1 MOTION AND FORCES

1. Displacement vs Distance

a. Displacement

$$\Delta x = x_f - x_i$$

- Change in position of an object
- Can be positive or negative
- Δx: Displacement [$\pm$m]
- x_f: Final Position [m]
- x_i: Initial Position [m]

b. Distance

$$\text{Distance} \geq \text{Displacement}$$

- The *magnitude* or size of displacement between two positions
- Distance travelled: the *total length* of the path traveled between two positions

2. Scalar VS Vector
3. Time, Velocity, Speed and Acceleration
4. Graphs: Distance-Time, Speed-Time and Acceleration-Time
5. Kinematic Equations (Constant Acceleration)
6. Falling Objects
7. Vectors
8. Projectile Motion

a. Equations of Projectile Motion

b. Horizontal Motion ($x$direction)

$$a$$

$$(v_y)_f = (v_y)_i - g\Delta t$$

$$y_f - y_i + (v_y)_i \Delta t - \frac{1}{2} g(\Delta t)^2$$

-

c. Vertical Motion ($y$direction)

$$a_y =- g$$

$$(v_y)_f = (v_y)_i - g\Delta t$$

$$y_f - y_i + (v_y)_i \Delta t - \frac{1}{2} g(\Delta t)^2$$

- Change in position of an object
- Can be positive or negative
- Δx: Displacement [m]
- x_f: Final Position [m]
- x_i: Initial Position [m]

2 CIRCULAR MOTIONS, ENERGY AND OSCILLATIONS

1. Reflection

c. Law of Reflection

$$\theta_i = \theta_r$$

- θ_i: Angle of reflection
- θ_r: Angle of incidence

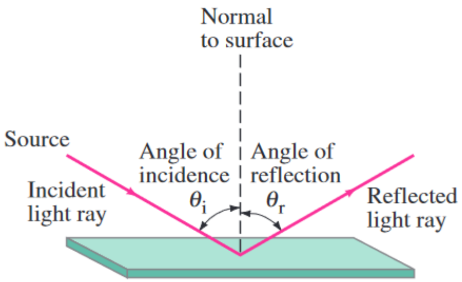
3 WAVES AND OPTICS

1. Reflection

d. Law of Reflection

$$\theta_i = \theta_r$$

- θ_i: Angle of reflection
- θ_r: Angle of incidence



e.

2. Mirrors

a. Objects appear *behind* the mirror

3. Refraction

a. Velocity of light depends on material, just like sound

$$v = \frac{c}{n}$$

- v: Observed Speed of Light $[m/s]$
- c: Speed of Light in Vacuum $[m/s]$
  - $c = 3.00 \times 10^8 m/s$
- n: Index of Refraction
  - $n > 1$ so $v < c$

b. Frequency depends on source - does not change; wavelength must

$$\lambda = \frac{\lambda_0}{n}$$

Proof: $v = \frac{c}{n}$, $v = f\lambda$

$\lambda = \frac{v}{f} = \frac{c}{nf} = \frac{\lambda_0}{n}$

- λ: Frequency $[Hz]$
- λ_0:
- n: Index of Refraction
  - $n > 1$

c.

$$\frac{\lambda_i}{\lambda_t} = \frac{n_t}{n_i}$$

- λ_i: Frequency
- λ_0:
- n: Index of Refraction

d. Reduced velocity of wavefront passing across boundary

4. Snell's Law/Law of Refraction

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

- n_1: Index of Refraction for Medium 1
- n_2: Index of Refraction for Medium 2
- n_1: Angle between Ray and Surface Normal of Medium 1
- n_2: Angle between Ray and Surface Normal of Medium 2

a. Ray changes direction (refracts) because leading wavefront slows

b. Wavelength decreases because frequency unchanged and speed reduced

c. Beam in the glass is wider, hence intensity is less inside

5. Total Internal Reflection

a. Critical Angle

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

- θ_c: Critical Angle $[°/rad.]$
- P_0: Present Value // Principal Value

b.

6. Image Formation

a. A lens converts the direction of rays to a common position (focal point)

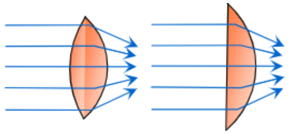
$$y = - f\theta$$

- y: Critical Angle $[°/rad.]$

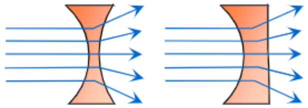
- f: Present Value // Principal Value
- θ:

b. Thin lenses

i. Convex - converging - positive: thicker at the middle



ii. Concave - diverging - negative: thinner at the middle



c. Thin Lens Formula

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

- d_o: Critical Angle [$°/rad.$]
- d_i: Critical Angle [$°/rad.$]
- f: Present Value // Principal Value

Variable	Positive (+) when...	Negative (−) when...
d_o	Left of lens	Right of lens
d_i	Right of lens	Left of lens
$y,\ y'$	Above optical axis	Below optical axis
f	Converging	Diverging

7. Human Eye

a. Lens Power

$$P = \frac{1}{f}$$
$$P = P_1 + P_2$$

- P: Lens Power [diopters, dpt/D]
- f: $[m]$

b. Colour Vision: Rods and Cones

i. Rods: detect light and dark

ii. Cones: colour sensitive (red, green, blue) but less sensitive than Rods

c. Accommodation

i. Ciliary Muscle: changes radius of curvature

ii. Relaxed: focus to infinity

iii. Contract: focus nearer

d. Vision Defects

i. Myopia: Near-sighted; lens too strong - needs diverging lens

ii. Hyperopia: Far-sighted; lens too weak - needs converging lens

4 ELECTRICITY AND MAGNETISM

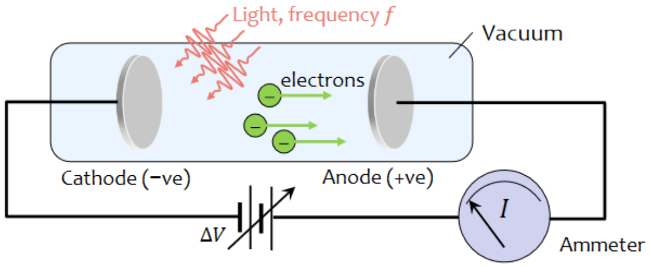
1. Photons and Photoelectric Effect

5 ATOMIC PHYSICS, RADIATION AND POWER

1. Photons and Photoelectric Effect

- Light(photons) knocks electrons out of metal plates if it meets the minimum threshold energy/frequency required (this minimum energy is given by the Work Function, W_0)
  - After reach minimum threshold, if ↑intensity, ↑number of electrons knocked out
- Current is proportional to intensity
- Current appears immediately
- Current only if frequency is above some minimum threshold
- Threshold frequency depends on cathode metal

- Current stopped by applying some minimum stopping potential (Vstrop)
- Stopping potential depends on frequency



a. Photon Energy

$$E = hf = h\frac{c}{\lambda}$$

b. Kinetic Energy of Ejected Electron

$$KE = E - W_0$$
$$KE = hf - W_0$$

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

c. Least tightly held Electron Energy

- Least tightly held electrons will be ejected with the most kinetic energy (KE_{max})

$$KE_{max} = E - W_0$$

d. Stopping potential/stopping voltage

$$eV_{stop} = hf - W_0[\text{eV}]$$
$$V_{stop} = \frac{hf}{e} - V_0[\text{V}]$$

Conservation of Energy (Gain in PE=Loss of KE)

$$eV_{stop} = KE_{max}$$
$$eV_{stop} = E - W_0$$
$$\therefore eV_{stop} = hf - W_0$$

- E: Photon energy [J]
- h: Planck's constant
  - $h = 6.63 \times 10^{-34}$[Js]
  - $h = 4.14 \times 10^{-15}$[eVs]
- f: Frequency [Hz]
  - $f = \frac{c}{\lambda}$
- KE: Kinetic Energy of Ejected Electron [J]
- h: Planck's constant = 6.63×10^{-34}[Js]
- f: Frequency [Hz]
- V_{stop}: stopping potential/stopping Voltage [V]
  - Voltage when the current in the circuit is 0
- h: Planck's constant = 6.63×10^{-34}[Js]
- f: Frequency [Hz]
  - $f = \frac{c}{\lambda}$
- W_0: Work function/Binding Energy [eV]
  - $W_0 = hf_0$
- V_0: Work function/Binding Energy as Voltage [V]
- f_0: Threshold frequency
  - Minimum energy required to free an electron
- eV : Electron Volts
  - $1eV = 1.6 \times 10^{-19}$[J]

2. Magnetic Resonance Imaging

a. Magnetic Dipole Moment

$$\vec{\mu} = I\vec{A}$$

b. Potential Energy of Magnetic Dipole

$$U = -\vec{\mu} \times \vec{B}$$

c. Energy Difference

$$\Delta U = 2\mu B$$
$$f = \frac{E}{h} = \frac{\Delta U}{h}$$

- $\vec{\mu}$: Magnetic Dipole Moment [J/T]
- $\vec{A}$: Area in the ‘current(I) circle’[m^2]
  - Vector because current moves in specific direction
- I: current in the loop
- B: [T]
- U: Potential Energy [J]

3. Matter Waves

a. De Broglie wavelength of a particle

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

b.

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

- $\vec{\mu}$: Magnetic Dipole Moment [J/T]
- $\vec{A}$: Area in the ‘current(I) circle’[m^2]
  - Vector because current moves in specific direction
- I: current in the loop
- B: [T]

c. Standing Waves

d.

4. Quantized Energy

a.

b. Energy levels

- When particle confined to specific regions of space
  - They bounce back and forth between the walls/boundaries of the confined space
  - This creates a standing wave
  - The wavelength of the standing wave is λ_n
- Quantum systems (like the one described) can only exist at specific energy levels (n)
  - Can make transitions between energy levels by *absorbing* or *emitting* photons
  - Ground state: $n = 1$
  - ALWAYS INTEGERS

c.

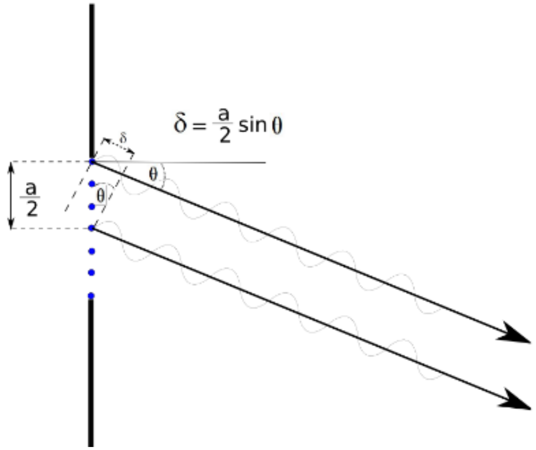
5. Photons, Huygens Principle, Diffraction

a. Huygens’ Principle

- The new position of the wavefront is a surface tangent to the wavelets

b. Single-slit diffraction

$$a \sin \theta = \lambda$$



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6. Heisenberg Uncertainty

a. Huygens’ Principle

$$\Delta x \Delta p_x \geq \frac{h}{2\pi}$$

-

b.

c.

$$\frac{1}{\lambda} = R(\frac{1}{n'^2} - \frac{1}{n^2})$$

- θ_i: Angle of reflection
- θ_r: Angle of incidence

d.

$$\frac{1}{\lambda} = \frac{hf}{hc} = \frac{1}{hc}(E_n - E_{n'})$$

- θ_i: Angle of reflection
-

$$hf = E_u - E_1$$

- θ_i: Angle of reflection
-

$$PE =- eV = k\frac{Ze^2}{r}$$

- θ_i: Angle of reflection
-

$$E_n =- 13.6eV\frac{Z^2}{n^2}$$

- θ_i: Angle of reflection
-

$$L = mvr_n = n\frac{h}{2\pi}$$

- θ_i: Angle of reflection
-

$$E = mc^2$$

- θ_i: Angle of reflection
-

$$n \rightarrow p + e^- + neutrino$$

- θ_i: Angle of reflection
-

$$\Delta N =- \lambda N \Delta t$$

- θ_i: Angle of reflection
-

$$\Delta E = kB_T$$

- θ_i: Angle of reflection
-

$$A' = nAl\sigma$$

- θ_i: Angle of reflection
-

$$R = R_0\frac{A'}{A}$$

- θ_i: Angle of reflection

7. Photons and Photoelectric Effect

- Light(photons) knocks electrons out of metal plates if it meets the minimum threshold energy/fre

Question 7 **14 marks**

(a) Lulu is a recent PHYC10009 graduate, and now trying to invent a type of anti-gravity using her knowledge of electrostatics. She wants to lift herself from the ground by charging herself and an "anti-gravity device" on the ground, with the same charge, such that the electrostatic repulsion will exactly cancel her weight. She models the system assuming that she and the "anti-gravity device" are both point charges, separated by a distance of 1.0 cm. Her weight is 60 kg; $g = 9.8\ \mathrm{m/s^2}$.

(i) Calculate the magnitude of the required charge on each assuming the two charges are equal.

(ii) Calculate the electric potential at the midpoint between the two charges.

(b) Lulu remembers that the force on a moving charge in a magnetic field, $F = qvB\sin\theta$. She thinks that if she is charged with, say, $q = +1.0$ C, if she runs at some velocity through a region of magnetic field B, she can generate an anti-gravity force.

(i) Calculate the speed at which she must move such that the force is enough to counteract her weight of 60 kg, if the magnetic field strength is $B = 1.0\ \mathrm{T}$.

(ii) Lulu wants to create the magnetic field with a current-carrying wire, remembering that $B_{\text{wire}} = \frac{\mu_0 I}{2\pi r}$. Calculate the current needed to generate a 1.0 T field at 1.0 cm from the wire.

(iii) Draw a diagram showing the direction of current in the wire, the magnetic field, and her motion, such that there is an upward force against gravity.

(3 + 3) + (3 + 2 + 3) = 14 marks

i) $\pm\ 2.57 \times 10^{6} C$