AP Physics 1: Algebra Based

Review for AP Exam

Exam: Thursday, May 11th, 2023 @ 12PM

Exam Layout

Section I: 50 multiple choice, 1 hr 30 min

Section II: 5 free response, 1 hr 30 min

- 1 Experimental Design question
- 1 Qualitative/Quantitative Translation question
- 1 Short Answer: Paragraph Argument question
- 2 Short Answer questions

Materials

- Calculator
- No. 2 Pencils
- Pens with blue and black Ink
- A watch that doesn't make noise and no access to the internet (optional)
- Straight-edge ruler (optional)

Exam Weight

- Kinematics: 12-18%
- Dynamics: 16-20%
- Circular Motion & Gravitation: 6-8%
- Energy: 20-28%
- Momentum: 12-18%
- Simple Harmonic Motion: 4-6%
- Torque & Rotational Motion: 12-18%

Contents of Packet

There is a section for reference sheets
at the end of the packet. Please tear off for easy use.

NOTES

Unit 1 → Kinematics

Measurements

- Scalar
  - Magnitude (size) only
- Vector
  - Magnitude AND direction

Adding Vectors

- Tail-to-tail
  - Parallelogram
- Head-to-tail
  - Complete the triangle
- R→resultant vector; sum of 2 or more vectors

Measuring Length

- Distance (scalar)
  - Length of path traveled
- Displacement (vector)
  - Straight line length from start to finish
- Fundamental unit
- Meters (m)

Speed and Velocity

- Speed (scalar)
  - Rate at which *distance* changes
- Velocity (vector)
  - Rate at which *displacement* changes
- Fundamental unit
  - Meters per second ($\frac{m}{s}$)
- Reference table: $\underline{v_x} = \frac{\Delta x}{t} = \frac{v_{x0}+v_x}{2}$
  - Δx→change in position (m)
  - v_{x0}→initial speed or velocity ($\frac{m}{s}$)
  - v_x→ final speed or velocity ($\frac{m}{s}$)
  - $\underline{v_x}$→ average speed or velocity ($\frac{m}{s}$)

Acceleration (vector)

- Rate at which *velocity* changes
- Fundamental unit
    - Meters per second per second; meters per second squared; $(\frac{m}{s^2})$
- Direction
    - Speeding up
        - Acceleration and motion in the *same* direction
    - Slowing down
        - Acceleration and motion in the *opposite* direction
- Reference table (some equations are simplified)
    - $v_x = v_{x0} + a_x t$
    - $\Delta x = v_{x0} t + \frac{1}{2} a_x t^2$
    - $v_x^2 = v_{x0}^2 + 2 a_x \Delta x$
    - $a_x \rightarrow$ acceleration in the x-direction

Free-Fall Motion

- Description of an object's motion when the only unbalanced force acting on it is gravity

- CONFINED TO Y-AXIS ONLY
- Depends on acceleration due to gravity (g)
- Does *not* depend on mass (m)
- Acceleration due to gravity
    - Varies planet to planet
        - Determined by planet
    - Same for ALL objects
    - Constant
- Time
    - Height determines time
    - Same height = same time
- Reference Table
    - Acceleration due to gravity = $g = -9.8\frac{m}{s^2}$
        - On Earth *ONLY*
        - Different planets have different g values
        - Always points down (-) towards center of the planet
- Key terms
    - Falls freely
    - Dropped
    - Released from rest
- Free-fall with v_{y0}
    - Key terms
        - Vertically/straight upward/downward
- Free-fall with v_i
    - At max height
        - Velocity = $0\,m/s$
    - Vertically when thrown up = velocity when it hits the ground
        - Only applied when starts and ends at same height
- Max height
    - Y-axis ONLY
        - $v_y = 0\,m/s$
        - $a_y = -9.8\,m/s^2$
        - Δy = height
        - $v_y^2 = v_{y0}^2 + 2a_y\Delta y$

Graphing Motion

- Important information
    - Axis → tells you what information you're given
    - Slope → tells you how to break up your work
- Do individual slopes first; combine at the end

- Slope equation→$\frac{y_2-y_1}{x_2-x_1} = \frac{\Delta y}{\Delta x}$
- Area under a graph
    - Area = base × height = $x \times y$
    - Velocity vs. time
        - Area = Δx

Adding Vectors

- At 0°
    - $a + b = c$
- At 90°
    - $a^2 + b^2 = c^2$
    - $c = \sqrt{a^2 + b^2}$
- At 180°
    - $a + \text{-}b = c$
- Resolution of vectors
    - $a_x + b_x = R_x$
    - $a_y + b_y = R_y$
    - $R_x^2 + R_y^2 = R^2$
- Steps
    - Add components
    - Find Resultants

Horizontal Projectile Motion

- Depends on…
    - Acceleration due to gravity (g)
    - Air resistance (ignore it)
- Does *not* depend on…
    - Mass (m)
- Acceleration

- Y-axis
    - Determined by gravity of the planet
    - Same for all objects
    - Constant
  - X-axis
    - No jetpack, no air resistance
    - Constant a_x at $0\,m/s^2$
- Time
  - X and Y axis
    - Height determines time
    - Same in both axis (scalar)
  - Same objects have the same time
- Key terms
  - Thrown horizontally
  - Fired horizontally
  - ANYTHING horizontally
  - Range → horizontal displacement (Δx)

Angled Projectile Motion
- 45°
  - Greatest range
  - Longest horizontal displacement
- 30° or 60°
  - 45°±15°
  - Same range
- 15° or 75°

    - 45°±30°
    - Same range
- 90°
    - Greatest height
- Relationships
    - Greater angle, greater height, greater time
- Key terms
    - At an *angle* above or below the horizontal
- Max height
    - $v_y = 0\,m/s$
    - $a_y = -9.8\,m/s^2$
    - $\Delta y =$ height
    - $v_y^2 = v_{y0}^2 + 2a_y\Delta y$

Unit 2 → Forces

Newton's First Law

- An object stays at rest or in motion unless acted upon by an unbalanced force
  - F_{net} is the overall net force which may be considered as unbalanced
- Inertia→Object's stubbornness to change
  - Inertia = mass
- Mass (kg)→amount of matter in an object
  - Scalar quantity

Newton's Second Law

- Reference Table: $a = \frac{F_{net}}{m}$
  - Also can be written as $F_{net} = ma$
- Relationships
  - $a \propto F_{net}$
  - $m \propto F_{net}$
  - $a \propto \frac{1}{m}$
  - $m \propto \frac{1}{a}$
- F_{net}→net force (N); unbalanced force; vector quantity
  - $F_{net} = \sum \quad F$
- F_{net} and a are *always in the **same** direction*

Newton's Third Law

- For every action there is an equal and opposite reaction
- Action→who creates the force
- Object→who experiences the force
- Action and reaction pairs are *never the same object*
- Effects of push and pull depend on the mass of object

Force

- Force is a push or pull
- Force acts on an object
- An *agent* causes the push or pull

Mass (m)

- Mass is the measure of the amount of matter in an object
  - Scalar quantity measured in kilograms (kg)

- MASS DOES NOT CHANGE BASED ON LOCATION

Weight (F_g)

- Represented by F_g
- Force of attraction between a planet and an object near its surface
- ALWAYS pulls towards the center of a planet
- ALWAYS attractive
- ALWAYS pulling down on us near the surface of a planet
- CAN change based on location
- Reference table: $g = \frac{F_g}{m}$
  - Can also be written as $F_g = mg$
- F_g→gravitational force (N); vector
- g→acceleration due to gravity ($\frac{m}{s^2}$); vector

Normal Force (F_N)

- F_N→normal force
- Normal→perpendicular
- SUPPORTIVE FORCE between an object and a surface it's in contact with
- F_N= apparent weight
  - What we FEEL as weight is the ground pushing up
- When you are flat on a surface and *not* accelerating up or down
- F_N= F_g
- Weightless during free-fall
  - $F_N = 0N$
  - Nothing is supporting us

Friction

- Force caused by contact between 2 objects
- Reference table: $|F_f| \leq \mu|F_N|$
  - F_f→force of friction (N); vectors
  - μ→coefficient of friction; always less than 1; NO UNITS
    - Motion

        - Materials
        - Lubrication

Kinetic Friction
- Moving friction
- Directed opposite motion
- If you are moving, force of friction is set to some value
    - $F_{f_{kinetic}} = \mu_{kinetic} F_N$
        - $F_f \propto F_N$

Static Friction
- Not moving; stationary
    - Static friction is stationary friction
- Directed opposite intended motion
- If you are *not* moving, your force of static friction will vary
- The harder you push, the harder the force of static friction pushes back
- There is a maximum force of static friction
- Once you reach the max, the object begins to move and transforms to kinetic friction
- $F_{f_{static}} \leq \mu_{static} F_N$

SHOUT IT OUT!!
- ❖ CONSTANT VELOCITY
- ❖ ZERO ACCELERATION
- ❖ $F_{net} = 0N$
- ❖ EQUILIBRIUM

Equilibrium
- Forces are balanced
- Forces add up to 0
    - $\Sigma F_{net} = 0N$
- Equalibriant
    - The force that creates equilibrium
    - Equal and opposite to the resultant of the forces; you are in balance

Unbalanced Forces

- Elevators
  - Moving in the y-axis
  - Mass and planet are constant
- F_N will vary
  - If $F_N = F_g$
    - Balanced
    - Constant velocity
    - Up or down
  - If $F_N < F_g$
    - We feel lighter
    - Accelerating down
    - F_{net} is down
  - If $F_N > F_g$
    - We feel heavier
    - Accelerating up
    - Moving up or down
    - F_{net} is up

Unit 3 → Circular Motion

Horizontal Circular Paths

- Uniform Circular Motion
  - Constant, consistent, evenly applied *speed*
  - Uniform
    - Consistent, constantly, evenly applied
- Circular Motion
  - Objects are moving in a curved path
  - How can we find the speed of an object as it moves through a circle?
  - Reference Table
    - $\underline{v} = \frac{d}{t} = \frac{circumference}{period} = \frac{2\pi r}{T}$
    - $T = period =$ time for one circle(s)
    - As r increases, so does v
- Tangential Velocity
  - The direction of velocity is constantly changing
  - The direction is *tangent* to the circle
  - Speed is constant
  - Velocity is *not* constant
    - Change in direction therefore there is acceleration
- Centripetal Acceleration
  - Reference Table
    - $a_c = \frac{v^2}{r}$
      - $a_c =$ centripetal acceleration (m/s^2)
      - $v =$ speed (m/s)
      - $r =$ radius (m)
    - $F_{net} = F_{net\ circular} = F_c = ma_c = \frac{mv^2}{r}$
  - The force that causes an object to move toward the inside of a circle
    - Centripetal force is circular net force
    - Centripetal force causes centripetal acceleration
    - F_{net} produces a_c of circular motion

- Horizontal Circular Motion
    - Flat tabletop
    - Car on a curve
    - Record player
    - Force of gravity DOES NOT directly play a role
    - Particular Cases
        - Make towards the center of the circle positive (+)
        - Flat curve

$$F_c = F_F$$
$$F_{net_x} = F_{net_x}$$
$$F_{c_x} = F_{c_x}$$

$ma_c = \Sigma F_x$

$$ma_c = F_F$$
$$ma_c = \mu F_N$$
$$F_{net_y} = F_{net_y}$$
$$ma_y = \Sigma F_y$$

$0N = F_N + \text{-} F_g$

$$F_g = F_N$$
$$ma_c = \mu F_g$$
$$a_c = \mu g$$
$$\frac{v^2}{r} = \mu g$$

- Conical pendulum
  - Object on a string

    F_c is a component of the tension force (F_T)

$$F_{net_x} = F_{net_x}$$
$$F_{c_x} = F_{c_x}$$
$$ma_c = \Sigma F_x$$
$$ma_c = F_{T_x}$$
$$F_{T_x} = F_{T_Y} tan\theta$$
$$ma_c = F_{T_y} tan\theta$$
$$ma_c = F_g tan\theta$$
$$ma_c = mgtan\theta$$
$$a_c = gtan\theta$$
$$\frac{v^2}{r} = tan\theta$$

- Banked curve
  - F_c is a component of F_N
  - Proper banking angle indicates no friction
  - SAME SITUATION AS CONICAL PENDULUMS

$$F_{net_x} = F_{net_x}$$
$$F_{c_x} = F_{c_x}$$
$$ma_c = F_{N_x}$$

$$F_{net_y} = F_{net_y}$$
$$ma_y = \Sigma F_y$$
$$0N = F_{N_y} +\text{-}F_g$$
$$F_g = F_{N_y}$$
$$F_{N_x} = F_{N_y} tan\theta$$
$$ma_c = F_g tan\theta$$
$$\frac{mv^2}{r} = mgtan\theta$$
$$\frac{v^2}{r} = gtan\theta$$

Vertical Circular Paths

- Vertical Circular Motion
  - Examples
    - Roller Coaster loop
    - Driving over a bump
    - Walking
  - Force of gravity ***DOES*** play a *direct* role
- Particular Cases
  - Towards the center of the circle is positive (+)
  - Bottom of a curve

    $F_{net_y} = F_{net_y}$

    $F_{c_y} = F_{c_y}$

    $ma_c = \Sigma F_y$

    $ma_c = F_N + -F_g$
  - Top of a curve

    $F_{net_y} = F_{net_y}$

    $F_{c_y} = F_{c_y}$

    $ma_c = \Sigma F_y$

    $ma_c = F_g + -F_N$
  - Top of a curve (upside-down)

    $F_{net_y} = F_{net_y}$

    $F_{c_y} = F_{c_y}$

    $ma_c = \Sigma F_y$

    $ma_c = F_N + F_g$
- Critical Speed
  - Slowest speed at which an object can complete a circle
  - At the top of a curve
    - $F_N = 0N$
      - $F_N = F_g$

$$\frac{mv^2}{r} = F_N + F_g$$

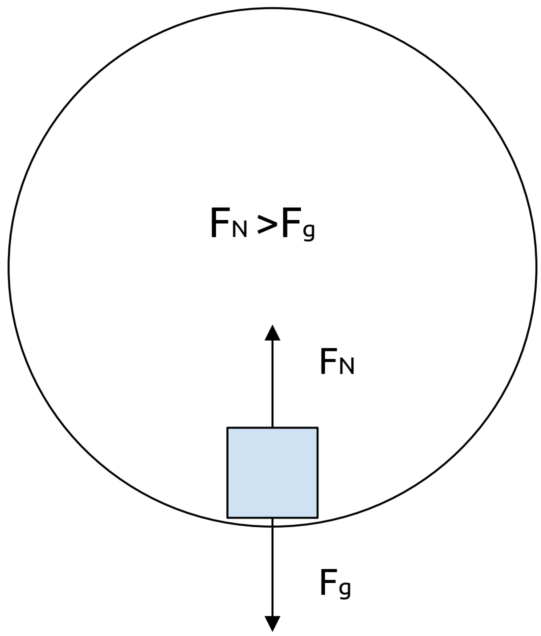
$$\frac{mv^2}{r} = F_g$$

$$\frac{mv^2}{r} = mg$$

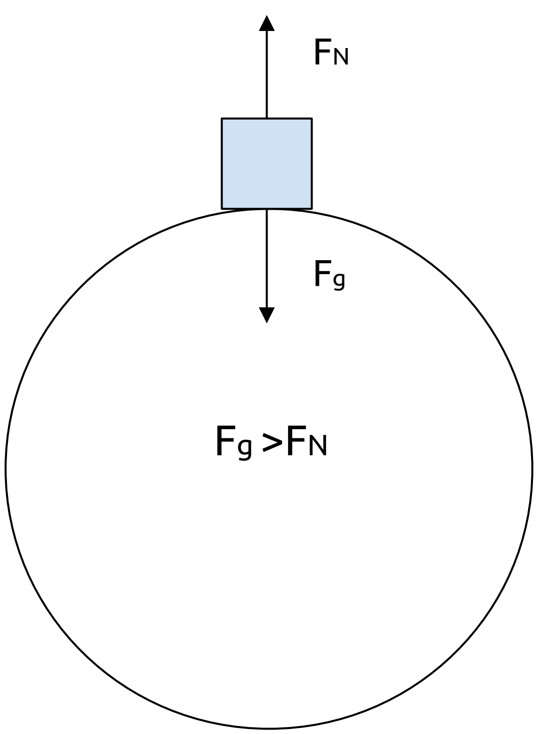
$$\frac{v^2}{r} = g$$

Vertical Circular Motion

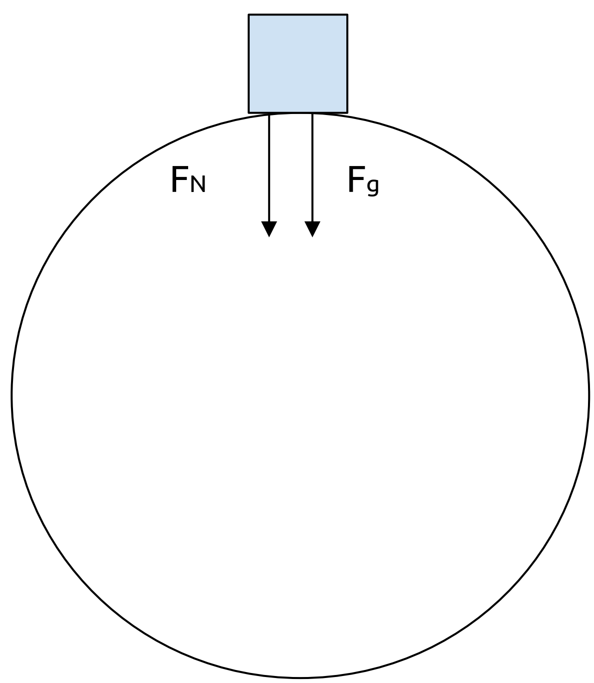
Bottom of the Curve



Top of the Curve



Top of the Curve, Upside Down



Force of Gravity

- Long Rangeforce
    - No need for contact
    - Extends to infinity
    - Always attractive
- $F_g = mg$
    - Force of attraction between Earth and another object *on* Earth
        - $F_g = m_{object}\, g_{Earth}$
        - Weight
- $F_g = G\frac{m_1 m_2}{r^2}$
    - Force of attraction between 2 objects
        - m_1 and m_2
        - G is the Universal Gravitation Constant
            - $G = 6.67 \times 10^{-11}\ N \cdot \frac{m^2}{kg^2}$
- Acceleration due to gravity
    - $|F_g| = F_g$
    - $\frac{G m_P m_o}{r^2} = m_o g$
        - $g = \frac{G m_P}{r^2}$
            - m_P represents the mass of a planet
            - m_o represent the mass of an object
- The Skeleton
    - Equation
        - $F_g = \frac{G m_1 m_2}{r^2}$
    - Skeleton
        - $\frac{(1)(\ )(\ )}{(\ )^2} F_g$

Orbits

- Orbits
  - Vertical circular motion
  - Objects are in free-fall
    - $F_c = F_g$
    - $a_c = g$
  - Period (T) is the time for one full revolution
- Period of an orbit

$$a_c = g$$
$$\frac{v^2}{r} = G\frac{m_P}{r^2}$$
$$\frac{(\frac{2\pi r}{T})^2}{r} = G\frac{m_P}{r^2}$$
$$T = \sqrt{\frac{4\pi^2 r^3}{Gm_P}}$$

Unit 4 → Energy

Understanding Energy

- Total energy of a system is represented by: E_{total}
    - Sum of all energies in a system
    - $E_{total} = K + U_g + U_s + Q$
- Energy transfer
    - Energy of one kind can be transformed into another
    - Exchange of energy between a system and its environment
    - TYPES
        - Work
            - Mechanical transfer of energy (pushing and pulling)
        - Heat
            - Nonmechanical transfer of energy (temperature difference)
- Law of conservation of energy
    - Total energy of an isolated system is conserved
        - In an isolated system, there is no way of transferring energy in and out of the system
    - $\Delta E = W$

Work

- Forces
  - An external force occurs when work is done from outside of a system
  - An internal force occurs from forces within an object
  - Greatest force is done when force points in the same direction as displacement
  - $F \rightarrow F_{\parallel}$ and $F_{\perp}$
    - $F_{\parallel}$
      - $F_{\parallel}$ can increase kinetic energy
      - $F_{\parallel} = cos\theta$
- Relationship between work and displacement
  - For a change in energy to occur, there must be a displacement
  - Larger the displacement, greater the work done
  - $d \propto W$ or $\Delta x \propto W$
  - If force is constant, force will point in the same direction as displacement
- Relationship between work and force
  - Stronger the force, the greater the work done
  - $F \propto W$
- Equations and units
  - $W = Fd$ or $W = F\Delta x$
  - $W = F_{\parallel}\, d = Fdcos\theta$
  - $Newtons \cdot meters = N \cdot m = Joules = J$
  - Joules (J) is the unit used for ALL forms of energy
  - Sign of W is determined by the angle between force and displacement
  - $W = \Delta E_{total} = \Delta K + \Delta U_g + \Delta U_s + \Delta E_{th}$
  - $W = \Delta E$
    - Expand to all forms when ΔE is equal to different types of energy
- Systems with NO work
  - Systems that undergo NO displacement
  - A force is perpendicular to the displacement
  - Part of an object with a force undergoes no displacement

Kinetic Energy

- Understanding kinetic energy
  - Depends on velocity of an object squared
  - Must always be zero or positive
  - NOT a vector, although velocity is
- An object's energy in motion
- Equation and units
  - $W = \Delta K$
    - $W = \Delta K = K - K_0 = K_{final} - K_{initial}$
  - J (Joules)
    - $kg \cdot \frac{m^2}{s^2} = kg \cdot m \cdot \frac{m}{s^2} = N \cdot m = J$
  - $\Delta K = \frac{1}{2} m \Delta v^2$
  - Proving the formula using manipulation

$$v^2 = v_0^2 + 2a\Delta x$$

Substitute $a = \frac{F}{m}$

$$v^2 = v_0^2 + \frac{2F\Delta x}{m}$$

Substitute $F\Delta x = W$

$$v^2 = v_0^2 + \frac{2W}{m}$$

$$W = \frac{1}{2} m(v^2 - v_0^2)$$

$K_{final} = \frac{1}{2} m v_{final}^2$ $\qquad$ $K_0 = \frac{1}{2} m v_0^2$

$$\Delta K = \frac{1}{2} m \Delta v^2$$

If it starts from rest,

$$K = \frac{1}{2} m v^2$$

Potential Energy

- An object's stored energy
- Forces
    - Conservative forces
        - Interactive forces that store useful energy
        - Gravity and elastic forces
            - Mechanical energy is only conserved when conservative forces act upon it
    - Nonconservative forces
        - Forces where energy is not stored
        - Friction
- Gravitational potential energy
    - Gravitational potential energy depends on height of an object, not path taken to the position
        - As an object is thrown up, ΔU_g increases because height increases
            - At its highest point, it will start to decrease
    - Equations
        - $\Delta U_g = mg\Delta y$
        - $W = \Delta U_g$
        - Proof of formula

$$U_g = U_{g_0} + W$$

Substitute $W = Fd = mg\Delta y$

$$U_g = U_{g_0} + mg\Delta y$$

$$\Delta U_g = mg\Delta y$$

- Elastic potential energy
    - Energy stored in compressed or extended springs
    - Hooke's Law
        - $|F_s| = -k\Delta x$
    - Equations
        - $\Delta U_s = \frac{1}{2}k\Delta x^2$
        - $W = \Delta U_s$
        - Proof of formula

$$W = F_s\Delta x$$

Substitute $F_s = k\Delta x$

$$W = (k\Delta x) \cdot \Delta x$$

$$W = k\Delta x^2$$

Substitute $W = \Delta U_s$ and halve the equation because some of the energy goes to the spring

$$\Delta U_s = \frac{1}{2}k\Delta x^2$$

Conservation of Energy

- Total energy of a system equals the energy transferred to or from systems of work
- Energy of an isolated system is conserved
- Mechanical energy

    - Sum of potential and kinetic energy of a system
    - Conserved if the isolated system DOES NOT have friction
- Equations
    - $W = \Delta K + \Delta U_g + \Delta U_s + Q$
    - $E_{total} = U_g + K + Q + U_s$
    - $W_{friction} = Q = F_f d = F_d \Delta x$

Heat

- *HEAT IS THE SAME THING AS THERMAL ENERGY*
- Sum of all microscopic potential and kinetic energies
    - Atoms move fast → higher temperature → higher kinetic energy
    - Further away from equilibrium → higher potential energy
- Describes the energy lost
- Internal energy describes the energy inside of a system
    - Friction is a type of internal energy
- Force is the force of kinetic friction
    - $F = F_f$
        - F is a force on the box
        - F_f is the frictional force
    - Box is at a constant speed
- Equations
    - $Q = \Delta E_{th} = F_k \Delta x$
    - $W = W_f = Q = \Delta E_{th}$
    - Proof of formula

$$W = F\Delta x$$

Substitute $F = F_k$

$$W = F_f \Delta x$$

Substitute $W = Q$

$$Q = F_f \Delta x$$

Q can further be expanded into more components

$$Q = \mu F_N \Delta x$$

When dealing along the *y-axis*, F_N *may* be substituted for F_g

$$Q = \mu F_g \Delta x$$

$$Q = \mu m g \Delta x$$

Power

- Rate at which energy is transferred
- Equations
    - $P = \frac{\Delta E}{\Delta t}$
    - W (watts)
        - $\frac{J}{s}$ (Joules per second)
    - Proof of formula

To find the power of each type of energy use the general formula,

$$P = \frac{\Delta E}{\Delta t}$$

FInd P_W by substituting $\Delta E = W$

$$P_W = \frac{W}{\Delta t}$$

Substitute $W = F\Delta x$

$$P_W = \frac{F\Delta x}{\Delta t}$$

$$P_W = F\frac{\Delta x}{\Delta t}$$

Substitute $\frac{\Delta x}{\Delta t} = v$

$$P_W = Fv$$

Find P_K by substituting $\Delta E = \Delta K$

$$P_K = \frac{\Delta K}{\Delta t}$$

Substitute $\Delta K = \frac{1}{2}m\Delta v^2$

$$P_K = \frac{\frac{1}{2}m\Delta v^2}{\Delta t}$$

$$P_K = \frac{m\Delta v^2}{2\Delta t}$$

Find P_g by substituting $\Delta E = \Delta U_g$

$$P_g = \frac{\Delta U_g}{\Delta t}$$

Substitute $U_g = mg\Delta y$

$$P_g = \frac{mg\Delta y}{\Delta t}$$

$$P_g = mg\frac{\Delta y}{\Delta t}$$

Substitute $\frac{\Delta y}{\Delta t} = v$

$$P_g = mgv$$

Find P_s by substituting $\Delta E = \Delta U_s$

$$P_s = \frac{\Delta U_s}{\Delta t}$$

Substitute $\Delta U_s = \frac{1}{2}k\Delta x^2$

$$P_s = \frac{\frac{1}{2}k\Delta x^2}{\Delta t}$$

$$P_s = \frac{k\Delta x^2}{2\Delta t}$$

“Skeletons”

- Kinetic Energy
  - $K = \frac{1}{2}mv^2$
  - $K(\frac{1}{2})()()^2$
  - $\Delta K(\frac{1}{2})()\,()^2 - ()_0^2$
- Potential Energy
  - Gravitational Potential Energy
    - $U_g = mg\Delta y$
    - $U_g()()()$
  - Elastic Potential Energy
    - $U_s = \frac{1}{2}k\Delta x^2$
    - $U_s(\frac{1}{2})()()^2$
    - $\Delta U_g(\frac{1}{2})()\,()^2 - ()_0^2$
- Work
  - $W = F\Delta x$
  - $W()()$
- Heat
  - $Q = F_f\Delta x$
  - $Q()()$

Applying Formulas

- Linear Motion
    - Prove $v_y^2 = v_{y_0}^2 + 2a_y\Delta y$

$$\Delta K = \Delta U_g$$

$$\frac{1}{2}m\Delta v_y^2 = mg\Delta y$$

Substitute $g = a_y$

$$\frac{1}{2}m\Delta v_y^2 = ma_y\Delta y$$

Cancel m

$$\frac{1}{2}\Delta v_y^2 = a_y\Delta y$$

Solve for v_y^2

$$\Delta v_y^2 = 2a_y\Delta y$$

Expand $\Delta v_y^2 = (v_y^2 - v_{y_0}^2)$

$$v_y^2 - v_{y_0}^2 = 2a_y\Delta y$$

$$v_y^2 = v_{y_0}^2 + 2a_y\Delta y$$

    - Why does this work?
        - The masses cancel each other out, therefore indicating mass is not a determining factor in the equation
        - It describe the velocity and acceleration over a certain distance

Unit 5 → Momentum

Momentum

- An object's "stop-ability"
  - The more momentum, the starter to stop
- Two factors
  - Mass and velocity
- Examples
  - Nickel vs. bullet
  - Kickball vs. bowling ball
- Reference table and Equations
  - $p = mv$
    - $p = momentum\ (kg \cdot \frac{m}{s})$
    - Momentum and velocity are vectors
- Change of momentum
  - An individual object can have a change in momentum
  - $\Delta p_x = p_x - p_{x_0}$
  - $\Delta p_x = m\Delta v_x = m(v_x - v_{x_0})$

Impulse

- Means change in momentum
- When we change momentum, or impart an impulse, we change object velocity
  - How do we change an object's velocity?
    - Exert a force on it!
- Represented by Δp, I, or J
- Reference table and Equations
  - $\Delta p = F\Delta t$
    - $m\Delta v = m(v - v_0)$
  - Impulse is a vector
  - $kg \times \frac{m}{s} = kg\frac{m}{s}$
- When two objects interact…
  - Same F_{net} on each action/reaction
  - Same amount of time (t)
  - Each object receives the *same* impulse (change in momentum)
- Collision
  - Short duration interaction between objects
  - Time to *COMPRESS* and time to *EXPAND*
  - Perfectly elastic
    - Bounce apart
  - Perfectly inelastic
    - Stick together

Conservation of momentum

- Impulse and change in momentum
  - Exerts a force over time
  - Accelerate an object
  - Change the velocity
  - Change its momentum
- Conservation
  - 2 or more objects collide
    - Colliding
    - Exploding apart
  - Individual momentum changes
  - Total momentum remains the same
- Types of Collisions
  - *Perfectly* elastic collision
    - No object deformation
  - Inelastic collision
    - Object deforms to a certain degree
  - *Perfectly* inelastic collision
    - Objects stick together
- Conservation of momentum
  - Total momentum of an isolated system is constant
  - Interactions within the system *do not* change the total momentum
- Equations and the reference table
  - $p_{total\ before} = p_{total\ after}$
- Scenarios
  - 1→2

$$p_{total\ before} = p_{total\ after}$$

$$p_{AB} = p_A + p_B$$

$$m_{AB}v_{AB} = m_A v_A + m_B v_B$$

  - 2→1

$$p_{total\ before} = p_{total\ after}$$

$$p_A + p_A = p_{AB}$$

$$m_A v_A + m_B v_B = m_{AB}v_{AB}$$

  - 2→2

$$p_{total\ before} = p_{total\ after}$$

$$p_A + p_B = p_A + p_B$$

$$m_A v_A + m_B v_B = m_A v_A + m_B v_B$$

Unit 6 → Simple Harmonic Motion

Period of a simple harmonic motion

- Definitions
  - Simple Harmonic Motion
    - A repeated constant motion around a single point
  - Oscillation
    - A type of simple harmonic motion
    - Regular, repeated, variation in a position around a singular point
  - Equilibrium Position
    - The central point about which an object oscillates
  - Frequency
    - Number of waves, cycles, oscillations, or disturbances per unit of time
    - $f = \frac{\#\, of\ waves, oscillations, or\ disturbances}{time}$
    - Units: cps, Hz, s^{-1}
  - Period
    - Time for one complete wave, cycle, oscillation, or disturbance
    - $T = \frac{time}{\#\, of\ waves, oscillations, or\ disturbances}$
  - Linear restoring force
    - The F_{net} that forces the object back to its equilibrium position
- Reference Table
  - General period
    - $T = \frac{2\pi}{\omega} = \frac{1}{f}$
      - $T = period$
      - $\omega = angular\ speed/angular\ frequency\ (rad/s)$
        - $\omega = 2\pi f$
      - $f = frequency\ (Hz)$
  - Period of a pendulum
    - $T_P = 2\pi\sqrt{\frac{\ell}{g}}$
      - $T_P = period\ of\ the\ pendulum\ (s)$
      - $\ell = length\ of\ the\ string\ (m)$
      - $g = acceleration\ due\ to\ gravity\ (\frac{m}{s^2})$
  - Period of a spring
    - $T_S = 2\pi\sqrt{\frac{m}{k}}$
      - $T_S = period\ of\ the\ spring\ (s)$
      - $k = spring\ constant\ (\frac{N}{m})$
      - $m = mass\ (kg)$

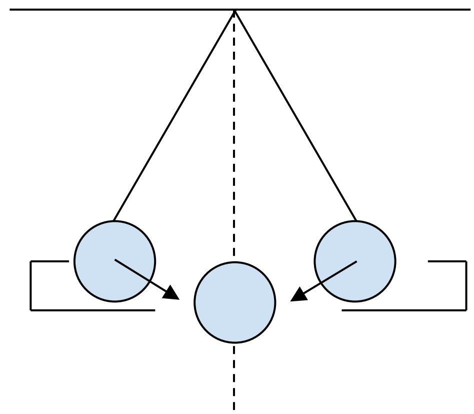
- What’s happening, where?
    - At maximum displacement from equilibrium
        - Amplitude = maximum
        - F_{net} = maximum
        - Acceleration = maximum
        - Velocity = zero
    - At equilibrium
        - Amplitude = zero
        - F_{net} = zero
        - Acceleration = zero
        - Velocity = maximum
- Reference Table
    - *THESE EQUATIONS MUST BE IN* ***<u>RADIAN MODE</u>***
    - Position of an object
        - $x = Acos(2\pi ft)$
            - $x = position\ (m)$
            - $A = amplitude\ (m)$
            - $f = frequency\ (Hz)$
            - $t = time\ (s)$
    - Velocity and acceleration
        - Base
            - $v(x) = 2\pi fx$
            - $a(x) = (2\pi f)^2x$
                - $a(x) = \omega^2x$
        - At maximum
            - $v(max) = 2\pi fA$
            - $a(max) = (2\pi f)^2A$
                - $a(max) = \omega^2A$

Energy of a simple harmonic motion

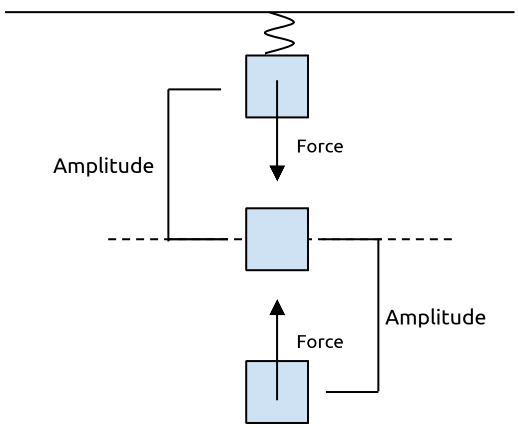
- Energy in a simple harmonic motion
  - Only applies to springs
  - Potential energy is based on position
    - The greater the distance from equilibrium, the greater the stored energy
  - Kinetic energy is based on speed
    - The greater the speed, the greater the kinetic energy
- Reference Table
  - At base
    - $K = \frac{1}{2}mv^2$
    - $U_s = \frac{1}{2}kx^2$
  - At maximum
    - $K_{max} = \frac{1}{2}mv_{max}^2$
    - $U_{s_{max}} = \frac{1}{2}kA^2$

Scenarios at Equilibrium

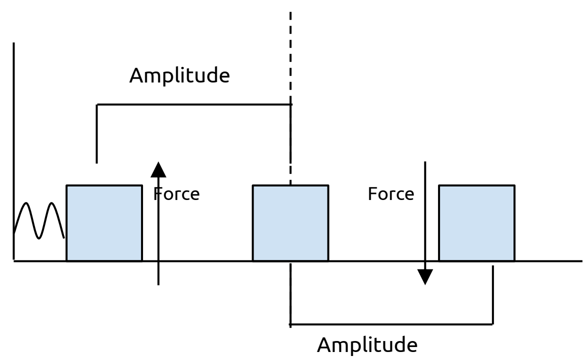
Pendulu



Vertical Spring



Horizontal Spring



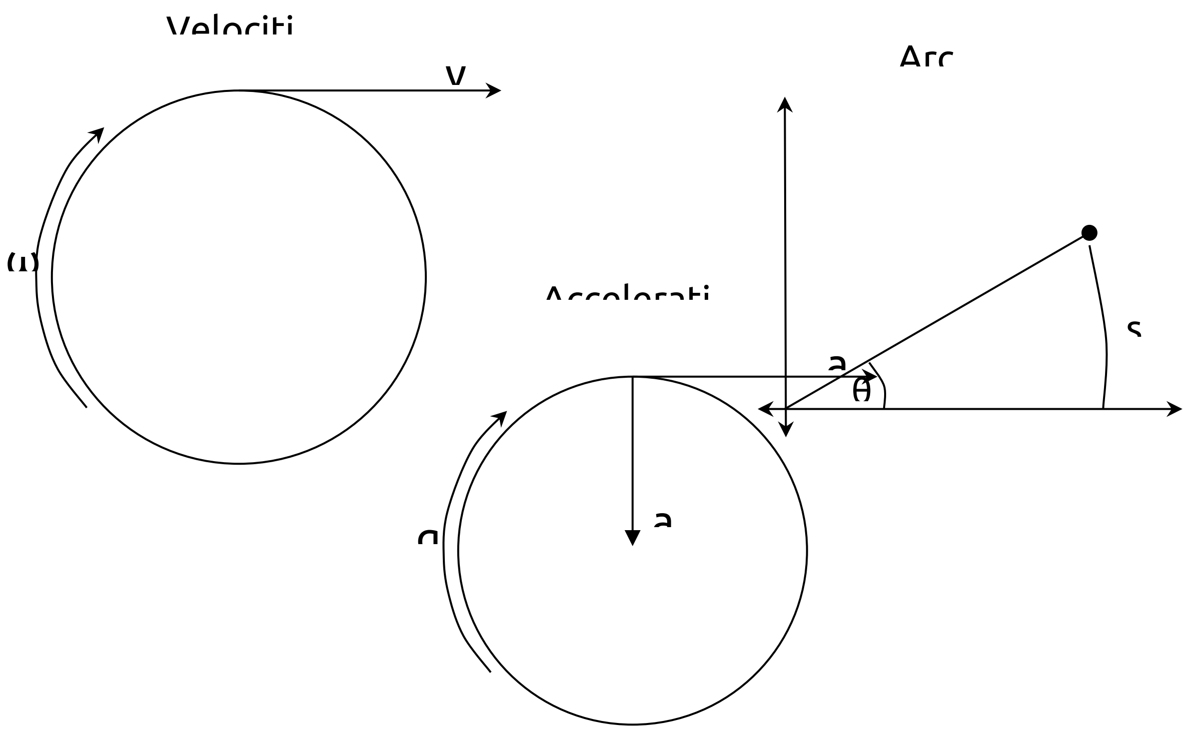
Unit 7 → Rotational Motion

Rotational Motion

- Rotational Motion
  - The motion of objects that spin about an axis
  - Variables are assigned new types of equations using properties of rotation such as the radius
- Arc Length
  - Distance the object has traveled around its circular path
  - Formula
    - $s = \theta r = \Delta x$
      - $s = arc\ length\ (m)$
      - $r = radius\ (m)$
      - $\theta = angular\ position\ (rad)$
  - The arc length around one full circle is the circumference
- Sign Convention
  - Counterclockwise is positive (+)
  - Clockwise is negative (-)
- Angular Position
  - Represented by θ and $\Delta\theta$, measured in radians or rad
  - Rotational equivalent to x and Δx, which are measured in meters
- Angular Velocity
  - Rate at which angular position changes, measured in rad/s
    - Uniform circular motion = constant angular velocity
  - Represented by lowercase omega, ω
  - Formula
    - $\omega = \frac{\Delta\theta}{\Delta t}$
  - Rotational equivalent to v_x, which is measured in m/s
  - May also be called angular speed or angular frequency
- Angular Acceleration
  - Rate at which angular velocity changes
  - Represented by lowercase alpha, α
  - Formula
    - $\alpha = \frac{\Delta\omega}{\Delta t}$
  - Rotational equivalent to a_x, which is m/s^2

- Converting Equations
    - $\omega = \omega_0 + \alpha t$
        - Was $v_x = v_{x_0} + at$
    - $\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
        - Was $\Delta x = v_{x_0} t + \frac{1}{2} a t^2$
    - $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$
        - Was $v_x^2 = v_{x_0}^2 + 2a_x\Delta x$
- Velocities
    - Angular speed (ω)
    - Tangential velocity (v_t)
        - Tangent to the circle
        - $v_t = \omega r$
- Accelerations
    - Angular acceleration (α)
    - Tangential acceleration (a_t)
        - Tangent to the circle
        - $a_t = \alpha r$
    - Centripetal acceleration (a_c)
        - $a_c = \frac{v_t^2}{r}$

Concepts of Rotational Motion



Rotational Forces

- Moment of Inertia
  - An object rotating wants to stay rotating and an object not rotating wants to stay not rotating unless acted upon by an unbalanced torque
  - The resistance to change in rotation
    - Stubbornness
  - Depends on…
    - Mass
    - Axis of rotation
  - Greater the radius, greater the moment of inertia
  - Equations
    - NOT IN THE REFERENCE TABLE
    - $I_{collection\ of\ particles} = \Sigma m_i r_i^2$
    - $I_{collection\ of\ particles} = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \ldots$
    - $I = moment\ of\ inertia\ (kg \cdot m^2)$
- Torque
  - A rotational force
  - Depends on…
    - Magnitude of force
    - Distance from pivot
    - Angle of force
  - Equations
    - ON the reference table
    - $\tau = r_{\perp} F = rF sin\theta$
      - $\tau = torque\ (N \cdot m)$
      - $r = distance\ from\ pivot\ (m)$
  - The Set Up

$$\tau_{net} = \tau_{net}$$
$$I\alpha = \Sigma\tau$$
$$I\alpha = \tau_1 + \tau_2 + \tau_3 + \ldots$$

- Center of gravity
  - $\tau_{net} = 0N$ when the pivot point is the center of gravity
  - BALANCED
  - Equations
    - $x_{cg} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \ldots}{m_1 + m_2 + m_3 + \ldots}$
    - $y_{cg} = \frac{y_1 m_1 + y_2 m_2 + y_3 m_3 + \ldots}{m_1 + m_2 + m_3 + \ldots}$

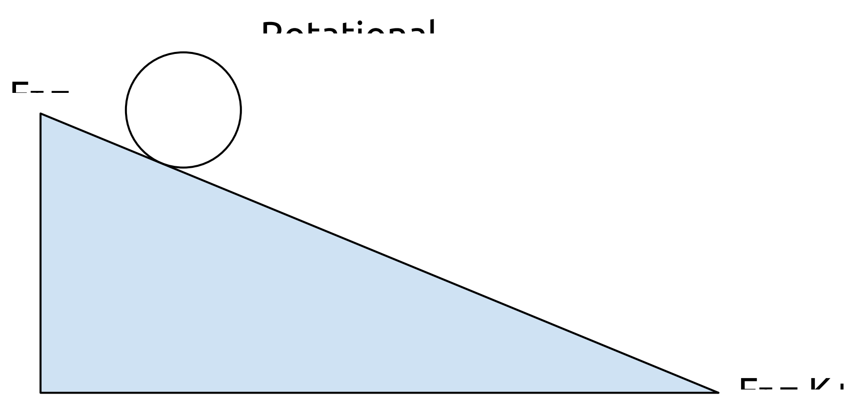
- Constraints due to ropes and pulleys
    - Non Slipping rope
    - $v_{obj} = \omega R$
        - Rim speed
    - $a_{obj} = \alpha R$
        - Rim acceleration

Rotational Momentum

- Angular momentum
    - $L = angular\ momentum\ (kg \cdot m^2/s)$
    - Equations
        - $L = I\omega$
        - $\Delta L = \tau \Delta t$
        - $L_{total\ before} = L_{total\ after}$
- Conservation of angular momentum
    - Relationships
        - When radius decreases, moment of inertia increases
        - When moment of inertia decreases, angular momentum decreases
    - Zero total momentum
- Transfer of angular momentum
    - $L = r_{\perp} p = prsin\theta = mvrsin\theta$
        - Relationship between linear and angular momentum

Rotational Energy

- Rotational kinetic energy
    - $K_{rot} = rotational\ kinetic\ energy\ (J)$
    - Equations
        - $K_{rot} = \frac{1}{2} I\omega^2$
        - $E_T = E_T \rightarrow U_g = K + K_{rot}$



Good luck on your exam!

Get that 5!

You got this!

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS, EFFECTIVE 2015

CONSTANTS AND CONVERSION FACTORS			
Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude,	$e = 1.60 \times 10^{-19}$ C
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg	Coulomb's law constant,	$k = 1/4\pi\varepsilon_0 = 9.0 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$
Speed of light,	$c = 3.00 \times 10^8$ m/s	Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$

UNIT SYMBOLS								
	meter,	m	kelvin,	K	watt,	W	degree Celsius,	°C
	kilogram,	kg	hertz,	Hz	coulomb,	C		
	second,	s	newton,	N	volt,	V		
	ampere,	A	joule,	J	ohm,	Ω		

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES							
θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following conventions are used in this exam.

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. Assume air resistance is negligible unless otherwise stated.
III. In all situations, positive work is defined as work done <u>on</u> a system.
IV. The direction of current is conventional current: the direction in which positive charge would drift.
V. Assume all batteries and meters are ideal unless otherwise stated.

ADVANCED PLACEMENT PHYSICS 1 EQUATIONS, EFFECTIVE 2015

MECHANICS

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$$

$$\left|\vec{F}_f\right| \le \mu\left|\vec{F}_n\right|$$

$$a_c = \frac{v^2}{r}$$

$$\vec{p} = m\vec{v}$$

$$\Delta\vec{p} = \vec{F}\,\Delta t$$

$$K = \frac{1}{2}mv^2$$

$$\Delta E = W = F_{\parallel}d = Fd\cos\theta$$

$$P = \frac{\Delta E}{\Delta t}$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

$$x = A\cos(2\pi ft)$$

$$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$$

$$\tau = r_{\perp}F = rF\sin\theta$$

$$L = I\omega$$

$$\Delta L = \tau\,\Delta t$$

$$K = \frac{1}{2}I\omega^2$$

$$\left|\vec{F}_s\right| = k\left|\vec{x}\right|$$

$$U_s = \frac{1}{2}kx^2$$

$$\rho = \frac{m}{V}$$

a = acceleration
A = amplitude
d = distance
E = energy
f = frequency
F = force
I = rotational inertia
K = kinetic energy
k = spring constant
L = angular momentum
ℓ = length
m = mass
P = power
p = momentum
r = radius or separation
T = period
t = time
U = potential energy
V = volume
v = speed
W = work done on a system
x = position
y = height
α = angular acceleration
μ = coefficient of friction
θ = angle
ρ = density
τ = torque
ω = angular speed

$$\Delta U_g = mg\,\Delta y$$

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

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$\left|\vec{F}_g\right| = G\frac{m_1 m_2}{r^2}$$

$$\vec{g} = \frac{\vec{F}_g}{m}$$

$$U_G = -\frac{Gm_1 m_2}{r}$$

ELECTRICITY

$$\left|\vec{F}_E\right| = k\left|\frac{q_1 q_2}{r^2}\right|$$

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

$$R = \frac{\rho\ell}{A}$$

$$I = \frac{\Delta V}{R}$$

$$P = I\,\Delta V$$

$$R_s = \sum_i R_i$$

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

A = area
F = force
I = current
ℓ = length
P = power
q = charge
R = resistance
r = separation
t = time
V = electric potential
ρ = resistivity

WAVES

$$\lambda = \frac{v}{f}$$

f = frequency
v = speed
λ = wavelength

GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2}bh$

Circle
$A = \pi r^2$
$C = 2\pi r$

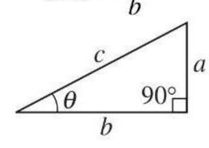
Rectangular solid
$V = \ell wh$

Cylinder
$V = \pi r^2\ell$
$S = 2\pi r\ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius

Right triangle
$c^2 = a^2 + b^2$
$\sin\theta = \frac{a}{c}$
$\cos\theta = \frac{b}{c}$
$\tan\theta = \frac{a}{b}$



Unit 7: Rotation Supplementary Reference Table

$$s = \theta r = \Delta x$$

$$v_t = \omega r$$

$$a_t = \alpha r$$

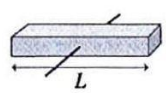
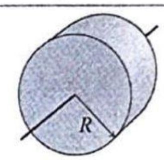
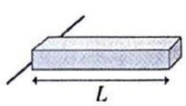
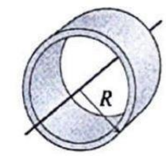
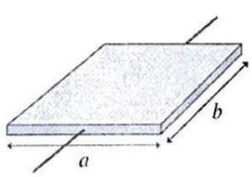
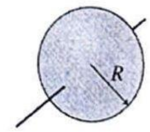
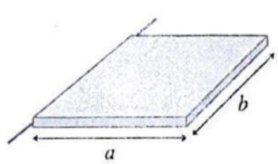
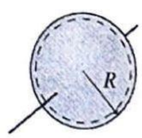
$$I_{collection\ of\ particles} = \sum m_i r_i^2$$

$$x_{cg} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \cdots}{m_1 + m_2 + m_3 + \cdots}$$

$$y_{cg} = \frac{y_1 m_1 + y_2 m_2 + y_3 m_3 + \cdots}{m_1 + m_2 + m_3 + \cdots}$$

$$L = pr \sin\theta = mvr \sin\theta$$

TABLE 7.1 Moments of inertia of objects with uniform density and total mass M

Object and axis	Picture	I	Object and axis	Picture	I
Thin rod (of any cross section), about center		$\frac{1}{12}ML^2$	Cylinder or disk, about center		$\frac{1}{2}MR^2$
Thin rod (of any cross section), about end		$\frac{1}{3}ML^2$	Cylindrical hoop, about center		MR^2
Plane or slab, about center		$\frac{1}{12}Ma^2$	Solid sphere, about diameter		$\frac{2}{5}MR^2$
Plane or slab, about edge		$\frac{1}{3}Ma^2$	Spherical shell, about diameter		$\frac{2}{3}MR^2$