Session 14: Ray Optics – Refraction at plane surfaces

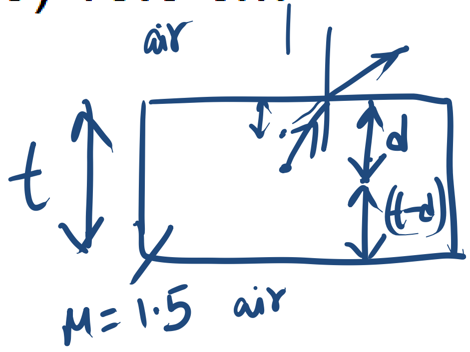
- Sunday Test Discussion
- Magnification & Refraction Mnemonics
- Concepts review (Ref index, App depth, normal shift, TIR, Dispersion, 3 conditions in Prism)
- Examples (prism)
- Dispersive power of a prism
- Combination of prisms (angular dispersion & mean deviation)
- Examples (dispersion)

- Reflection at curved surfaces

Q 1). A bubble in glass slab ($\mu=1.5$) when viewed from one side appears at 5 cm and 2 cm from the other side, then thickness of slab is :-

(1) 3.75 cm (2) 3 cm

(3) 10.5 cm (4) 2.5 cm



$$\frac{d}{\mu} = 5$$

$$\frac{(t-d)}{\mu} = 2$$

$d = 5\mu$

$(t-d) = 2\mu$

$t = 5\mu + 2\mu$

$= 7\mu = 7 \times 3/2 = 10.5$

Q 2). A ray of light travelling in air haves wavelength λ, frequency n, velocity v and intensity I. If this ray enters into water than these parameter are λ', n', v' and I' respectively. Which relation is correct from following -

(1) $\lambda = \lambda'$

(2) n = n'

(3) v = v'

(4) $I = I'$

Q 3). Light travels through a glass plane of thickness t and having refractive index n. If c is the velocity of light in vacuum, then the time taken by light to travel this thickness of glass is.

(1) $\frac{t}{nc}$ (2) tnc

(3) $\frac{nt}{c}$ ✓ (4) $\frac{tc}{n}$

$v_g = c/n$ time $= t/v_g = \frac{tn}{c}$

Q 4). A ray of light propagates from glass (refractive index = 3/2) to water (refractive index = 4/3). The value of the critical angle.

(1) $\sin^{-1}(1/2)$ (2) $\sin^{-1}\left(\frac{\sqrt{8}}{9}\right)$

(3) $\sin^{-1}(8/9)$ ✓ (4) $\sin^{-1}(5/7)$

$r = 4/3 = 1.33$

$d = 3/2 = 1.5$

$\sin\theta_c = 1/\mu$ $(\mu > 1)$

$(\mu = \mu_d/\mu_r)$

$= \frac{2 \times 4}{3 \times 3} = 8/9$ $\theta_c = \sin^{-1}(8/9)$.

Q 5). Critical angle of light passing from glass to air is minimum for.

(1) Red (2) Green

(3) Yellow (4) Violet

$\sin\theta_c = 1/\mu$

$\theta_c \to$ min

$\mu \to$ max

$\mu(\lambda) = a + b/\lambda^2$

$\lambda \to$ min.

↳ Violet

$\lambda \uparrow$

γ X UV VIBGYOR IR MW RW

λ_{min} λ_{max}

$f\uparrow$ $E\uparrow$.

Q 6). The angle of a glass prism is 4.5^0 and its refractive index is 1.52. The angle of minumum deviation will be -

(1) 1.5^0

(2) 2.3^0 ✓

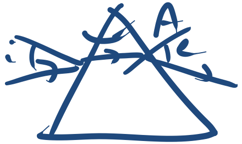
(3) 4.5^0

(4) 2^0

$\delta = i + e - A$

$\delta_{min} \rightarrow i = e$.

$A \rightarrow$ small



$\delta_{min} = (\mu - 1)A = (1.52 - 1) \times 4.5^0$

$= 2.3^0$.

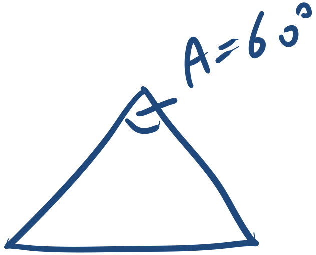
Q 7). A ray of light passes through equilateral prism (μ=1.5) such that angle of incidence is equal to angle of emergence and the later equal to 3/4 of prism angle. The angle of deviation is.

(1) 60^0

(2) 30^0 ✓

(3) 45^0

(4) 120^0



$i = e = \frac{3}{4}A$

$= \frac{3}{4} \times 60^\circ$

$= 45^\circ$

$\delta = i + e - A = 45^\circ + 45^\circ - 60^\circ$

$= 30^\circ$.

Q 8). Angle of incidence 2A on the first surface returns back through the same path after suffering reflection at second silvered surface. Refractive index of the material of prism is.

(1) 2 sin A

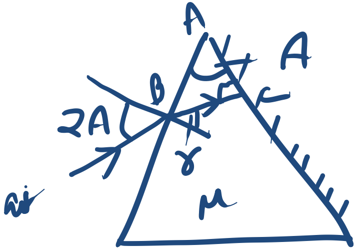
$A + 90° + (90 - r) = 180$

$(r = A)$

(2) 2 cos A

(3) 1/2 cosA

(4) tanA



$(\mu = 2\cos A)$

$1 \times \sin 2A = \mu \sin r = \mu \sin A$

$2\sin A \cos A = \mu \sin A$

Q 9). Three prism 1,2 and 3 have the prism angle A = 60^0, but their refractive indices are respectively 1.4, 1.5 and 1.6. If δ_1, δ_2, and δ_3, be their respectively angles of deviation then -

(1) $\delta_3 > \delta_2 > \delta_1$ ✓

(2) $\delta_1 > \delta_2 > \delta_3$

(3) $\delta_1 = \delta_2 = \delta_3$

(4) $\delta_2 > \delta_1 > \delta_3$

$\delta = (\mu - 1)A$ ✗

→ δ_{min} & $A \to$ small

$\delta = i + e - A$

$i = e$

$\Rightarrow \delta_m = 2i - A$

$i = (\delta_m + A)/2$

$\mu = \dfrac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin A/2}$

$\sin\left(\frac{\delta_{min}+A}{2}\right) = \mu \sin A/2$

$\left(\frac{\delta_{min}+A}{2}\right) = \sin^{-1}(\mu \sin A/2)$

$\delta_{min} = 2\sin^{-1}(\mu \sin A/2) - A$

$(\sin A/2 = \sin 30° = \frac{1}{2})$

$= 2\sin^{-1}(\mu/2) - A$

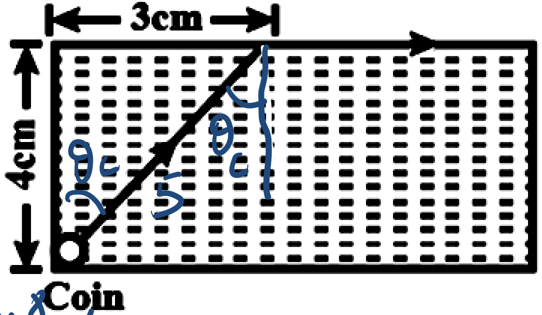
$\delta_1 = 2\sin^{-1}(0.7) - A$

$\delta_2 = 2\sin^{-1}(0.75) - A$

$\delta_3 = 2\sin^{-1}(0.8) - A$

$\delta_3 > \delta_2 > \delta_1$

Q 10). A small coin is resting on the bottom of a beaker filled with a liquid. A ray of light from the coin travels up to the surface of the liquid and moves along its surface (see figure).



$\sin\theta_c = 3/5 = 1/\mu$

$\mu = 5/3$

$v = c/\mu = \frac{3\times10^8\times3}{5} = \frac{9}{5}\times10^8 = 1.8\times10^8$ m/s.

How fast is the light traveling in the liquid ?

(1) 1.2×10^8 m/s

(2) 1.8×10^8 m/s

(3) 2.4×10^8 m/s

(4) 3.0×10^8 m/s

1	2	3	4	5	6	7	8	9	10
3	2	3	3	4	2	2	2	1	2

Recap – (Reflection @ plane surfaces) – MicroNote

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Plane Mirror

① → $i = r$

② → $\delta = \pi - 2i$

↳ $(2\pi - 2\theta)$

③ → $l = H/2$

④ → $m = \frac{360^\circ}{\theta}$

obj position → symm / odd } no of images
- → $m-1$
- → m (if there are two odds)
- → closest even int to m (if $m \to$ fraction)

⑤ → magnification, $m = -\frac{v}{u} = \frac{h_I}{h_O}$

↳ $= 1$ (for plane mirror)

⑥ → $v_i = 2v_m - v_o$

⑦ → $\theta_i \to \theta_r = -\theta_i$

$\theta_m \to \theta_r = 2\theta_m$

Refraction @ plane surfaces – MicroNote-2

① → $\dfrac{\sin i}{\sin r} = \dfrac{v_1}{v_2} = \dfrac{\mu_2}{\mu_1} = {}_1\mu_2 = \dfrac{{}_1\mu_2}{1}$

② → Lateral shift $= \dfrac{t}{\cos r}\sin(i-r)$

③ → Normal shift $= t_1\left(1-\dfrac{1}{\mu_{1rel}}\right)+t_2\left(1-\dfrac{1}{\mu_{2rel}}\right)+\dots$

$\mu_{rel}\,d$ ⟵ (single ref) ⟶ d/μ_{rel} $(\mu_{rel}>1)$

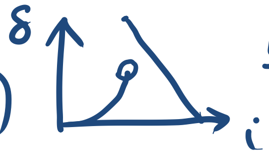
④ → App depth $= \dfrac{t_1}{\mu_{1rel}}+\dfrac{t_2}{\mu_{2rel}}+\dots$

$\mu_{1rel} = \dfrac{\mu_1}{\mu_{obs}}$

⑤ → TIR, $\sin\theta_c = 1/\mu_{rel}$ $(\mu_{rel} = \mu_D/\mu_R)$

$r = d\tan\theta_c$

$\delta = |i-r|$ to $(\pi-2i)$



⑥ → Prism → $\delta = i+e-A$

$r_1+r_2 = A$

→ 3 Conditions → ① δ_{min} $(i=e)$

$\mu = \dfrac{\sin\left(\dfrac{A+\delta_{min}}{2}\right)}{\sin(A/2)}$

A → small

$\delta_{min} = (\mu-1)A$

Mirage, h↑ μ↑ (inverted)

Looming, h↑ μ↓ (erect)

⑥ → Prism

↳ ② δ_{max} ($e = 90°$, TIR @ second surface, $i < i_g$)

↓

$$\sin i_g = \sqrt{\mu^2 - 1}\,\sin A - \cos A$$

③ No Emergence condⁿ (Set $i_g = 90°$)

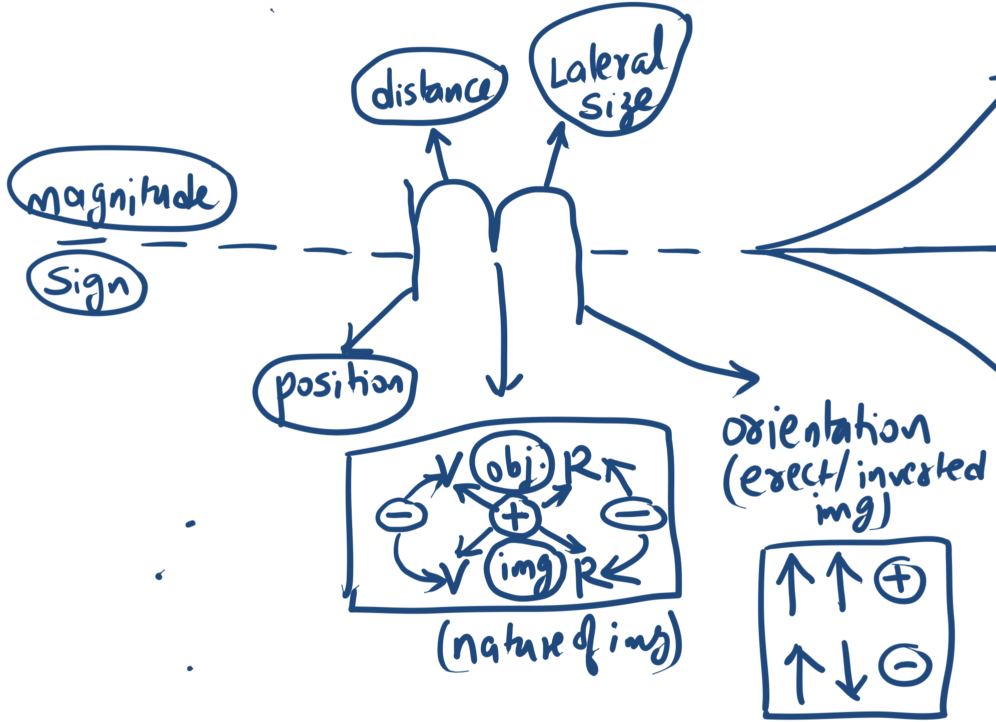
$\boxed{\mu > \frac{1}{\sin(A/2)}}$ $\boxed{A > 2\theta_c}$ $\boxed{r_2 > \theta_c}$

⑦ → Dispersion

↳ ① $\mu(\lambda) = a + b/\lambda^2 \rightarrow \lambda_{med} = \frac{\lambda}{\mu(\lambda)}$

$\left(\frac{d\mu(\lambda)}{d\lambda} < 0\right) \rightarrow$ Normal $\quad v_\lambda = \frac{c}{\mu(\lambda)}$

Magnification - Mnemonic



$\left(-\frac{v}{u}\right)$ (Reflection)

$\left(\frac{v/\mu_2}{u/\mu_1}\right)$ (Refraction)

$\left(\frac{v}{u}\right)$ (lenses)

$= \frac{h_I}{h_O}$ (m) Transverse or linear or lateral magnificatn

Refraction - Mnemonic

R → D
D → R
(NORMAL)

Axial/Longitudinal magnification $= \dfrac{|L_{img}|}{|L_{obj}|} = m^2$

→ $-\dfrac{dv}{du}$ (mirrors)

→ $\dfrac{dv}{du}$ (lenses)

Superficial magnification $= \dfrac{|A_{img}|}{|A_{obj}|} = m^2$ (both mirror & lenses)

$\left(\dfrac{dv}{dt}\right)_M = -m^2\left(\dfrac{du}{dt}\right)_M$ (for mirror)

$m_T = m_1 \times m_2 \times m_3 \cdots$

$\left(\dfrac{dv}{dt}\right)_L = m^2\left(\dfrac{du}{dt}\right)_L$ (for lenses)

Concept Review (Refraction)

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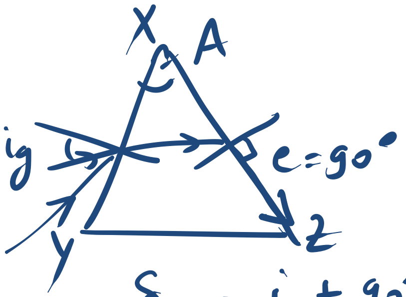
No emergence condⁿ (for any i)

(Set $i_g = 90°$)

~~$\sin i_g$~~ 9 ($i_g \geq 90°$) → (Mnemonic)

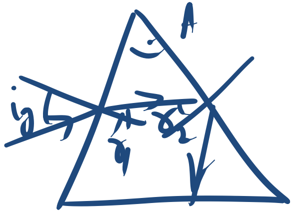


$\delta_{max} = i_g + 90° - A$

$\sin i_g = \sqrt{\mu^2 - 1}\sin A - \cos A$

$\sqrt{\mu^2 - 1}\sin A - \cos A = \sin i_g = \sin 90° = 1$

$$\boxed{\mu = \frac{1}{\sin A/2}}$$



$$\boxed{\mu \geq \frac{1}{\sin A/2}}$$

$r_2 \geq \theta_c$

$i_g = 90°$

$1 \times \sin i_g = \mu \sin r_1$

$\sin 90° = \mu \sin r_1$

$\Rightarrow 1 \quad \sin r_1 = 1/\mu$

$\Rightarrow r_1 = \theta_c$

$r_1 + r_2 = A$

$\theta_c + r_2 = A$

$A = \theta_c + r_2$

$\boxed{A \geq 2\theta_c}$ $\quad$ $\boxed{r_2 \geq \theta_c}$

$r_2 \geq \sin^{-1} 1/\mu$

$A \geq 2\sin^{-1} 1/\mu$