Harold's High School Physics
Cheat Sheet
3 February 2026

The 7 Base Units of Measure

Quantity Name	Symbol (Value)	Metric Units (SI)	Imperial Units (English)
1. Length / Distance	w, x, y, z	meter (m)	foot (ft)
2. Mass	m	kilogram (kg)	slug (or lb)
3. Time	t	second (s)	
4. Temperature	T	Kelvin (K) Celsius (^0C)	Fahrenheit (^0F)
5. Electrical Current	i	Ampere (A)	
6. Amount of Substance	M, χ	mole (mol)	1 mol = 6.022 140 76 × 10^{23}
7. Luminous Intensity	lv	Candela (cd)	
Note: The 7 base units are mutually independent from each other. **All** other units of measurement can be derived from them.			

Derived Units of Measure

Quantity Name	Symbol (Value)	Metric Units (SI)		Imperial Units (English)	
Length / Displacement	d, l, h, r, s	meter (m)	m	foot (ft)	ft
Area	A, SA		m^2		ft^2
Volume	V	liter (l)	m^3	fluid ounce (fl)	ft^3
Velocity / Speed	v, s		$\frac{m}{s}$		$\frac{ft}{s}$
Acceleration	a, g		$\frac{m}{s^2}$		$\frac{ft}{s^2}$
Impulse	I		$N \cdot s$ $kg \cdot \frac{m}{s}$		$lb \cdot \frac{ft}{s}$
Linear Momentum	p		$kg \cdot \frac{m}{s}$		$lb \cdot \frac{ft}{s}$
Force	F	Newton (N)	$kg \cdot \frac{m}{s^2}$	pound (lb)	$slug \cdot \frac{ft}{s^2}$
Energy / Work / Heat	E, W, K or KE, U_g, U_s, U_E, Q	Joule (J)	$N \cdot m$ $C \cdot V$ $W \cdot s$ $kg \cdot \frac{m^2}{s^2}$	calorie (cal)	$ft \cdot lb$
Power	P	Watt (W)	$\frac{J}{s}$ $V \cdot A$ $kg \cdot \frac{m^2}{s^3}$	horsepower (hp)	$ft \cdot \frac{lb}{s}$

Conversions

Constant Name	Symbol	Metric Units (SI)	Imperial Units (English)
Length	x	$1.0\ m$	$39.37\ in$ $3.281\ ft$
		$2.54\ cm$	$1.0\ in$
		$30.48\ cm$	$1.0\ ft$
		$1.61\ km$	$1.0\ mi$
		$1.0\ km$	$0.621\ mi$
		$1\ km = 1{,}000\ m$	$1\ mi = 5{,}280\ ft = 1{,}760\ yd$
Mass	m	$1.0\ kg$	$2.205\ lb$
		$0.454\ kg$	$1.0\ lb$
		$1.0\ g$	$0.035\ oz$
		$14.594\ kg$	$1\ slug$
		(standard gravity)	$1\ slug = 32.174\ lb$
Time	t	$1\ yr = 365.24\ d$ $1\ d = 24\ h$	$1\ h = 60\ min$ $1\ min = 60\ s$
Temperature	T	$0\ °C$	$32\ °F$
		$100\ °C$	$212\ °F$
		$-17.8\ °C$	$0\ °F$
		$37.8\ °C$	$100\ °F$
		$0\ K = -273.15\ °C$	$-459.67\ °F$
Force	F	$1.00\ N$	$0.225\ lb$
		$4.45\ N$	$1.00\ lb$
Volume	V	$3.785\ L$	$1.0\ gallon$
		$1.0\ L$	$1.057\ quarts$ $0.264\ gallons$

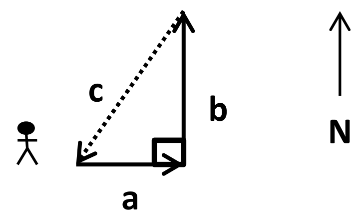
How to Solve Physics Word Problems

Modified GUESS Method

1. Read
2. Diagram
3. **G**ivens
4. Observations
5. **U**nknowns
6. **E**quations
7. **S**olve
8. **S**ubstitute
9. Double-Check

Scenario

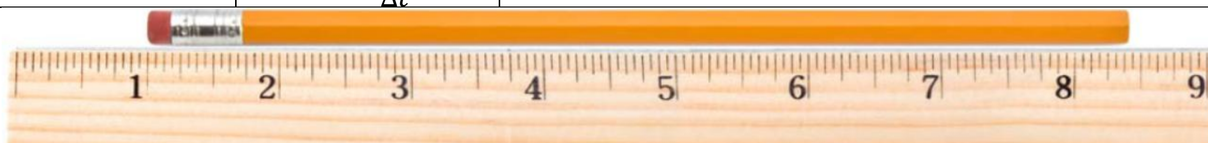
A marching band cadet marches on a football field.
First, he marches 10 yards East, then 40 feet North.
What is the shortest distance he must march to return to where he started?

#	Step	Example
	1. Carefully **read** the problem. Translate each word of each sentence into math.	Reread the problem several times to make sure you did not miss anything.
	2. Draw a **diagram**. Clearly label everything.	
G	3. Write down the **givens** as variables with units. What information did they provide? Are any of them extraneous?	a = 10 yards East b = 40 feet North
	4. Calculate **observations** or easily derived information. Don't forget unit conversions for consistency.	$10 \text{ yards} \times \left(\frac{3 \text{ feet}}{1 \text{ yard}}\right) = 30 \text{ feet}$
U	5. Write down the **unknowns**. What are they asking for?	The shortest distance is a straight line, or the hypotenuse. 'c'. c = ____?____ <units>
E	6. Recall relevant **equations** and formulas.	Since the path marched is a right triangle, we can use the Pythagorean Theorem: $a^2 + b^2 = c^2$
S	7. **Solve** symbolically for the unknown variable. Reduce algebraically to the simplest form. Do not substitute until fully solved.	$a^2 + b^2 = c^2$ $c = \sqrt{c^2} = \sqrt{a^2 + b^2}$
S	8. **Substitute** the givens into the solved formula. Use a calculator as needed to calculate the answer.	a = 30 feet b = 40 feet $c = \sqrt{(30 \text{ feet})^2 + (40 \text{ feet})^2} = 50 \text{ feet}$
✓✓	9. **Double-check** your work. Ask yourself if the answer is reasonable and makes sense. Don't forget the units. Box in your answer.	The shortest distance the cadet must march is 50 feet.

See also: GUESS Method for problem-solving.

Chapter 1: Let’s Move! (Velocity)

Term	Equation	Description
Vector Quantity	$\vec{x} = 10\frac{m}{s}\ East$	A quantity that includes direction. (e.g., magnitude and direction)
Scalar Quantity	b	A quantity that does **not** include direction.
Friction	F_{μ}	A force that resists motion when two bodies are in contact.
Inertia	I	The tendency of a body to resist changes in its velocity.
Average Velocity	$v_{ave} = \frac{v_f - v_i}{\Delta t}$	The average of the velocity over a given time interval.
Instantaneous Velocity	$v = \frac{\Delta x}{\Delta t}$	The velocity at a given instant in time.
Acceleration	$a = \frac{\Delta v}{\Delta t}$	A change in an object’s velocity.



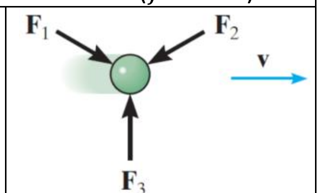
Rulers	When using a ruler that is marked off in 16ths of an inch, report your answers to a hundredth of an inch.	
Units	$g = -9.81\frac{m}{s^2}$	You must always list the units after the number. (The units are just as important as the number.)
Significant Figures	1. All non-zero figures (1, 2, 3, 4, 5, 6, 7, 8, & 9) are significant. 2. A zero (0) is significant if it is between two significant digits. 3. A zero (0) is also significant if it is at the end of the number *and* to the right of the decimal point.	
Using SigFigs	1. When **adding** and **subtracting** measurements, you must report your answer to the same precision as the least precise number in the problem. 2. When **multiplying** and **dividing** measurements, you must report your answer with the same number of significant figures as the measurement that has the fewest significant figures. 3. There is always some **error** in the last significant figure of a measurement.	
Precision vs. Accuracy	• **Precision:** The consistency and reproducibility of measurements (e.g., 10 decimal places). • **Accuracy:** How close a measurement is to the true or accepted value.	
Scientific Notation	14,000,000 = 1.4×10^{7} = 1.4E7	0.00000014 = 1.4×10^{-7} = 1.4E–7
Systematic Errors	*“Science cannot prove anything.”* There is always a possibility that our experiments are wrong since they contain systematic errors.	
Unit Conversion (Train Track Method)	17 years = ? sec	

17 yr	365.24 ~~days~~	24 hours	60 min	60 sec	**536,464,512 sec**
	1 yr	1 ~~day~~	1 hour	1 min	

<table>
<tr><td>Prefixes</td><td colspan="2">

Prefix	Abbreviation	Meaning	Scientific
giga	G	1,000,000,000	10^9
mega	M	1,000,000	10^6
kilo	**k**	**1,000**	$\mathbf{10^3}$
hector	H	100	10^2
deca	Da	10	10^1
centi	**c**	**0.01**	$\mathbf{10^{-2}}$
milli	**m**	**0.001**	$\mathbf{10^{-3}}$
micro	µ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}

</td></tr>
<tr><td>Speed</td><td>$s = \frac{\Delta d}{\Delta t}$</td><td>Speed ($s$) is a scalar quantity.</td></tr>
<tr><td>Velocity</td><td>$\boldsymbol{v} = \frac{\Delta \boldsymbol{x}}{\Delta t}$</td><td>Velocity ($v$) is a vector quantity.</td></tr>
<tr><td>Relative Velocity</td><td colspan="2">$\boldsymbol{v}_{relative} = \boldsymbol{v}_{moving\_object} - \boldsymbol{v}_{reference\_object}$</td></tr>
<tr><td>Unit Consistency</td><td colspan="2">Before solving a problem, look at the units and make sure they are consistent. If they are not, convert the inconsistent units before you continue. (ft vs. m)</td></tr>
<tr><td>Newton's First Law of Motion
(Law of Inertia)</td><td>An object will remain at rest, or in motion at a constant velocity (v or constant speed in a straight line), unless acted upon by a net external force (F).</td><td>



Equilibrium

</td></tr>
<tr><td>Velocity with Acceleration</td><td colspan="2">

- When acceleration and velocity are in the **same** direction (⇉), an object's speed **increases**. (↑)
- When acceleration and velocity are in **opposite** directions (⇄), an object's speed **decreases**. (↓)

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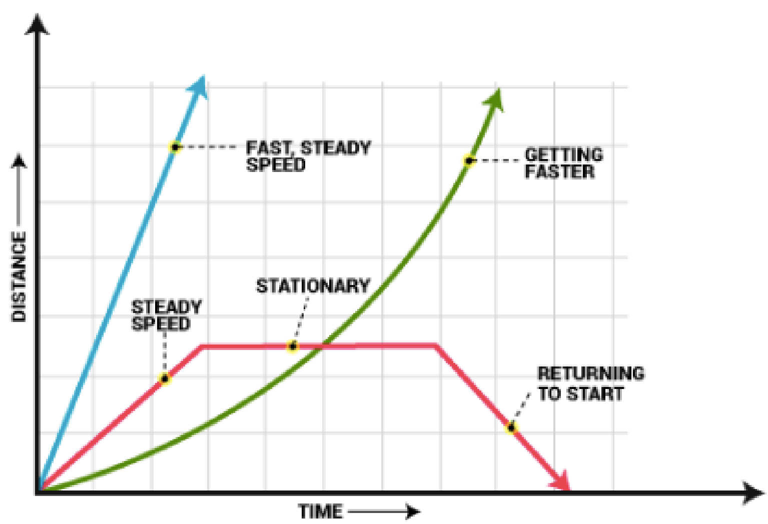
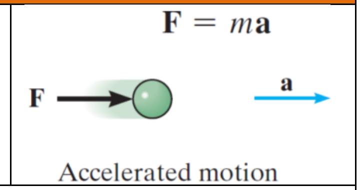
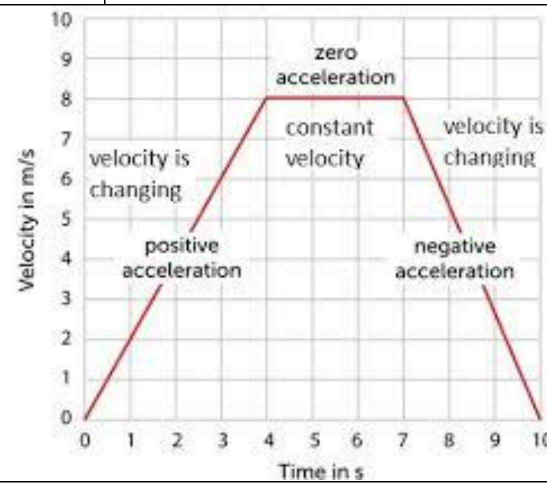
<tr><td>Velocity Graph</td><td colspan="2">

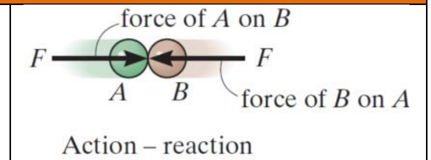
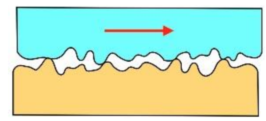
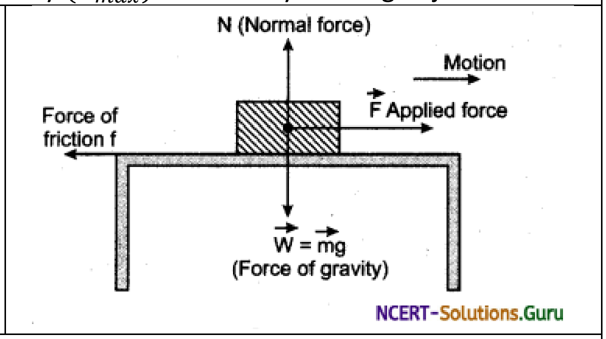
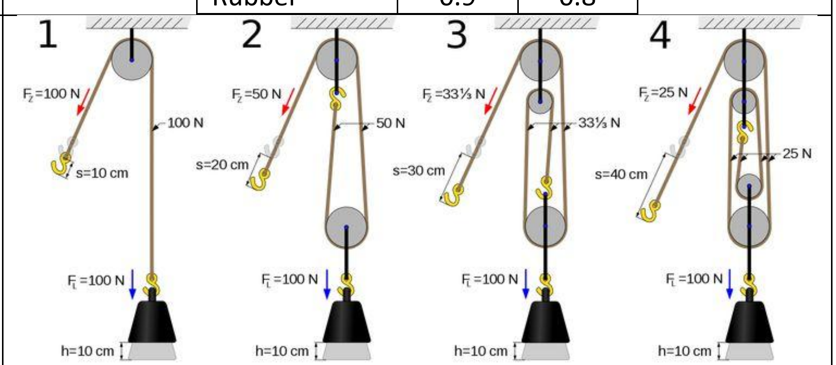


</td></tr>
<tr><td>Slope = Velocity</td><td colspan="2">The slope of a position ($\boldsymbol{x}$) versus time (t) graph is the velocity ($\boldsymbol{v}$).</td></tr>
</table>

Chapter 2: Force and Acceleration

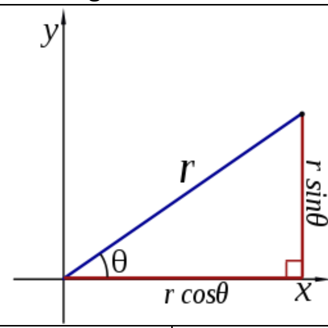
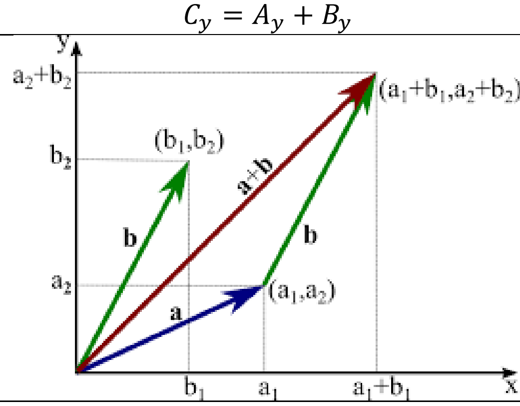
Term	Equation	Description
Newton's Second Law of Motion (Law of Acceleration)	At any instant of time, the net force on an object is equal to the object's mass multiplied by its acceleration ($F = ma$) or, equivalently, the rate at which the object's momentum changes with time ($\Delta p/\Delta t$).	
Free Fall	The motion of an object when the only force acting on it is the force due to gravity ($\boldsymbol{F_g}$).	
Air Resistance	The force with which air resists motion through it.	
Acceleration	$\boldsymbol{a} = \frac{\Delta \boldsymbol{v}}{\Delta t}$	A change in an object's velocity.
Acceleration Graph		
Slope = Acceleration	The slope of a velocity ($\boldsymbol{v}$) versus time (t) graph is the acceleration ($\boldsymbol{a}$).	
Force	$\boldsymbol{F} = m\boldsymbol{a}$	Force ($\boldsymbol{F}$) is any interaction that, when unopposed, changes the motion of an object.
Acceleration	$\boldsymbol{v} = \boldsymbol{v}_0 + \boldsymbol{a}t$	$\boldsymbol{a} = \frac{\Delta \boldsymbol{v}}{\Delta t} = \frac{\boldsymbol{v}_f - \boldsymbol{v}_0}{t}$
Velocity	$\boldsymbol{v}^2 = \boldsymbol{v}_0^2 + 2\boldsymbol{a} \cdot \Delta \boldsymbol{x}$	Derivation: Solve for t, set $t = t$, then simplify. $\frac{\boldsymbol{v}_f + \boldsymbol{v}_0}{2} = \frac{\Delta \boldsymbol{x}}{t}$ and $\boldsymbol{v}_f = \boldsymbol{v}_0 + \boldsymbol{a}t$
Position (Displacement)	$\boldsymbol{x} = \boldsymbol{x}_0 + \boldsymbol{v}_0 t + \frac{1}{2}\boldsymbol{a}t^2$ $\Delta \boldsymbol{x} = \boldsymbol{v}_0 t + \frac{1}{2}\boldsymbol{a}t^2$	Displacement ($\Delta \boldsymbol{x}$) is the area underneath a velocity versus time graph.
$\boldsymbol{a}$ is Constant	$\boldsymbol{J} = \frac{\Delta \boldsymbol{a}}{\Delta t}$ (Jerk/Jolt)	These equations of motion apply **only** when the acceleration ($\boldsymbol{a}$) is constant.
Gravity	$\boldsymbol{g} = -9.81\frac{m}{s^2}$ $\boldsymbol{g} = -32.2\frac{ft}{s^2}$	The acceleration due to gravity ($\boldsymbol{g}$) on the surface of the Earth is the same for all objects. It is negative ($-$) since it is directed downwards (↓).
Weight vs. Mass	$weight = mg$	Weight is a force. Since $\boldsymbol{F} = m\boldsymbol{a}$, and $\boldsymbol{a}$ on Earth is $\boldsymbol{g}$, then $weight = mg$.

Chapter 3: Friction

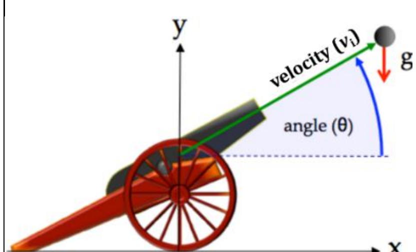
Term	Equation	Description
Newton's Third Law of Motion (Law of Action and Reaction)	If object A exerts a force on object B, then B will exert an equal but opposite force on A.	
Static Friction (μ_s)	The frictional force between two surfaces that are <u>stationary</u> relative to each other.	
Kinetic Friction (μ_k)	The frictional force between two surfaces that are <u>moving</u> relative to each other.	
Tension (T)	A force transmitted through a rope or similar object (e.g., a thread or chain) when it is pulled.	
Streamlined Shape	A shape that reduces air resistance.	
Wind Resistance	The faster an object moves through the air, the stronger the air resistance.	
Terminal Velocity	The maximum velocity (v_{max}) attained by a falling object.	
Normal Force (N or F_N)	$F_f = \mu \cdot F_n$	
Coefficient of Friction (μ)	The coefficient of friction is unitless. It represents a percentage of the normal force that is opposing the applied force. Static friction (μ_s) is generally larger than kinetic friction (μ_k). $0 \le \mu \le 1$	
Block and Tackle (Pully System)		

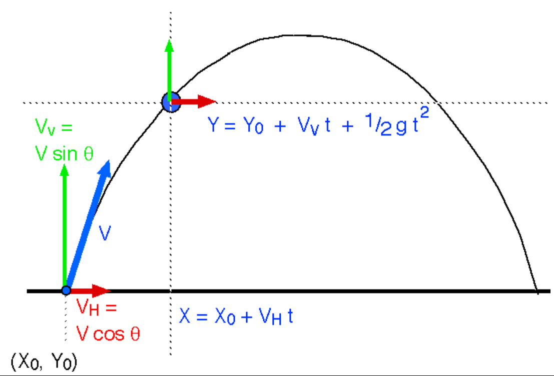
Material	Static (μ_s)	Kinetic (μ_k)
Zero friction	0	0
Ice or grease	0.15	0.03
Paper	0.35	0.25
Wood	0.5	0.4
Rubber	0.9	0.8

Chapter 4: Two-Dimensional Vectors

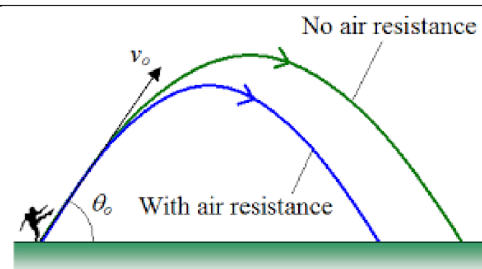
Term	Equation	Description
Vector Anatomy	An arrow is used to represent a two-dimensional vector. You must always put an arrowhead on your vectors. The length of the arrow is the magnitude (a scalar quantity). The counterclockwise angle from the positive x-axis is the direction. 3D arrow symbols: ⊙ out of page (+), ⊗ into the page (–).	
Vectors "Float"	Arrows representing vectors can be moved freely, as long as their length and direction are not changed.	
Hypotenuse	The longest side of a right triangle.	
Trig Review		
Converting Between Coordinate Systems	***Polar → Rect.*** $r\angle\theta \rightarrow (x\,,y)$ $x = r\cos\theta$ $y = r\,sin\,\theta$ $tan\,\theta = \left(\frac{y}{x}\right)$	***Rect. → Polar*** $(x\,,y) \rightarrow r\angle\theta$ $r^2 = x^2 + y^2$ $r = \sqrt{x^2 + y^2}$ $\theta = tan^{-1}\left(\frac{y}{x}\right)$
Vertical Component	$A_y = \boldsymbol{A}\cdot\sin(\theta)$	
Horizontal Component	$A_x = \boldsymbol{A}\cdot\cos(\theta)$	
Angle	$\theta = \tan^{-1}\left(\frac{A_y}{A_x}\right)$ You may need to add 180° to put θ into quadrants I or II.	
Magnitude	$\lvert\boldsymbol{A}\rvert = \sqrt{A_x^2 + A_y^2}$ $a^2 + b^2 = c^2$	
Vector Addition	When adding vectors **A** and **B** to get **C**, add each dimension separately. $C_x = A_x + B_x$ $C_y = A_y + B_y$ 	

Chapter 5: Two-Dimensional Motion

<table>
<tr><th>Term</th><th>Equation</th><th>Diagram</th></tr>
<tr><td>Projectile</td><td colspan="2">An object that has an initial velocity ($\boldsymbol{v}_0$) but experiences only the force of gravity ($\boldsymbol{g}$).</td></tr>
<tr><td>Parabolic Motion</td><td colspan="2">Motion along a parabolic path, which is exhibited by projectiles.</td></tr>
<tr><td>Dimensions</td><td colspan="2">Two-dimensional (2D) situations can often be analyzed as two one-dimensional (2x 1D) situations. Time (t) spans all dimensions.</td></tr>
<tr><td>Orthoganal</td><td colspan="2">In two-dimensional (2D) motion, perpendicular (⊥) components of the motion operate independently.</td></tr>
<tr><td>Graph Orientation</td><td colspan="2">The way we define the angle makes motion up (↑) and motion to the right (→) (or to the east) positive (+).
These are the best definitions to use with our one-dimensional (1D) motion equations.</td></tr>
<tr><td>Projectile Motion</td><td colspan="2">


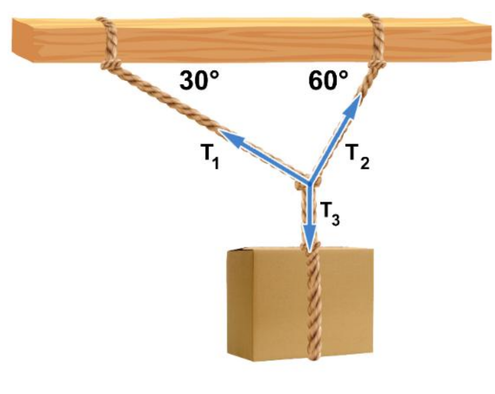
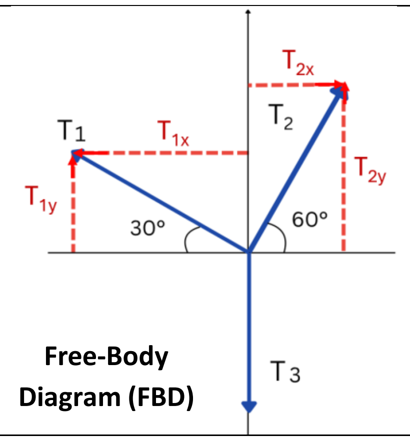
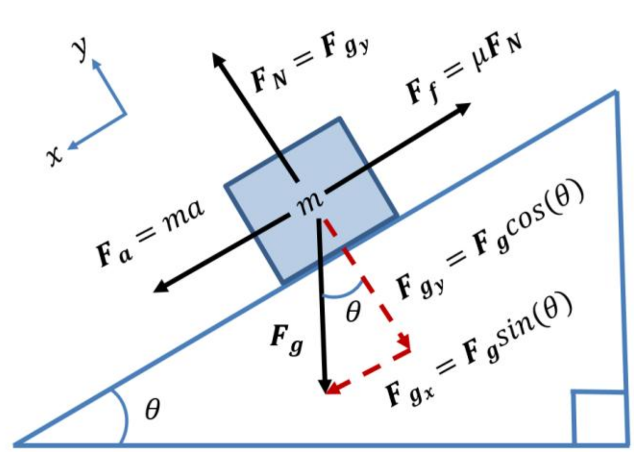


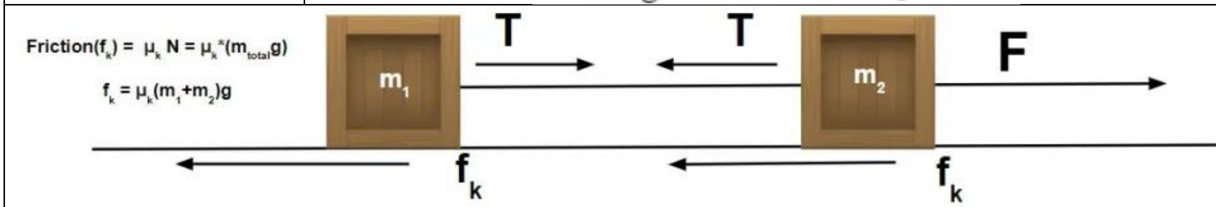
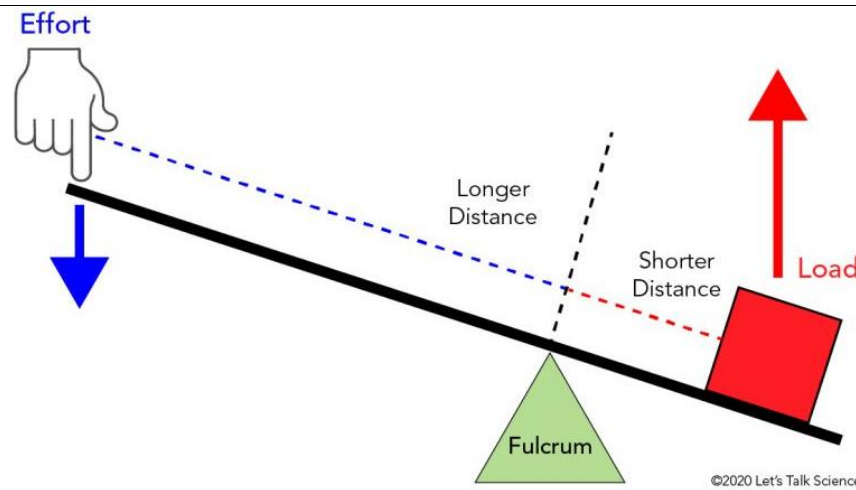
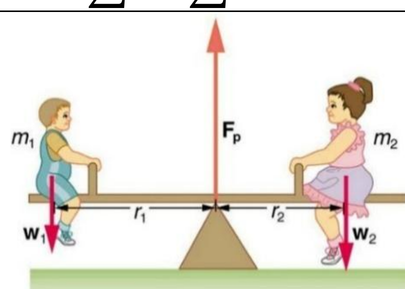
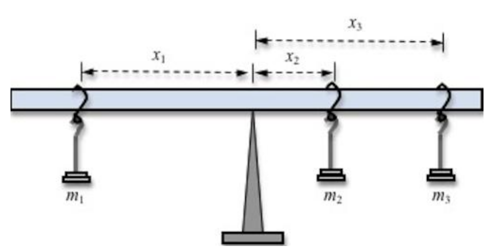
</td></tr>
<tr><th></th><th>Horizontal (x-axis)</th><th>Vertical (y-axis)</th></tr>
<tr><td>Position Equations</td><td>$\boldsymbol{x}(t) = x_0 + v_x t + \frac{1}{2}\boldsymbol{a}_x t^2$</td><td>$\boldsymbol{y}(t) = y_0 + v_y t - \frac{1}{2}\boldsymbol{g} t^2$</td></tr>
<tr><td>Velocity Equations</td><td>$v_x = \boldsymbol{v}\cos(\theta)$</td><td>$v_y = \boldsymbol{v}\, sin(\theta)$</td></tr>
<tr><td>Range Equations</td><td>$\text{range} = x_{max} = \frac{v^2 \cdot \sin(2\theta)}{g}$</td><td>$\text{height} = y_{max} = y\left(\frac{t_{max}}{2}\right)$</td></tr>
<tr><td>Air Resistance</td><td>Assume no air/wind resistance (drag).

(If we factor in air/wind resistance, then differential calculus is needed.)</td><td>


</td></tr>
</table>

Chapter 6: Newton's Second Law and Two-Dimensional Motion

Term	Equation	Diagram
Translational Equilibrium	The state in which the net force ($\boldsymbol{F}$) acting on an object is equal to zero (0).	
Static Translational Equilibrium	The state in which an object is in translational equilibrium and **is not** moving ($\boldsymbol{v} = 0$).	
Dynamic Translational Equilibrium	The state in which an object is in translational equilibrium and **is** moving ($\boldsymbol{v} \neq 0$).	
Accelerometer	A device that measures acceleration ($\boldsymbol{a}$).	
Axis of Rotation	An imaginary line around which all points of a rotating body move in circles.	
Rotational Equilibrium	Force ($\boldsymbol{F}$) causes changes in translational motion, while torque ($\boldsymbol{\tau}$) causes changes in rotational motion.	
Tension	Tension ($\boldsymbol{T}$) is a force on a string, rope, or cable.	
		
	Horizontal Forces $T_{1x} = T_{2x}$ $T_1 \cos(30°) = T_2 \cos(60°)$	**Vertical Forces** $T_{1y} + T_{2y} = T_3$ $T_1 \sin(30°) + T_2 \sin(60°) = mg$
Gravity Components (on an inclined plane)	On an incline, whose angle (θ) is defined relative to the horizontal, the component of the force due to gravity: • Parallel to the incline: $m\boldsymbol{g} \cdot \sin(\theta)$. • Perpendicular to the incline: $m\boldsymbol{g} \cdot cos(\theta)$.	
	$\boldsymbol{F_x} = m\boldsymbol{g} \cdot \sin(\theta)$	$\boldsymbol{F_y} = m\boldsymbol{g} \cdot cos(\theta)$
		

<table>
<tr><td rowspan="2">Coefficient of Friction</td><td>Static
$$\mu_s = \frac{sin(\theta)}{\cos(\theta)} = \tan(\theta)$$</td><td>Use as the maximum angle before the mass starts to slide down the incline.
$0 \leq \mu \leq 1$</td></tr>
<tr><td>Kinetic
$$\mu_k = \frac{g\ sin(\theta) - a}{g\ \cos(\theta)}$$</td><td>Use when the mass is accelerating down the incline.</td></tr>
<tr><td>Translational Motion of Two Objects</td><td colspan="2">
</td></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Torque</td><td>$\tau = \boldsymbol{F}_{\perp} \cdot r$</td><td></td></tr>
<tr><td rowspan="2">Lever Arm</td><td colspan="2">The distance between the axis of rotation and the force used to produce rotational motion.</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td rowspan="2">Static Rotational Equilibrium
(Rigid Bodies)</td><td>$\sum \boldsymbol{F} = \sum m\boldsymbol{a} = 0$</td><td>$\sum \boldsymbol{\tau} = \sum \boldsymbol{F}r = 0$</td></tr>
<tr><td>
</td><td>
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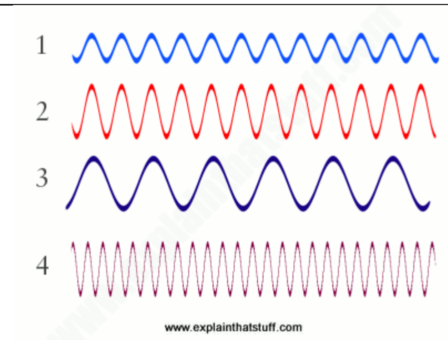
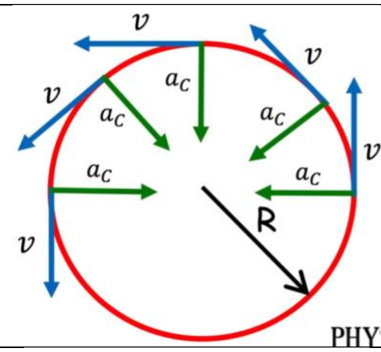
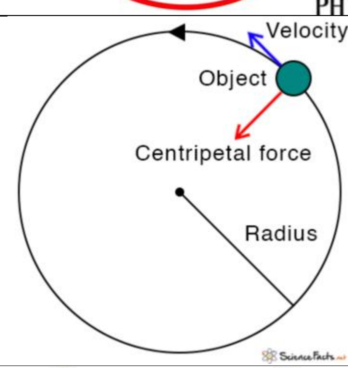
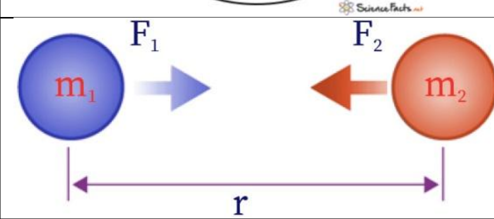
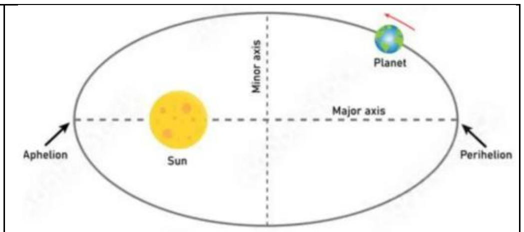
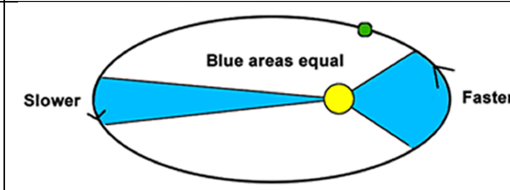
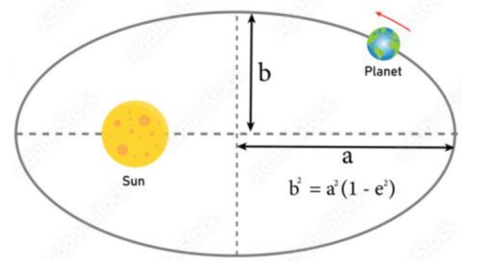
Chapter 7: Uniform Circular Motion and Gravity

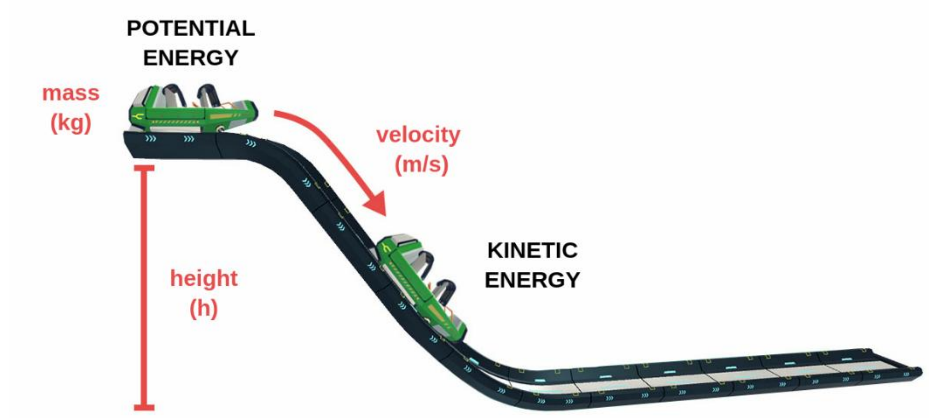
Term	Equation	Diagram
Centripetal Force	A force directed to the center of a circle.	
Period (T)	The time it takes to complete one full cycle (full circle or revolution).	
Frequency (f)	The number of cycles that can be completed every second.	
Gravity (g)	The acceleration of the attractive force that exists between all physical objects that have mass.	
Satellite	A body that orbits another body.	
Frequency (Hertz (Hz))	$f = \frac{1}{T}$ $T = \frac{1}{f}$	
Speed $\left(\frac{m}{s}\right)$	$\boldsymbol{v} = \frac{circumference}{time\ per\ revolution} = \frac{2\pi r}{T}$	How fast it is going in circles.
Centripetal Acceleration $\left(\frac{m}{s^2}\right)$	$\boldsymbol{a_c} = \frac{\boldsymbol{v}^2}{r}$	
Centripetal Force (Newtons, N)	$\boldsymbol{F_c} = m\boldsymbol{a_c} = \frac{m\boldsymbol{v}^2}{r}$	
Gravitational Force	$\boldsymbol{F_g} = -\frac{Gm_1m_2}{r^2}$	
Gravitational Constant (G)	$G \approx 6.67430 \times 10^{-11} \frac{Nm^2}{kg^2}$	

Kepler's Laws (of planetary motion)	**1. Orbits**: All planets move in elliptical orbits, with the sun at one focal point. $$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$	
	2. Areas: A line that connects a planet to the sun sweeps out equal areas in equal time intervals. $$A_1 = A_2$$	
	3. Periods: The square of a planet's period is proportional to the cube of its orbit's semi-major axis. $$T^2 \propto a^3$$	

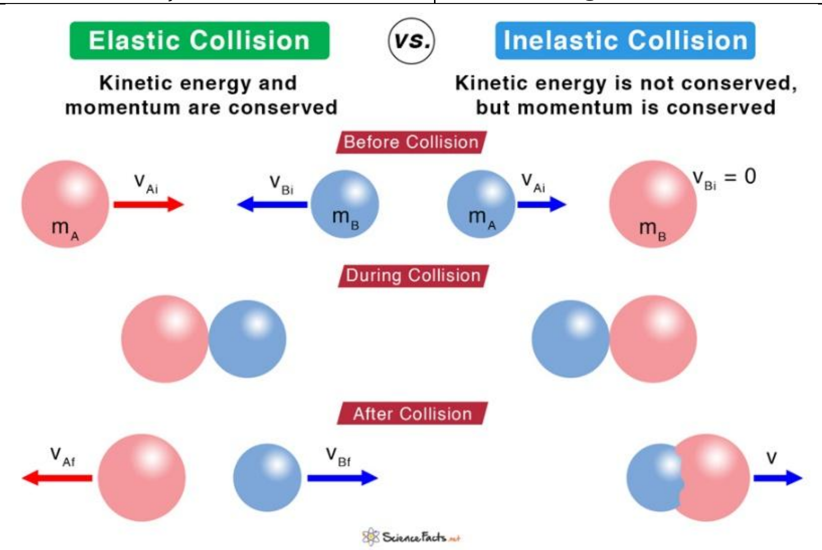
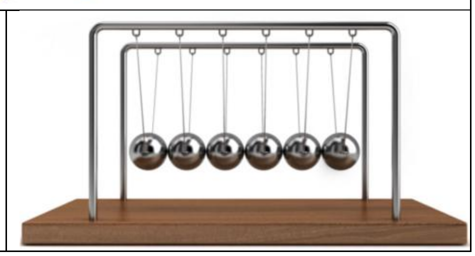
Planetary Constants

Property	Symbol	Sun	Earth	Moon	Mars
Mass	M	1.989×10^{30} kg	5.972×10^{24} kg	7.346×10^{22} kg	6.42×10^{23} kg
Radius	R	6.96×10^{8} m (mean)	6.371×10^{6} m (mean)	1.74×10^{6} m	3.39×10^{6} m
Gravity (Acceleration)	g	$274\ \frac{m}{s^2}$	$9.81\frac{m}{s^2}$	$1.625\ \frac{m}{s^2}$	$3.71\ \frac{m}{s^2}$
Distance (Between each center of mass)	r	NA	~1.496×10^{11} m (1 AU) (Earth to Sun)	~3.844×10^{8} m (Moon to Earth)	~2.279×10^{11} m (1.52 AU) (Mars to Sun)

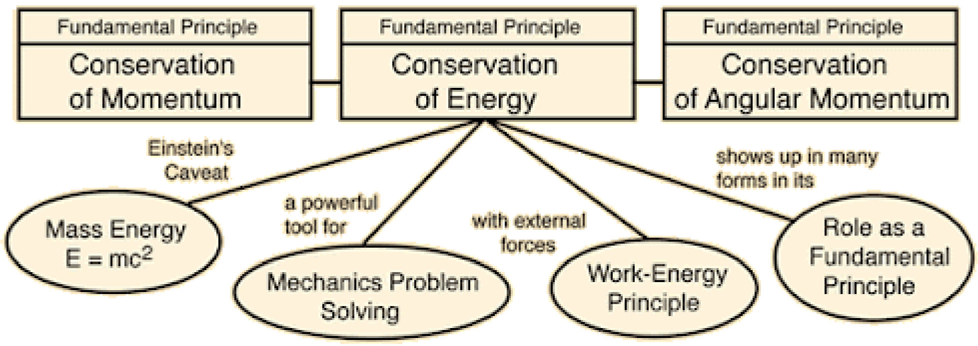
Chapter 8: Energy

Term	Equation	Description
Energy	E	The ability to do work.
Potential Energy (PE)	$PE = mgh$	Energy that is stored but not currently doing work. Potential energy is **relative**, so it must be defined relative to a reference point.
Kinetic Energy (KE)	$KE = \frac{1}{2}mv^2$	Energy in the form of motion.
PE → KE		
Heat (W_f) (Work due to Friction)	$W_f = Q$	Examples: Brake pads, bent paper clip
Work (W)	$W = Fd$ $W = F_{\parallel} \cdot \Delta x$	The magnitude of an object's displacement times the parallel component of the applied force. When a body does work, it **loses** energy. When a body is worked on, it **gains** energy.
Total Energy (TE)	$TE = PE + KE = constant$ $TE = PE + KE + W_f = constant$ (added **Work** energy due to friction) $TE = PE + KE + W_f + W = constant$ (added **Work** energy due to force) $E = U_g + K + Q + W = constant$ (alternate representation)	
Rotational Kinetic Energy (KE)	Rotational energy of a uniform sphere (e.g., ball bearing): $KE = \frac{1}{5}mv^2$	
The First Law of Thermodynamics	Energy (E) cannot be created or destroyed. It can only change forms.	
Power	$P = \frac{\Delta W}{\Delta t}$ $P = Fv = \frac{Fd}{t}$	The amount of energy converted or transferred per unit of time.
Units	E W $PE \text{ or } U$ $KE \text{ or } K$ $TE \text{ or } E_{Total}$	Joules (J) ($kg \cdot m^2/s^2$)
	P	Watt (W) (J/s)

Chapter 9: Momentum and Its Conservation

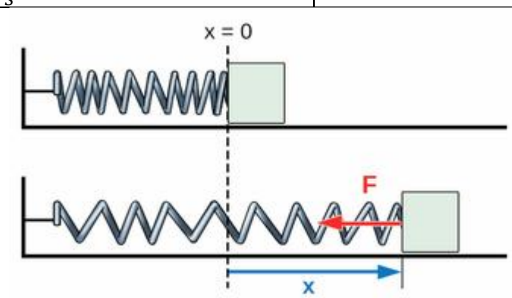
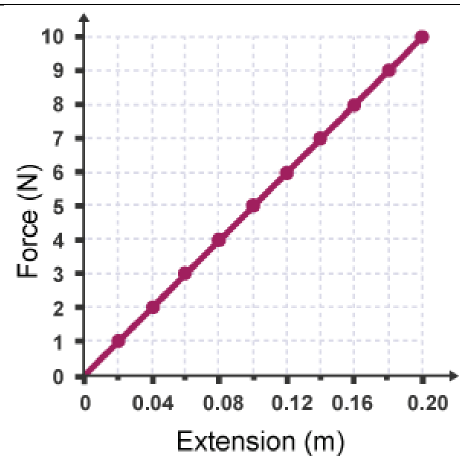
Term	Equation	Description
Momentum	The mass of an object times its velocity.	
Law of Momentum Conservation	When the net external force on a system is zero, the total momentum cannot change.	
Elastic Collision	A collision in which the total energy of the colliding objects does not change.	
Inelastic Collision	A collision in which the total energy of the colliding objects is <u>lower</u> after the collision.	
Law of Angular Momentum Conservation	When the net external torque on a system is zero, the total angular momentum cannot change.	
Momentum (Linear Momentum)		
Momentum	$\boldsymbol{p} = m\boldsymbol{v}$	$kg \cdot m/s$
Impulse	$\Delta\boldsymbol{p} = \boldsymbol{F} \cdot \Delta t$ $\Delta\boldsymbol{p} = \boldsymbol{p}_{final} - \boldsymbol{p}_{initial}$	$N \cdot s$ or $kg \cdot m/s$ The change in momentum.
Collision Types		
Newton's Cradle	Example of an elastic collision	

Angular Momentum		
Angular Momentum	$\boldsymbol{L} = m\boldsymbol{vr}$	$kg \cdot m^2/s$
Spinning Tire	A spinning bicycle tire requires effort to tilt since it has angular momentum ($\boldsymbol{L}$). You must apply a torque ($\boldsymbol{\tau}$) to change the angular momentum.	
Conservation Laws		
Conservation of Linear Momentum: $\boldsymbol{p}_i = \boldsymbol{p}_f$	*Conservation of Energy:* $\boldsymbol{E}_i = \boldsymbol{E}_f$	*Conservation of Angular Momentum:* $\boldsymbol{L}_i = \boldsymbol{L}_f$



Conservation of Momentum	When the net external force is zero: $\boldsymbol{p}_{before} = \boldsymbol{p}_{after}$
Conservation of Angular Momentum	When the sum of the torques is zero: $\boldsymbol{L}_{before} = \boldsymbol{L}_{after}$

Chapter 10: Periodic Motion

Term	Equation	Description
Periodic Motion	Motion that repeats itself in equal intervals of time.	
Hooke's Law	The restoring force exerted by an elastic object is directly proportional to the distance it is displaced from its equilibrium position.	
Amplitude	The maximum extent of a periodic motion, defined from the equilibrium position.	
Simple Harmonic Motion	Periodic motion produced by a restoring force that is directly proportional to the distance from the equilibrium position.	
Damped Harmonic Motion	Periodic motion whose amplitude decreases over time.	
	Spring	
Spring Force	$\boldsymbol{F_s} = -k \cdot \boldsymbol{\Delta x}$	N
Equalibrium		
Spring Force Graph		Linear $y = mx + b$ $F = -kx + 0$
Spring Period	$T_s = 2\pi\sqrt{\frac{m}{k}}$	s
	The period of a mass / spring system depends on π because it is a one-dimensional projection of uniform circular motion.	
Max. Spring PE	At the amplitude of a mass / spring system's motion, the restoring force is the greatest, and the speed of the mass is zero.	
Max. Spring KE	At the equilibrium position of a mass / spring system's motion, the restoring force zero, and the speed of the mass is at its maximum value.	
Spring Energy	$PE_S = \frac{1}{2}k\Delta x^2$	$KE_S = \frac{1}{2}mv^2$
	$TE_S = \frac{1}{2}mA^2$	A is amplitude in $\boldsymbol{x}(t) = A\cos(2\pi f t + \phi)$

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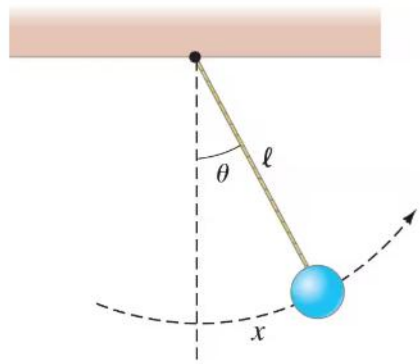
<tr><td>Simple Pendulum</td><td>
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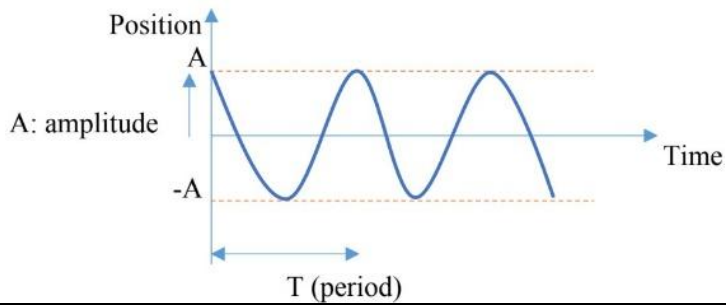
<tr><td>Small Displacement Simplification</td><td colspan="2">A simple pendulum will exhibit simple harmonic motion if the angle that represents its amplitude is small. That is because the restoring force is directly proportional to the displacement only when $\sin\theta \approx \theta$.</td></tr>
<tr><td>Pendulum Period</td><td>$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$</td><td>s</td></tr>
<tr><td>Simple Harmonic Motion</td><td colspan="2">
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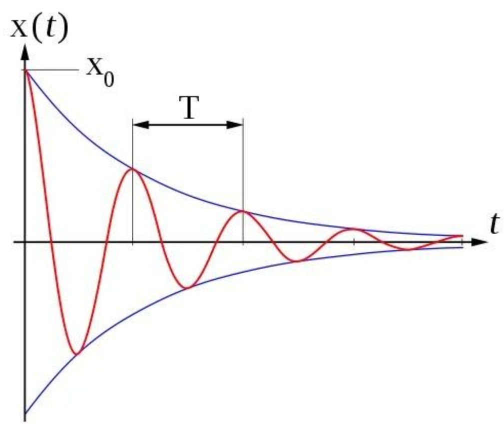
<tr><td>Damped Harmonic Motion</td><td colspan="2">
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Chapter 11: Sound and Light

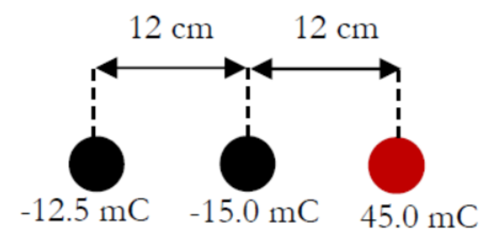
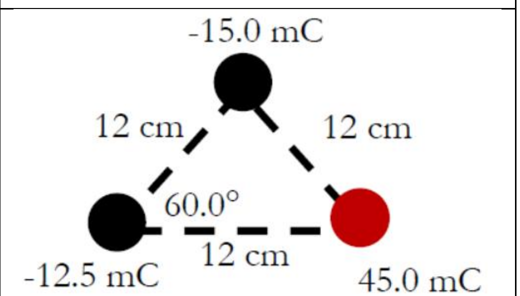
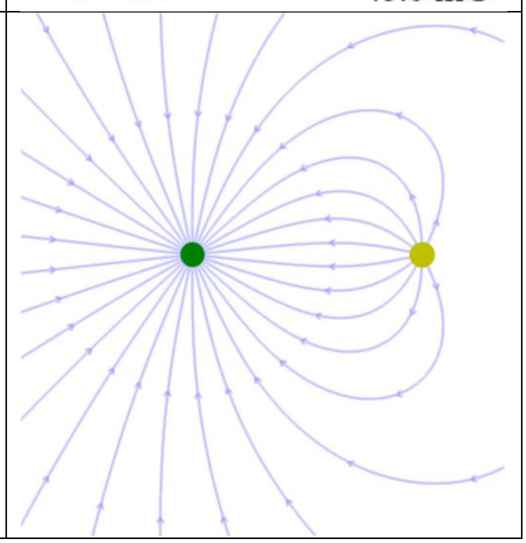
Term	Equation	Description
Oscillations		
Transverse Wave		
Wavelength		
Longitudinal Wave		
Doppler Effect		
Sonic Waves		
Ultrasonic Waves		
Infrasonic Waves		
Timbre		
Wave-Particle Duality		

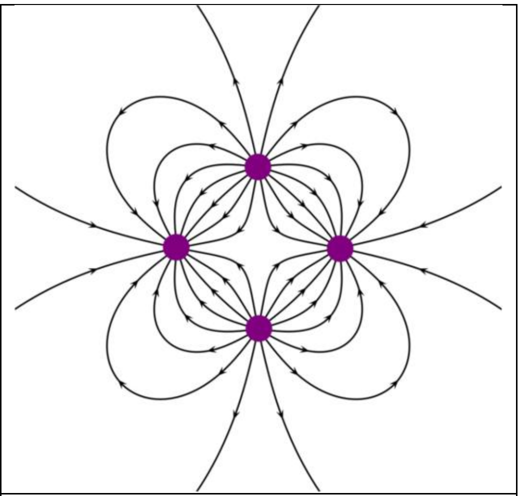
Chapter 12: Optics

Term	Equation	Description
Law of Reflection		
Virtual Image		
Real Image		
Refraction		
Spherical Aberration		
Chromatic Aberration		
		(see table of indices of refraction below)

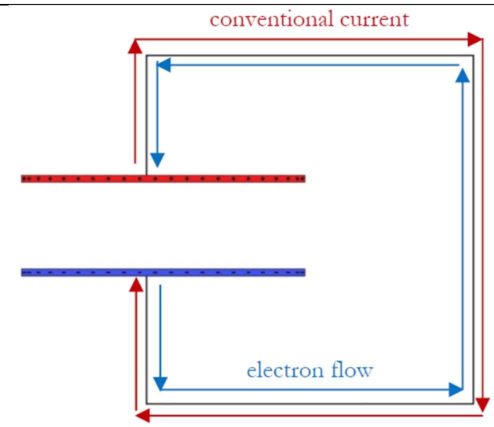
Medium	Index of Refraction
air	1.0003
water	1.333
ethanol	1.361
ice	1.309
glass, crown	1.52
glass, flint	1.66
fused quartz	1.458
diamond	2.419

Chapter 13: The Electrostatic Force

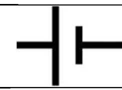
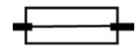
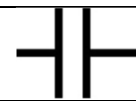
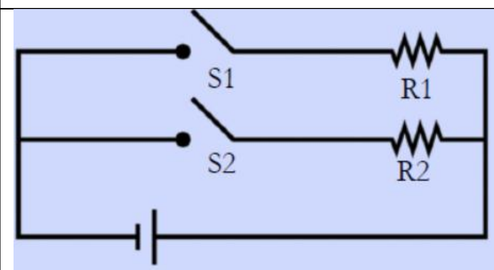
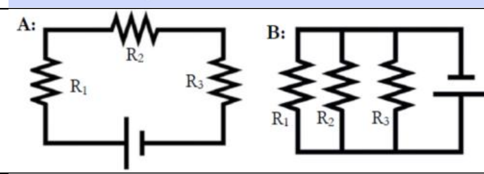
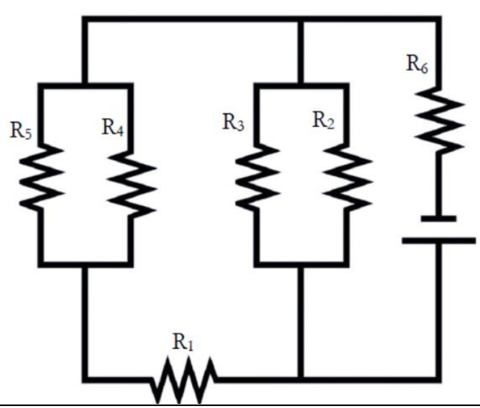
Term	Equation	Description
Electrostatic Force		
Triboelectric Charging		
Charging by Conduction		
Charging by Induction		
Conductor		
Insulator		
		
		
		

Chapter 14: Electricity Has Potential!

Term	Equation	Description
Electric Potential		
Electron Volt		
Capacitor		
Capacitance		
Electric Permittivity (ε)		
Ground (Electrical)		
Law of Charge Conservation		
Electric Current		
Electric Circuit		
		

Chapter 15: Electric Circuits

Term	Equation	Description
Drift Velocity		
Resistor		
Battery (Voltage source)		
Fuse		
Capacitor		
Switch		
		
		
		

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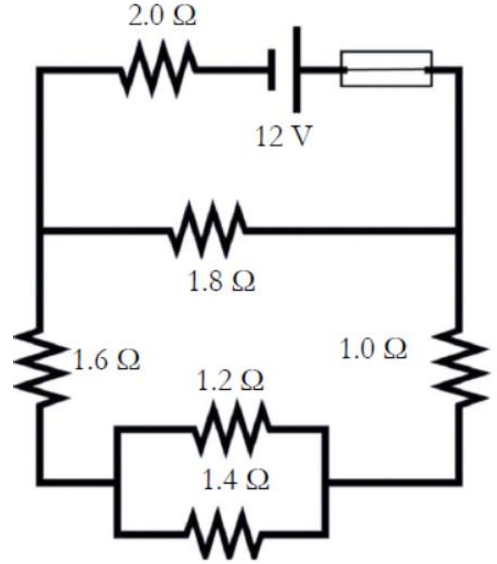
<tr><td></td><td></td><td>
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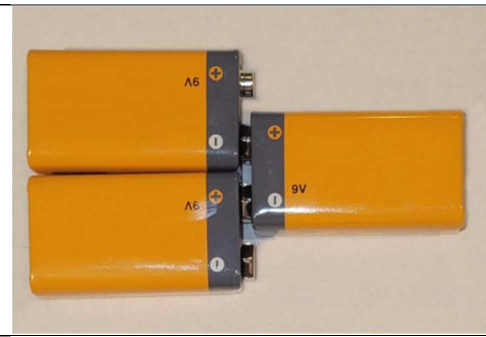
<tr><td></td><td></td><td>
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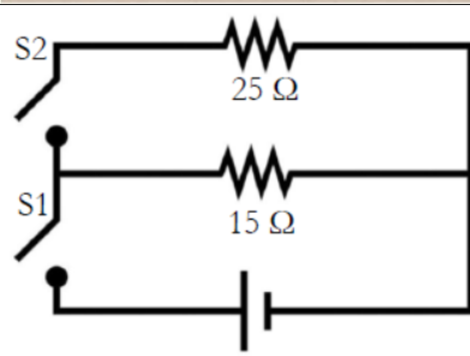
<tr><td></td><td></td><td>
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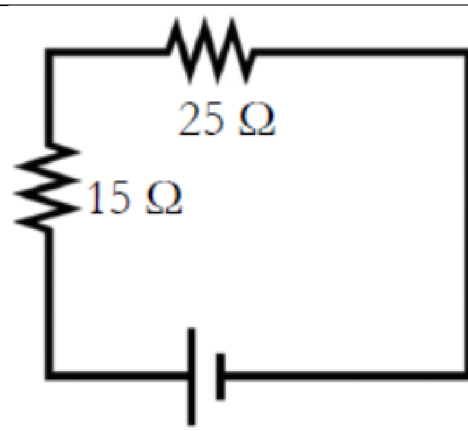
<tr><td></td><td></td><td>
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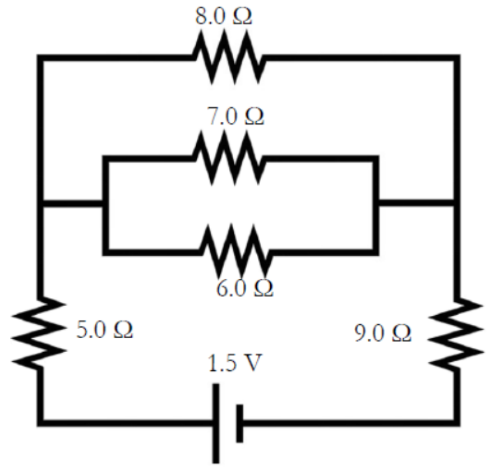
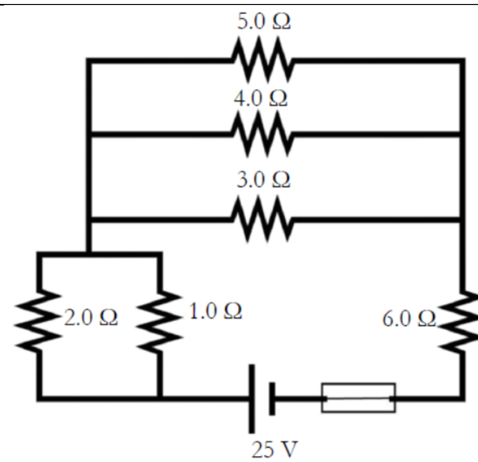
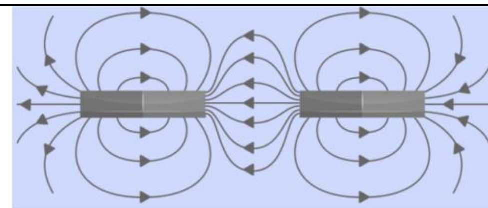
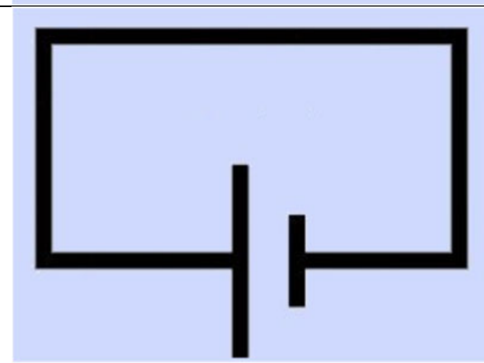
		8.0 Ω 7.0 Ω 6.0 Ω 5.0 Ω 9.0 Ω 1.5 V
		5.0 Ω 4.0 Ω 3.0 Ω 2.0 Ω 1.0 Ω 6.0 Ω 25 V

Chapter 16: Magnetism

Term	Equation	Description
Basic Law of Magnetism		
Magnetic Permeability (μ)		
Right-Hand Rule		
Diamagnetic Substance		
Paramagnetic Substance		
Ferromagnetic Substance		
Faraday's Law of Magnetic Induction		
Electromotive Force		
Alternating Current		
Direct Current		
Rectifier		
Inverter		
Lenz's Law		
		
		

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- Dr. Jay L. Wile (2023). Discovering Design with Physics, 1st Edition.

Image Sources

- Dr. Carl Rod Nave (1998). HyperPhysics, Conservation of Energy. http://hyperphysics.phy-astr.gsu.edu/hbase/conser.html