequency of the ambulance's siren you observe higher or lower than the actual emitted frequency? By what percentage is the frequency you observe different from the actual frequency? (v_{sound}=340m/s)

ELECTRIC FORCES AND FIELDS

Coulomb's Law

$F = qE$

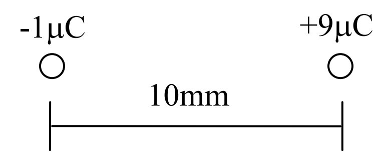
$F = \left| k\frac{q_1 q_2}{r^2} \right|$ $k = 8.99x10^9 N{\cdot}m^2/C^2$

Fundamental Charge
$e = 1.6x10^{-19}C$

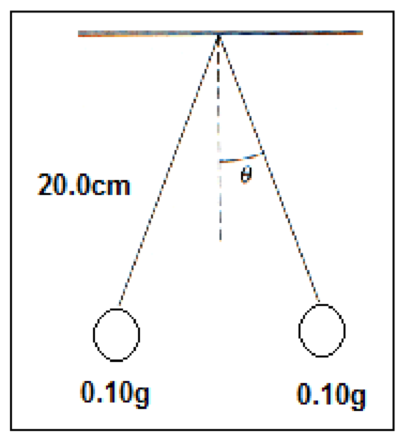
$E = k\frac{q}{r^2}$ Electric Field due to a point charge

1. Two point charges of +2.0μC are 1.0mm apart. What are the force and the electric field experienced by either of the point charges? ($k=8.99x10^9 N{\cdot}m^2/C^2$)

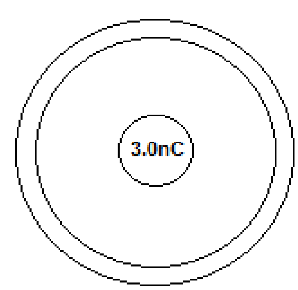
2. For the following arrangement of point charges, at what location along the x-axis is the electric field zero?



3. Two small metallic spheres, each of mass 0.10 g, are suspended as pendulums by light strings from a common point as shown in the figure below. The spheres are given the same electric charge, and it is found that they come to equilibrium when each string is at an angle of 4.0° with the vertical. If each string is 20.0 cm long, what is the magnitude of the charge on each sphere?



4. If the charge on the solid sphere at the center of the diagram is +3.0nC and the total charge on the hollow outer sphere is +5.0nC, then what are the charges on the inner and outer surfaces of the hollow sphere?

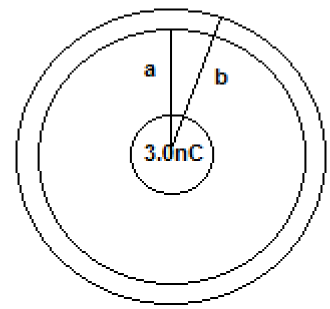


Gauss's Law (Electric Flux)

$$\Phi_E = EA\cos\theta = \frac{Q}{\varepsilon_0}$$

The electric field inside a hollow charged sphere is zero.

5. If the charge on the solid sphere at the center of the diagram is +3.0nC and the total charge on the hollow outer sphere is +5.0nC, then use Gauss's Law to derive expressions for the electric field for R > b and for r < a (but outside the solid sphere).



ELECTRICAL POTENTIAL (V)

$V = k\frac{q}{r}$ Potential (voltage)

$PE = qV$ Potential Energy

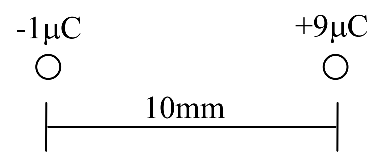
$\Delta V = Ed$ Relation between ΔV and E

$W = q\Delta V$

6. An electron ($q=1.6\text{x}10^{-19}$C, $m=9.11\text{x}10^{-31}$kg) is accelerated from rest through a potential difference of $1.0\text{x}10^{-6}$V. What is its final velocity?

7. A uniform electric field of magnitude 250 N/C is directed along the +*y*-axis. A 2.00 μC charge moves from the origin to the point (*x*, *y*) = (50 cm, -10 cm). What is the change in the charge's potential energy and through what potential difference did it move?

8. What is the potential at a point 5.0mm to the left of the -1μC charge?



Capacitance

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

Parralel Plate Capacitor

$C = \varepsilon_0 \dfrac{A}{d}$ $V = Ed$

$C = \kappa\varepsilon_0 \dfrac{A}{d}$ ($\kappa =$ dielectric constant)

$P.E. = \dfrac{1}{2}CV^2$ (stored in a capacitor)

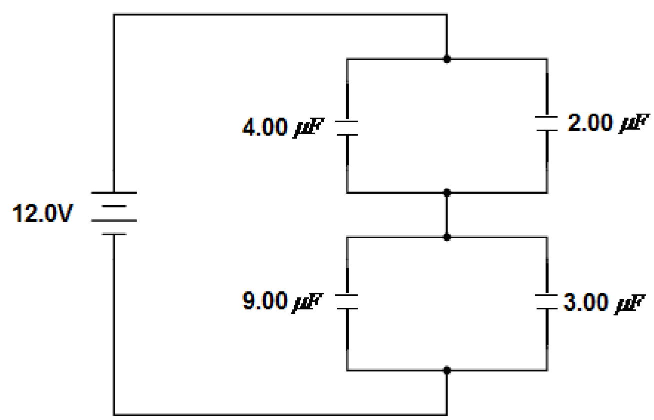
$\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$ Capacitors in Series (Circuits in series have the same current.)

$C_{eq} = C_1 + C_2 + \ldots$ Capacitors in Parallel (Circuits in parallel have the same potential.)

Capacitors in series store the same charge.

9. When a parallel plate capacitor is fully charged in a circuit with a 16V battery, there are 1×10^{12} excess electrons on one of the two plates. What is the capacitance of the capacitor.

10. The lengths of the sides of each of the plates of a square parallel plate capacitor are doubled and so is the distance of separation between the two plates. What is the effect on its capacitance?



11. Calculate the charge stored on each of the 4 capacitors in the above drawing.

ELECTRICAL CIRCUITS AND RESISTANCE

$V = IR$ V = potential I = current R = resistance Ohm's Law

Current

$I = \frac{q}{t}$

Resistance

$R = \rho\frac{L}{A}$ ρ = resistivity L = length A = cross-sectional area

$\rho = \rho_0(1 + \alpha\Delta T)$ Temperature dependence of resisitivity

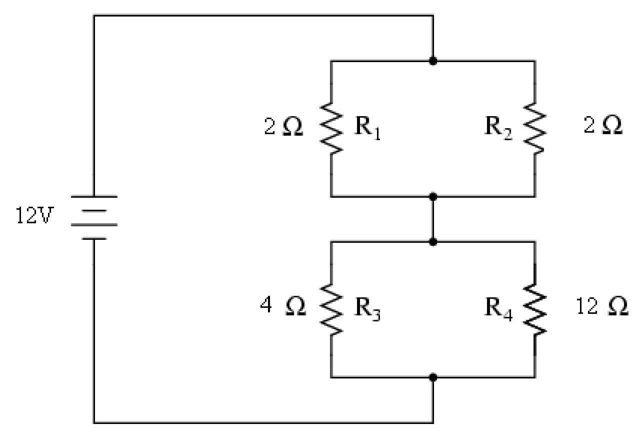
12. A piece of copper wire of resistance R is replaced with a new piece of copper wire that is twice as long and has a radius that is 3 times larger. What is the resistance of the second piece of wire?

$R_{eq} = R_1 + R_2 + ...$ Resistors in Series (Circuits in series have the same current.)

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ...$ Resistors in Parallel (Circuits in parallel have the same potential.)

$P = VI = I^2R = \frac{V^2}{R}$ Power

13. What is the equivalent resistance in the following circuit?
What is the total current in the circuit?
What is the potential across R_1?
What is the current through R_4?
What is the power dissipated through R_4?



14. A device requires a power of 20.0W when connected to a 12V battery. What power would be delivered when if it was connected to a 9.0V battery?

Electric Circuits

$V = IR$ V = potential I = current R = resistance Ohm's Law

Resistance

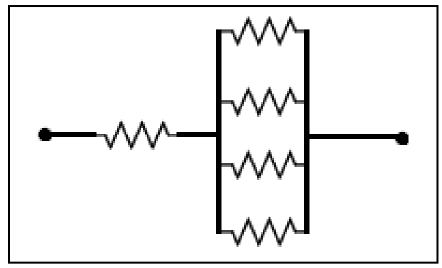
$R_{eq} = R_1 + R_2 + ...$ Resistors in Series

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ...$ Resistors in Parallel

1. Three 8.0 ohm resistors are connected in series with a 12V battery. What is the equivalent resistance in the circuit and what is the current passing through each resistor?

2. Three 8.0 ohm resistors are connected in parallel with a 12V battery. What is the equivalent resistance in the circuit and what is the current passing through each resistor?

3. What is the equivalent resistance in the following circuit? (All resistors are identical with a resistance R.)

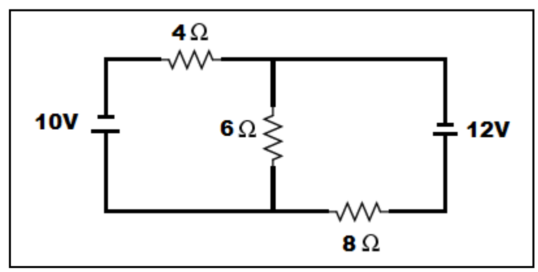


Kirchoff's Rules

1) Junction Rule-The current entering a junction will equal the current leaving a junction.

2) Loop Rule – The voltage increases will equal the voltage decreases within any single loop.

4. Find the current through each of the resistors in the following diagram.



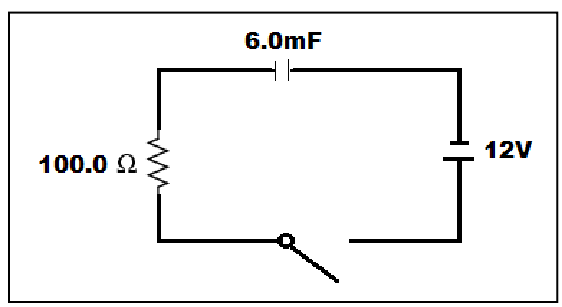
RC Circuits

$V(t) = \varepsilon\left(1 - e^{-t/\tau}\right)$ (charging) $\tau = RC$

$V(t) = \varepsilon e^{-t/\tau}$ (discharging)

$I(t) = \frac{\varepsilon}{R} e^{-t/\tau}$ (charging or discharging)

5. For the circuit shown to the right, what is the time constant? What will be the voltage in the circuit and the charge on the capacitor 1.2s after the switch is closed?



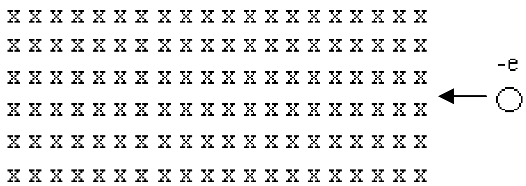
MAGNETIC FORCES AND FIELDS

Charged Particle Moving through a Magnetic Field

$F = qvB\sin\theta$ $\quad v = velocity$ $\quad$ B=magnetic field

Right Hand Rule
Thumb = v
Fingers = B
Palm = force

6. When the electron in the diagram below enters the magnetic field, it permanently starts moving in a repeating circular pattern. Give an expression for the radius of the electron's circular motion and state whether the motion is clockwise or counterclockwise.



Current-carrying Wire in a Magnetic Field

$F = I\ell B\sin\theta$

Right Hand Rule
Thumb = I
Fingers = B
Palm = force

7. A wire with a 10.0A current (directed west horizontally) and a linear mass density of 0.50g/cm is suspended vertically in the air due to the presence of a magnetic field. What is the magnitude and direction of the magnetic field?

Torque on a Current-Carrying Loop

$\tau = NIAB\sin\theta$

Magnetic Field Due to a Current Carrying Wire

$B = \dfrac{\mu_0 I}{2\pi r}$ $\quad \mu_0 = 4\pi \times 10^{-7}\, TmA^{-1}$

Right Hand Rule
Thumb = I
Fingers (curled) = B

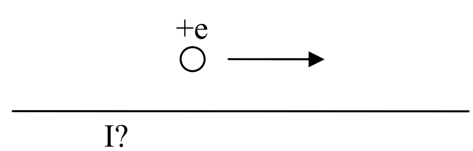
Magnetic Field at the Center of a Circular Current-Carrying Loop

$B = \dfrac{\mu_0 NI}{2r}$

Magnetic Field Inside an Ideal Solenoid

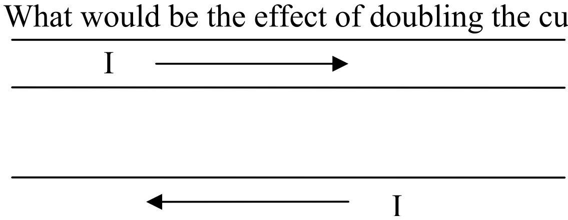
$B = \dfrac{\mu_0 NI}{L} = \mu_0 nI \qquad n = \dfrac{N}{L}$

8. The charged particle in the field below is experiencing a force in the upward direction due to the magnetic field created by the current in the wire. Which direction does the current in the wire point?



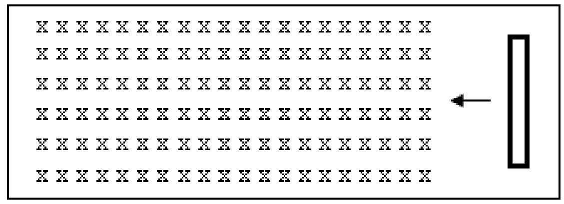
9. What is the magnitude of the magnetic field at a point 8.0cm from a wire carrying a current of 20.0A?

10. Is the force between the following two wires attractive or repulsive?
What would be the effect of doubling the current in both wires on the force between the two wires?



Electromagnetic Induction

$\varepsilon = vBL$



Magnetic Flux

$\Phi_B = B_\perp A = BA\cos\theta$

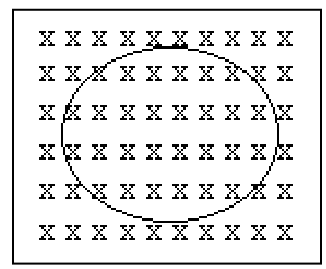
Faraday's Law

$$\varepsilon = -\frac{\Delta\Phi_B}{\Delta t} \qquad \varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$$

Lenz's Law

The direction of the induced current opposes the change in the magnetic flux.

11. A circular loop of wire lies in a uniform magnetic field of 0.20T oriented into the page. If the loop is constricted so that it's radius changes from 0.30m to 0.050m in 4s, then what is the induced emf in the loop? Clockwise or counterclockwise?



Transformers

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{N_2}{N_1} \qquad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

LIGHT
Reflection and Refraction of Light

$\lambda f = v$

$E_{photon} = hf = \frac{hc}{\lambda}$ $c = 3.0 \times 10^{8}\, m/s$ $h = 6.63 \times 10^{-34}\, J \cdot s$ $1eV = 1.6 \times 10^{-19}\, J$

1. The wavelength of a violet photon is 400nm. What is its frequency? What is its energy in J? in eV?

Law of Reflection

Angle of incidence = Angle of reflection

Snell's Law of Refraction

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n = \frac{c}{v}$ Index of Refraction   (Frequency of light doesn't change from medium to medium)

$\sin\theta_{critical} = \frac{n_2}{n_1}$ Total Internal Reflection

$d' = d\frac{n_2}{n_1}$ Apparent depth when an observer is directly above an object

2. If the angle of incidence of a flashlight's beam into a lake is 60°, what is the angle of reflection? What is the speed of light in water? (n_{air}=1, n_{water}=1.33)

3. The frequency of violet light in air is 7.5x10^{14}Hz in air. What are its frequency and wavelength in water? (n_{water}=1.33)

4. What is the critical angle for light traveling through glass (n = 1.52) that is surrounded by air?

5. When viewed directly overhead, what is the apparent depth of a fish that is 3.0m below the surface of a lake? (n_{water}=1.33)

MIRRORS AND LENSES

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ d_o = distance to object d_i = distance to image f = focal length

$m = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$ m = magnification h_i = height of image h_o = height of object

$f = \frac{1}{2}R$ R = radius of curvature

$\text{f-number} = \frac{f}{d}$

Mirror Type	**d_i**	**d_o**	**f**
Converging (Concave)	+ (d_o>f) - (d_o<f)	+	+
Diverging (Convex)	-	+	-

Lens Type	**d_i**	**d_o**	**f**
Converging (Convex)	+ (d_o>f) - (d_o<f)	+	+
Diverging (Concave)	-	+	-

$d_i>0$ real image (and inverted)
$d_i<0$ virtual image (and upright)
$m>0$ upright
$m<0$ inverted

6. If an object is placed 6.0cm in front of a concave mirror (f = 2.0cm), what will be the magnification of the image? Is it real or virtual, upright or inverted?

7. If an object is placed 6cm from a diverging lens with a focal length of 2.0cm, what is the magnification of the image? Is it real or virtual, upright or inverted?

8. If an object is placed 6cm from a converging lens (f = 4.0cm), where will the image appear? Will the image be real or virtual, upright or inverted?

WAVE OPTICS

Double Slit Interference

Bright Fringes: $d \sin\theta = m\lambda$ $m = 0, 1, 2, \ldots$ d = distance between slits

Dark Fringes: $d \sin\theta = \left(m + \frac{1}{2}\right)\lambda$ $m = 0, 1, 2, \ldots$ d = distance between slits

9. A laser beam (λ = 700nm) is incident on 2 slits separated by 0.20mm. What is the distance between the bright fringes on a screen placed 4.0m from the slits?

Thin Films

Reflected rays are inverted when going from smaller to larger index of refraction.

$2t = \left(m + \frac{1}{2}\right)\lambda_{film}$ $m = 0, 1, 2, \ldots$ (No phase shift)   t = thickness of film

$2t = m\lambda_{film}$ $m = 0, 1, 2, \ldots$ (Phase shift between reflected rays)

10. What is the minimum thickness of a layer of gasoline (n=1.40) floating on water (n=1.33) if green light (λ_{air} = 565nm) is eliminated from the reflected light by destructive interference?

Diffraction Grating

Bright Fringes: $d \sin\theta = m\lambda$ $m = 0, 1, 2, \ldots$ d = slit separation

Single Slit Interference

Dark Fringes: $a \sin\theta = m\lambda$ $m = 0, \pm 1. \pm 2, \ldots$ a = slit width