PHYS1205: Integrated Physics

University of Newcastle

1 1D Motion

Vector – A measurement with both magnitude and direction (e.g. Displacement)

Scalar – A measurement with only magnitude (e.g. distance)

Average Velocity

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

Instantaneous Velocity

$$v_{inst} = \frac{dx}{dt}$$

Average Acceleration

$$a_{avg} = \frac{\Delta v}{\Delta t}$$

Instantaneous Acceleration

$$a_{inst} = \frac{dx}{dt}$$

Final Velocity

$$v_{xf} = v_{xi} + a_x t$$

Final Displacement with Avg. Velocity

$$x_f = x_i + \frac{1}{2}(v_{xi} + v_{xf})t$$

Final Displacement with Velocity and Acceleration

$$x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$$

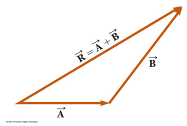
Final Velocity without Time

$$v_{xf}^2 = v_{xi}^2 + 2a_x(x_f - x_i)$$

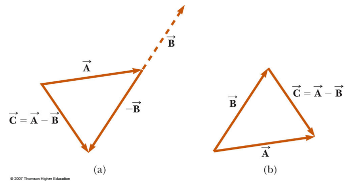
Objects in Freefall – Acceleration is –g (9.8m/s^2)

2 Vectors and 2D Motion

Vector Addition – Tip to Tail



Vector Subtraction – From the negative to the positive, or add the negative ($\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$)



Vector Multiplication/Division by a Scalar – Only magnitude is multiplied or divided. Direction is reversed for negative scalars.

Vector Components

- Length

$$|\vec{A}| = \sqrt{\vec{A}_x^{\,2} + \vec{A}_y^{\,2}}$$

- Direction

$$\theta = \tan^{-1}\frac{\vec{A}_y}{\vec{A}_x}$$

Unit Vectors:

$$\vec{A} = \vec{A}_x\hat{\imath} + \vec{A}_y\hat{\jmath}$$

Projectile Motion

- Position

$$\vec{r_f} = \vec{r_i} + \vec{v_i}t + \frac{1}{2}\vec{g}t^2$$

- Initial Horizontal Velocity

$$\overrightarrow{v_{xi}} = v_i \cos\theta$$

- Initial Vertical Velocity

$$\overrightarrow{v_{yi}} = v_i \sin\theta$$

Uniform Circular Motion

- Centripetal Acceleration

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

- Overall Acceleration

$$|a| = \sqrt{{a_r}^2 + {a_t}^2}$$

- Period

$$T = \frac{2\pi r}{v}$$

Relative Velocity

$$\overrightarrow{r_{PA}} = \overrightarrow{r_{PB}} + \overrightarrow{v_{BA}}t$$

3 Force and Motion

Newton's 1st Law - In the absence of external forces, when viewed from an inertial reference frame, an object at rest will remain at rest and an object in motion continues in motion with a constant velocity

Newton's 2nd Law - Net Force is the product of Mass and Acceleration

$$\Sigma F = ma$$

Newton's 3rd Law - If two objects interact, the force that object one is exerting on object 2 is equal and opposite to that object two is exerting on object one

$$\overrightarrow{F_{12}} = -\overrightarrow{F_{21}}$$

Equilibrium

$$\Sigma F = 0$$

Friction

- Kinetic Friction

$$F = \mu_k N$$

- Static Friction

$$F \leq \mu_s N$$

Circular Motion Dynamics

$$F = ma_r = m\frac{v^2}{r}$$

4 Work, Energy and Power

Scalar/Dot Product

$$\vec{A} \cdot \vec{B} = ABcos\theta$$

Work

- Same Direction as Displacement

$$W = F\Delta r$$

- Different Direction to Displacement

$$W = F\Delta rcos\theta$$

- Work by Varying Force

$$W_{net} = \int_{x_i}^{x_f} \sum F_x \, dx$$

Hooke's Law

$$F_s = -kx$$

Kinetic Energy

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

Work-Kinetic Energy Theorem

$$\Sigma W = \Delta KE$$

Potential Energy

- Gravitational

$$U = mg\Delta y$$

- Elastic

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

Conservative Force - Work done is independent of the path taken by an object (e.g. Gravity)

Non-conservative Force - Work done dependent o the motion of the object (e.g. Friction)

Conservation of Energy

- Mechanical Energy

$$E_{mech} = KE + U$$

- Total Energy

$$E_{tot} = KE + U + E_{int}$$

- Non-Conservative Force Absent

$$\Delta E_{mech} = 0$$

- Non-Conservative Force Present

$$\Delta E_{tot} = 0$$

Power

$$\bar{\varphi} = \frac{dW}{dt}$$

5 Momentum

Momentum

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

Impulse

- Definition

$$I = \Delta p$$

- For Constant Force

$$I = Ft$$

- For Non-Constant Force

$$\vec{I} = \int_{t_i}^{t_f} \vec{F}.dt$$

Collisions

- Conservation of Momentum (All Collisions)

$$p_i = p_f$$

- Conservation of KE (Elastic Collisions)

$$KE_i = KE_f$$

- Perfectly Inelastic

$$m_1\overrightarrow{v_{1i}} + m_2\overrightarrow{v_{2i}} = (m_1 + m_2)\overrightarrow{v_f}$$

- Perfectly Elastic

$$m_1\overrightarrow{v_{1i}} + m_2\overrightarrow{v_{2i}} = m_1\overrightarrow{v_{1f}} + m_2\overrightarrow{v_{2f}}$$

$$\frac{1}{2}m_1\vec{v}_{1i}^2 + \frac{1}{2}m_2\vec{v}_{2i}^2 = \frac{1}{2}m_1\vec{v}_{1f}^2 + \frac{1}{2}m_2\vec{v}_{2f}^2$$

6 Rotation

Arc Length

$$s = r\theta$$

Translational Velocity

$$v = \omega r$$

Translational Acceleration

$$a = \alpha r$$

Average Angular Velocity

$$\omega_{avg} = \frac{\Delta\theta}{\Delta t}$$

Instantaneous Angular Velocity

$$\omega_{inst} = \frac{d\theta}{dt}$$

Instantaneous Angular Acceleration

$$\alpha_{inst} = \frac{d\omega}{dt}$$

Final Angular Velocity

$$\omega_f = \omega_i + \alpha t$$

Final Angular Displacement

$$\theta_f = \theta_i + \omega t + \alpha t^2$$

Final Angular Velocity without Time

$$\omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i)$$

Final Angular Displacement with Avg. Velocity

$$\theta_f = \theta_i + \frac{1}{2}(\omega_i + \omega_f)t$$

Kinetic Energy of Rotation

$$K_r = \frac{\omega^2}{2}\sum m_i r_i^2$$

Moment of Inertia

- General

$$I = \int \rho r^2\, dV$$

- Sphere

$$I = \frac{2}{5}mr^2$$

- Cylinder

$$I = \frac{1}{2}mr^2$$

- Disk

$$I = mr^2$$

Parallel Axis Theorem

$$I = I_{CM} \times MD^2$$

Torque

- Using Radius

$$\tau = rFsin\phi$$

- Using Perpendicular Distance

$$\tau = Fd$$

- Net Torque

$$\Sigma\tau = I\alpha$$

and

$$E_0 = mc^2$$

Angular Momentum

- Angular Momentum

$$L = I\omega$$

- The Conservation of Momentum

$$L_f = L_i$$

7 Waves, Oscillations and SHM

Wave Number

$$k = \frac{2\pi}{\lambda}$$

Wave Equation

$$y(x,t) = Asin(kx - \omega t + \phi)$$

Speed of Wave on a String

$$v = \sqrt{\frac{T}{\mu}}$$

Simple Harmonic Motion

- General Equation

$$x(t) = Acos(\omega t + \phi)$$

- Acceleration

$$a_x = -\omega^2 x$$

- Angular Frequency

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

- Period

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

- Frequency

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

- Energy

$$E_{mech} = \frac{1}{2}kA^2$$

- Velocity

$$v = \pm\omega\sqrt{A^2 - x^2}$$

- SHM and Circular Motion – Uses SHM formulae for each direction of movement
- SHM and the Pendulum
  - Period

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

  - Physical Pendulum

$$T = 2\pi\sqrt{\frac{I}{dmg}}$$

8 Sound and EM Waves

Bulk Modulus

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

Sound Wave Displacement

$$s(x,t) = s_{max}\cos(kx - \omega t)$$

Sound Wave Pressure

- Including Bulk Modulus

$$\Delta P = B s_{max} \sin(kx - \omega t)$$

- Without Bulk Modulus

$$\Delta P_{max} = \rho v \omega s_{max}$$

Density

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

Speed of Sound

- Formula

$$v = \sqrt{\frac{B}{\rho}}$$

- Dependence on Temperature

$$v = 331\sqrt{1 + \frac{T_c}{273}}$$

EM Waves

- Electrical Component

$$E = E_m \sin(kx - \omega t)$$

- Magnetic Component

$$B = B_m \sin(kx - \omega t)$$

Intensity of a Sound Wave

- Per Unit Area

$$I = \frac{(\Delta P_{max})^2}{2\rho v}$$

- In Three Dimensions

$$I \equiv \frac{Power_{avg}}{4\pi r^2}$$

Sound Levels in Decibels

$$\beta = 10 \log\left(\frac{I}{I_0}\right)$$

Doppler Effect

$$f' = \left(\frac{v + v_0}{v - v_s}\right) f$$

Reflection of a Pulse

- When a pulse hits a fixed boundary, reflection is inverted
- When a pulse hits a free boundary, reflection is not inverted
- When a pulse moves from a light to a heavy string the reflected pulse is inverted
- When a pulse moves from a heavy to a light string, the reflection is not inverted

Superposition

$$y = 2A\sin\left(kx - \omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right)$$

Interference

$$\frac{path\ difference}{\lambda} \times 2\pi = phase\ difference$$

Standing Waves on a String

- Formula

$$y = 2A\sin(kx)\cos(\omega t)$$

- Amplitude

$$amp = 2A\sin(kx)$$

- Nodes

$$x = \frac{n\lambda}{2}\ (where\ n = 0, 1, 2 \ldots)$$

- Antinodes

$$x = \frac{n\lambda}{4}\ where\ n = 1, 3, 5 \ldots)$$

Boundary Conditions on a String

$$f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$$

Standing Waves in an Air Column

- Closed Pipe

$$f_n = \frac{nv}{4L}\ (where\ n = 1, 3, 5 \ldots)$$

- Open Pipe

$$f_n = \frac{nv}{2L}\ (where\ n = 1, 2, 3 \ldots)$$

- End Effects

$$L = \frac{n\lambda}{2} - 2 \times end\ effects$$

9 Fluids

Fluids at Rest

- Density

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

- Pressure

$$P = \frac{F}{A}$$

- Pressure in Liquids

$$p = p_0 + pgd$$

- Gauge Pressure

$$p_g = p - 1atm$$

- Barometers

$$p_{atmos} = pgh$$

- Manometers

$$p_{atmos} = 1atm + pgh$$

- Archimedes Principle

$$F_B = p_f V_f g$$

Fluids in Motion

- Equation of Continuity

$$v_1 A_1 = v_2 A_2$$

- Bernoulli's Equation

$$p_2 + \frac{1}{2}pv_2^2 + pgy_2 = p_1 + \frac{1}{2}pv_1^2 + pgy_1$$

10 Ray Optics

Refraction

$$n_1 sin\theta_1 = n_2 sin\theta_2\ (Snell's\ Law)$$

Total Internal Reflection

$$\theta_c = \sin^{-1}\frac{n_1}{n_2}$$

Spherical Mirrors

- Focal Length

$$f = \frac{1}{2}r$$

- Image Distance (thin lens equation)

$$\frac{1}{P} + \frac{1}{i} = \frac{1}{f}$$

Image Formation

- Magnification

$$m = -\frac{i}{p}$$

Thin Lens Equations

- Focal Length

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

- Focal Length (convex lens)

$$\frac{1}{f} = \frac{n-1}{r_1}$$

- Thin Lens Equation in i

$$i = \frac{Pf}{P-f}$$

- Thin lens equation in P

$$P = \frac{if}{i-f}$$

- Magnification in terms of P and f

$$m = \frac{f}{P-f}$$

- Magnification in terms of i and f

$$m = \frac{i-f}{f}$$

Thin Lens Images

Lens	P	Real?	Orientation	m
Convex	<F	No	↑	↑
	= F	N/A	N/A	N/A
	> F	Yes	↓	↑
	= 2F	Yes	↓	-
	> 2F	Yes	↓	↓
Concave	< F	No	↑	↑
	= F	N/A	N/A	N/A
	> F	No	↑	↑
	= 2F	No	↑	-
	> 2F	No	↑	↓

Two Lens System

$$m_{tot} = m_1 m_2$$

Optical Instruments

- Simple Magnifying Lens

$$m_\theta = \frac{25}{f}$$

- Compound Microscope

$$m = -\frac{s}{f_{ob}} \times \frac{25}{f_{ey}}$$

- Refracting Telescope

$$m_{RT} = -\frac{f_{ob}}{f_{ey}}$$

11 Wave Optics

Path Difference

- Constructive

$$\Delta r = m\lambda \; (where\; m = 1, 2, 3 \dots)$$

- Destructive

$$\Delta r = \left(m + \frac{1}{2}\right)\lambda \; (where\; m = 1, 2, 3 \dots)$$

Interference of Light in Double Slit

- Angles for Bright Fringes

$$\theta_m = \frac{m\lambda}{d}$$

- Distances of Bright Fringes

$$y_m = \frac{Lm\lambda}{d}$$

- Angles for Dark Fringes

$$\theta'_m = \frac{\left(m + \frac{1}{2}\right)\lambda}{d}$$

- Distances of Dark Fringes

$$y'_m = \frac{\left(m + \frac{1}{2}\right)L\lambda}{d}$$

- Distances Between Fringes

$$\Delta y = \frac{\lambda L}{d}$$

Interference of Light in Single Slit

- Angles for Dark Fringes

$$\theta_p = \frac{p\lambda}{a}$$

- Distances for Dark Fringes

$$y_p = \frac{p\lambda L}{a}$$

- Width of Central Maximum

$$w = \frac{2\lambda L}{a}$$

Circular Aperture Diffraction

$$w = \frac{2.44\lambda L}{D}$$

Interferometer

$$d = \frac{N\lambda}{2}$$

12 Charge

Coulomb's Law

$$F = \frac{Kq_1q_2}{r^2}$$

Electrical Field

- Vector Equation

$$\vec{E} = \frac{\vec{F}}{q}$$

- Electrical Field of a Point Charge

$$\vec{E} = \frac{Kq}{r^2}$$

Electrical Potential

$$U_{elec} = Vq$$

13 Electrical Circuits

Current

- Definition

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

- Conservation of Charge

$$\Sigma I_{in} = \Sigma I_{out}$$

Ohm's Law

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

Power and Energy

- Power delivered by an emf

$$P_{emf} = IE$$

- Power Dissipated by a Resistor

$$P_R = \frac{(\Delta V_r)^2}{R}$$

14 Units and Constants

Particle Kinematics in One Dimension

- g = 9.8m/s^2

Particle Dynamics

- N = kg.m/s^2

Work and Energy

- J = Nm = kg.m^2/s
- W = J/s
- 1Hp = 746W

Fluids

- Pa = N/m^2

Charge

- e$^-$ = -1.60 × 10^{-19} C
- K = 8.99 × 10^9 Nm^2/C^2
- V = J/C

Electrical Circuits

- A = C/s
- Ω = V/A