SOLVED EXAMPLES

Ex.1 The apparent depth of a swimming pool is 1.2 m . What is its real depth ?

Sol. Swimming pool means $\mu_{water} = 4/3$. So that the real depth

$$R = a \mu$$
$$= 1.2 \times \frac{4}{3}$$
$$= 1.6 \text{ m}$$

Ex.2 A glass plate 4 mm thick is viewed from the above through a microscope. The microscope must be lowered 2.58 mm as the operator shifts from viewing the top surface to viewing the bottom surface through the glass. What is the index of refraction of the glass ?

Sol. From the information given, it is clear that the apparent depth is 2.58 mm and the real depth is 4mm. Therefore, the refractive index will be

$$\mu = \frac{R}{a} = \frac{4}{2.58}$$
$$= 1.55$$

Ex.3 A vertical microscope is focussed on a point at the bottom of an empty tank. Water ($\mu = 4/3$) is then poured into the tank. The height of the water column is 4cm. Another lighter liquid, which does not mix with water and which has refractive index 3/2 is then poured over the water.The height of liquid column is 2cm. What is the vertical distance through which the microscope must be moved to bring the object in focus again ?

Sol. The apparent shift of the bottom point upwards will be
$$x = x_1 + x_2$$

$$= t_1 \left(1 - \frac{1}{\mu_1} \right) + t_2 \left(1 - \frac{1}{\mu_2} \right)$$

$$= 4 \left(1 - \frac{1}{(4/3)} \right) + 2 \left(1 - \frac{1}{(3/2)} \right)$$

$$= 4 \left(1 - \frac{3}{4} \right) + 2 \left(1 - \frac{2}{3} \right)$$

$$= 1.67 \text{ cm.}$$

Ex.4 Light from a sodium ($\lambda_0 = 589$ nm) passes through a tank of glycerin (refractive index 1.47) 20m long in a time t_1. If it takes a time t_2 to traverse the same tank when filled with carbon disulphide (index 1.63), then the difference $t_2 - t_1$ is

(A) 6.67×10^{-8} sec   (B) 1.09×10^{-7} sec

(C) 2.07×10^{-7} sec   (D) 1.07×10^{-7} sec

Sol. Since $v = \dfrac{C}{n}$

The time taken are

$$t_2 = \frac{20(1.63)}{C}$$

$$t_1 = \frac{20(1.47)}{C}$$

Therefore , the difference is

$$t_2 - t_1 = \frac{20(1.63 - 1.47)}{C}$$

$$= \frac{20 \times 0.16}{3 \times 10^8}$$

$$= 1.07 \times 10^{-7} \text{ sec.}$$

Hence the correct answer is (D).

Ex.5 A ray of light falls on a transparent glass slab of refractive index μ. If the reflected ray and refracted ray are mutually perpendicular, then the angle of incidence is
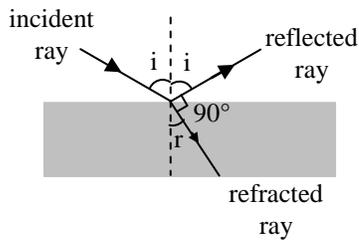
(A) $\sin^{-1}(\mu)$ (B) $\sin^{-1}(1/\mu)$

(C) $\tan^{-1}(1/\mu)$ (D) $\tan^{-1}(\mu)$

Sol. When the reflected ray and refracted ray are mutually perpendicular , then
$$i + r + 90° = 180°$$
or $\quad r = 90° - i$

incident ray ― reflected ray

i | i

90°

r

refracted ray

Therefore

$$m = \frac{\sin i}{\sin r} = \frac{\sin i}{\sin(90° - i)}$$

$$\frac{\sin i}{\cos i} = \tan i$$

Thus the angle of incidence is

$i = \tan^{-1} \mu$

The correct answer is (D).

Ex.6 Light is incident on the side of a $30° - 60° - 90°$ prism, as shown in the figure. A thin layer of a liquid is spread over the hypotenuse of the prism. If the index of refraction of the prism is 1.5, find the maximum refractive index of the liquid in order that a ray passing normally through the $60°$– base may be totally reflected.

Sol. The angle of incidence of the hypotenuse is $60°$

60°

60°
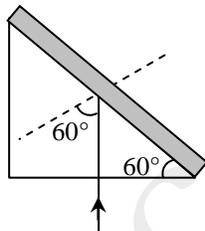
The ray is totally reflected if $60° \geq \theta_C$ where θ_C is the critical angle for the glass- liquid interface. or $\sin 60° \geq \sin \theta_C$

It is known that
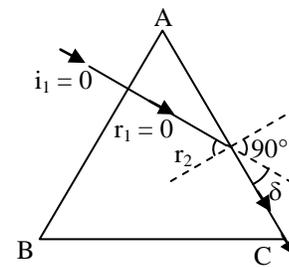
$1.5 \sin \theta_C = \mu \sin 90°$

Where μ is the refractive index of the liquid

or $\quad \sin \theta_C = \dfrac{\mu}{1.5}$

$\therefore \quad$ the ray is totally reflected if $\dfrac{\sqrt{3}}{2} \geq \dfrac{\mu}{1.5}$

or $\quad \mu \leq 1.299$

Ex.7 A ray of light fall normally on a refracting face of a prism of refractive index 1.5. Find the angle of the prism if the ray just fails to emerge from the prism.

Sol. At first face of the prism as $i_1 = 0$,

$\sin 0 = 1.5 \sin r_1$ i.e., $r_1 = 0$

And as for a prism

$r_1 + r_2 = A \qquad$ so $r_2 = A \qquad$ ......(1)

But at second face, as the ray just fails to emerge

i.e., $\quad r_2 = \theta_C \qquad \qquad$ ......(2)

So from Eqn,.(1) and (2)

$\qquad A = r_2 = \theta_C$

But as $\theta \sin^{-1}\left[\dfrac{1}{\mu}\right] = \sin^{-1}\left[\dfrac{2}{3}\right] = 42°$

So $\quad A = 42°$

Ex.8 The refractive indices of material of a prism for blue and red colours are 1.532 and 1.514 respectively. Calculate angular dispersion produced by the prism if angle of prism is $8°$.

Sol. Here, $\mu_b = 1.532$

and $\mu_r = 1.514 \quad A = 8°$

Angular dispersion

$\qquad = (\mu_b - \mu_r) A$

$\qquad = (1.532 - 1.514) \times 8$

$\qquad = 0.018 \times 8 = 0.144°$

Ex.9 Determine the angle of flint glass prism, which should be combined with a crown glass

prism of 5° so as to give dispersion but no deviation.

Given, for crown glass :

$\mu_v = 1.523$, $\mu_r = 1.515$;

for flint glass : $\mu_v' = 1.688$, $\mu_r' = 1.650$.

Sol. Crown glass

$\mu_v = 1.523$; $\mu_r = 1.515$; $A = 5°$

Flint glass

$\mu_v' = 1.688$; $\mu_r' = 1.650$; $A' = ?$

So that the combination of the two prisms does not produce any deviation,

$$A' = -\frac{A(\mu - 1)}{\mu' - 1}$$

Now, $\mu = \frac{\mu_v' + \mu_r}{2} = \frac{1.523 + 1.515}{2} = 1.519$

and $\mu' = \frac{\mu_v' + \mu_r'}{2} = \frac{1.688 + 1.650}{2} = 1.669$

∴ $A' = -\frac{5(1.519 - 1)}{1.669 - 1} = -\frac{5 \times 0.519}{0.669}$

$= -3.88°$

Ex.10 The dispersive powers of crown and flint glasses are 0.03 and 0.05 respectively. The refractive indices for yellow light for these glasses are 1.517 and 1.621 respectively . It is desired to form an achromatic combination of prisms of crown and flint glasses which can produce a deviation of 1° in the yellow ray. Find the refracting angles of the two prisms needed.

Sol. Suppose, the angle of the crown prism needed is A and that of the flint prism is A'.

We have

$$\omega = \frac{\mu_v - \mu_r}{\mu - 1}$$

or, $\mu_v - \mu_r = (\mu - 1)\, \omega$

The angular dispersion produced by the crown prism is

$(\mu_v - \mu_r)\, A = (\mu - 1)\, \omega\, A$

Similarly , the angular dispersion produced by the flint prism is

$(\mu' - 1)\, \omega'\, A'$

For achromatic combination , the net dispersion should be zero. Thus ,

$(\mu - 1)\, \omega\, A = (\mu' - 1)\, \omega'\, A'$

or , $\dfrac{A'}{A} = \dfrac{(\mu - 1)\omega}{(\mu' - 1)\omega'} = \dfrac{0.517 \times 0.03}{0.621 \times 0.05} = 0.50$ ...(1)

The deviation in the yellow ray produced by the crown prism is $\delta = (\mu - 1)\, A$ and by the flint prism is $\delta' = (\mu' - 1)\, A'$. The net deviation produced by the combination is

$\delta - \delta' = (\mu - 1)\, A - (\mu' - 1)\, A'$

or $1° = 0.517\, A - 0.621\, A'$ ...(2)

Solving (1) and (2), A = 4.8° and A' = 2.4°. Thus, the crown prism should have its refracting angle 4.8° and that of the flint prism should be 2.4°.

LEVEL # 1

Refractive index & Laws of Refraction

Q.1 The wavelength of monochromatic blue light in air is 420 nm. What will be its wavelength in water ? (μ of water is 4/3)
(A) 280 nm
(B) 560 nm
(C) 315 nm
(D) 400 nm

Q.2 V_1 is velocity of light in first medium, V_2 is velocity of light in second medium, then refractive index of second medium with respect to first medium is
(A) V_1/V_2
(B) V_2/V_1
(C) $\sqrt{V_1/V_2}$
(D) $\sqrt{V_2/V_1}$

Q.3 The refractive index of glass and water with respect to air are 3/2 and 4/3 respectively. The refractive index of glass with respect to water is
(A) 8/9
(B) 9/8
(C) 2
(D) 1/2

Q.4 Velocity of light in water, glass and vacuum have the values v_w, v_g and v_c respectively. Which of the following relations is true ?
(A) $v_w = v_g = v_c$
(B) $v_w > v_g$ but $v_w < v_c$
(C) $v_w = v_g$ but $v_w < v_c$
(D) $v_c = v_w$ and $v_w < v_g$

Q.5 A ray of light travels through a transparent slab with a speed of 2×10^{10} cms^{-1}. This implies that the refractive index of the slab material is
(A) 1.5
(B) 0.667
(C) 2.0
(D) 6.0

Q.6 The refractive index of water is (4/3) and that of glass is (3/2) .If the speed of light in glass is 2×10^8 m/s. The speed of light in water will be :
(A) 1×10^8 m/s
(B) $(9/4) \times 10^8$ m/s
(C) $(8/3) \times 10^8$ m/s
(D) 4×10^8 m/s

Q.7 Light travels through a glass of thickness t and refractive index n. If c is the velocity of light in vacuum, the time taken by light to travel through the plate is
(A) t/nc
(B) ntc
(C) nt/c
(D) tc/n

Q.8 Light of frequency 5×10^{14} Hz is travelling in a medium of refractive index 1.5. What is its wavelength ? ($c = 3 \times 10^8$ ms^{-1})
(A) 9000 Å
(B) 6000 Å
(C) 4500 Å
(D) 4000 Å

Q.9 If μ_r, ε_r are the relative permeability and the dielectric const. of a medium, its refractive index is given by
(A) $1/\sqrt{\mu_r \varepsilon_r}$
(B) $1/(\mu_r \varepsilon_r)$
(C) $\sqrt{\mu_r \varepsilon_r}$
(D) $\mu_r \varepsilon_r$

Q.10 When a ray of light enters a medium of refractive index μ, it is observed that the angle of refraction is half the angle of incidence then angle of incidence is
(A) $2\cos^{-1}(\mu/2)$
(B) $\cos^{-1}(\mu/2)$
(C) $2\cos^{-1}(\mu)$
(D) $2\sin^{-1}(\mu/2)$

Q.11 Monochromatic light is refracted from air into the glass of refractive index μ. The ratio of the wavelength of incident and refracted waves is
(A) $1 : \mu$
(B) $1 : \mu^2$
(C) $\mu : 1$
(D) $1 : 1$

Q.12 The refractive index of water, glass and diamond are 1.33, 1.50 and 2.40 respectively. The relative index of refraction of diamond relative to water and of glass relative to diamond respectively are nearly
(A) 1.80, 0.625
(B) 0.554, 0.625
(C) 1.80, 1.6
(D) 0.554, 1.6

Q.13 An electromagnetic radiation of frequency n, wavelength λ, travelling with velocity v in air, enters a glass slab of refractive index μ. The frequency, wavelength and velocity of light in the glass slab will be respectively

(A) $\dfrac{n}{\mu}$, $\dfrac{\lambda}{\mu}$ and $\dfrac{v}{\mu}$ (B) n, $\dfrac{\lambda}{\mu}$ and $\dfrac{v}{\mu}$

(C) n, 2λ and $\dfrac{v}{\mu}$ (D) $\dfrac{2n}{\mu}$, $\dfrac{\lambda}{\mu}$ and v

Q.14 The refractive index of a given piece of transparent quartz is the greatest for
(A) red light   (B) violet light
(C) green light   (D) yellow light

Q.15 The refractive index of material varies with wavelength according to the Cauchy's relation is

(A) $\mu = A\lambda + B$ (B) $\mu = A + \dfrac{B}{\lambda^2}$

(C) $\mu = A \times \dfrac{B}{\lambda}$ (D) $\mu = A^2\lambda + B$

Q.16 When a light ray travels into a single medium then refractive index is
(A) directly proportional to wavelength of light
(B) inversely proportional to wavelength of light
(C) inversely proportional to the square of wavelength of light
(D) directly proportional to the square of wavelength of light

Q.17 When a small lamp is held 1.5m above the surface of water in a tank, its image formed by reflection at the surface appears to coincide with the image of the bottom of the tank. (μ of water = 4/3). The depth of the tank is
(A) 2 m   (B) 1.5 m
(C) 1 m   (D) 4 m

Q.18 An air bubble in a glass slab (μ = 1.5) is 6 cm deep as viewed from one face and 4 cm deep as viewed from the other face. The thickness of the glass slab is
(A) 6.67 cm
(B) 10 cm
(C) 15 cm
(D) Data is incomplete

Q.19 A ray of light travels in a medium whose refractive index with respect to air is $\sqrt{2}$. When light is incident at an angle of 45° to the surface then which of the following is correct ?
(A) angle of refraction is 45°
(B) total internal reflection takes place
(C) angle of refraction is 90°
(D) the path of ray is undeviated

Q.20 If the critical angle for total internal reflection from a medium to vacuum is 30°, the velocity of light in the medium is
(A) 3×10^8 m/s   (B) 1.5×10^8 m/s
(C) 6×10^8 m/s   (D) $\sqrt{3} \times 10^8$ m/s

Q.21 A point source of light is placed 4 m below the surface of water of μ = $\dfrac{5}{3}$. The minimum diameter of a disc, which should be placed over the source, on the surface of water to cut off all light coming out of water, is
(A) 1 m   (B) 6 m   (C) 4 m   (D) 3 m

Q.22 Which statement is correct
(A) When light proceeds from denser to rare medium and the angle of incidence is greater than critical angle total internal reflection of light takes place.
(B) When light proceeds from rare to denser medium internal reflection of light takes place.
(C) When light proceeds from denser to rare medium, internal reflection always takes place
(D) None of the above

Q.23 An object is located at the bottom of a tank containing two immissible liquids and is seen vertically from above. The lower and upper liquids are of depth h_1 and h_2 respectively and of refractive indices μ_1 and μ_2 respectively. Locate the position of the image of the object from the surface-

(A) $\dfrac{h_1 + h_2}{\mu_1 + \mu_2}$ (B) $\dfrac{\mu_1 h_1 + \mu_2 h_2}{\mu_1 + \mu_2}$

(C) $\dfrac{h_1}{\mu_1} + \dfrac{h_2}{\mu_2}$ (D) None of these

Q.24 Just before the time of sun set or shine the sun appears to be oval because
(A) The sun changes its shape at that time
(B) Of the scattering of light
(C) Of the effects of refraction
(D) Of the effects of diffraction

Q.25 The twinkling of stars is due to
(A) the fact that star do not emit light continuously
(B) Frequent absorption of star light by their own atmosphere
(C) The fact that refractive index of the earth's atmosphere fluctuates
(D) intermittent absorption of star light by earth atmosphere

Q.26 A cut diamond (or air bubble in water) shines brilliantly due to
(A) Its molecular structure
(B) Absorption of light
(C) Total internal reflection
(D) Some inherent property

Q.27 Mirages are observed in deserts due to phenomenon of
(A) Interference of light
(B) Total internal reflection
(C) Scattering of light
(D) Double reflection of light

Q.28 We see the sun a little before it rises on the horizon and a little after it sets below the horizon. This is a consequence of the phenomenon of
(A) Total internal reflection
(B) Refraction
(C) Dispersion
(D) Scattering of light

Q.29 A glass prism of refracting angle 60° gives a minimum deviation of 30°. What is the refractive index of the glass –
(A) 1.5
(B) $\sqrt{1.5}$
(C) $\sqrt{2}$
(D) can not be determined

Q.30 Deviation δ produced by a prism of refractive index μ and small angle A is given by
(A) $\delta = (\mu -1) A$ (B) $\delta = (\mu + 1) A$
(C) $\delta = (A -1) \mu$ (D) $\delta = (A+ 1) \mu$

Q.31 The angle of prism is 6° and its refractive index for green light is 1.5. If a green ray passes through it, the deviation will be
(A) 30°   (B) 15°   (C) 9°   (D) 3°

Q.32 If the critical angle for the medium of a prism is C and the angle of the prism is A, then there will be no emergent ray when
(A) A < 2C   (B) A = 2C
(C) A > 2C   (D) A > = < 2C

Q.33 When a ray of light is refracted by a prism such that the angle of deviation is minimum, then
(A) the angle of emergence is equal to the angle of incidence
(B) the angle of emergence is greater than the angle of incidence
(C) the angle of emergence is smaller than the angle of incidence
(D) the sum of the angle of incidence and the angle of emergence is equal to 90°

Q.34 A ray falls on a prism ABC (AB = BC) and travels as shown in figure. The minimum refractive index of the prism material should be
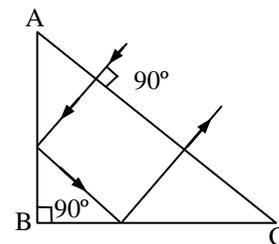
(A) $\dfrac{4}{3}$ (B) $\sqrt{2}$ (C) 1.5   (D) $\sqrt{3}$

Q.35 If the angle of a prism is 60° and angle of minimum deviation is 40°, then the angle of refraction will be

(A) 30° (B) 4° (C) 3° (D) 2.6°

Q.36 Angle of minimum deviation for a prism of refractive index 1.5, is equal to the angle of the prism. Then the angle of the prism is
(Given cos 41° = 0.75)

(A) 62° (B) 41° (C) 82° (D) 31°

Q.37 The refracting angle of a prism is 40°. A ray of light is incident at angle 38° and passes in the position of minimum deviation. The angle of minimum deviation is

(A) 40° (B) 38° (C) 36° (D) 32°

Q.38 The refractive index for the material of a 60° prism is 1.50. Further $\sin 42° \approx \frac{2}{3}$ and $\sin 49° \approx \frac{3}{4}$. Then the angle of incidence for minimum deviation is nearly

(A) 30° (B) 49° (C) 38° (D) 28°

Q.39 In question no.38, the angle of minimum deviation is nearly

(A) 30° (B) 49° (C) 38° (D) 28°

Q.40 The angle of a prism is 60° and the index of refraction of glass with air is 1.5. If the angle of incidence on the first face is I_1 and the angle of emergence at the second face is I_2, then the prism produces minimum deviation when

(A) $I_1 = 0$ (B) $I_1 > I_2$
(C) $I_1 < I_2$ (D) $I_1 = I_2$

Q.41 For a prism, graph between angle of deviation (δ) and angle of incidence will be
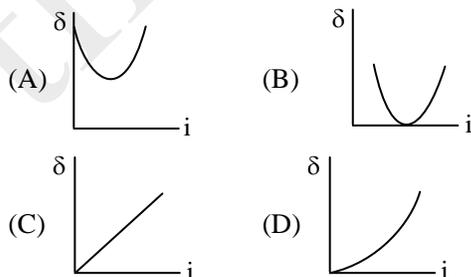
Q.42 A spectrum is formed by a prism whose dispersive power is ω. If the deviation of the mean ray is δ, the angular dispersion of the spectrum is :

(A) ω/δ (B) δ/ω (C) 1/ωδ (D) ωδ

Q.43 White light is passed through a prism whose angle is 5°. If the refractive indices for rays of red and blue colour are respectively 1.64 and 1.66, the angle of deviation between the two colours will be

(A) 0.1° (B) 0.2° (C) 0.3° (D) 0.4°

Q.44 The refractive indices of violet and red light are 1.54 and 1.52 respectively. If the angle of prism is 10°, the angular dispersion is

(A) 0.02° (B) 0.2° (C) 3.06° (D) 30.6°

Q.45 The refractive index of flint glass for blue line is 1.6333 and red line is 1.6161, then dispersive power of the glass is :

(A) 0.0276 (B) 0.276
(C) 2.76 (D) 0.106

Q.46 If the refractive indices of crown glass for red, yellow and violet colours are 1.5140, 1.5170 and 1.5318 respectively and for flint glass these are 1.6434, 1.6499 and 1.6852 respectively, then the dispersive power for crown and flint glass are respectively

(A) 0.034 and 0.064 (B) 0.064 and 0.034
(C) 1.3 and 0.064 (D) 0.034 and 1.0

Q.47 Indicate the correct statement in the following

(A) The dispersive power depends upon the angle of prism

(B) The angular dispersion depends upon the angle of the prism

(C) The angular dispersion does not depend upon the dispersive power

(D) The dispersive power in vacuum is one

Q.48 White light is passed through a prism of angle 5. If the refractive indices for the red and blue colours are 1.641 and 1.659 respectively, what is the angle of dispersion between them ?

(A) 5º   (2) 9º   (C) 0.09º   (D) 0.9º

Q.49 The refractive indices of red, violet and yellow light are respectively 1.42, 1.62 and 1.50. The dispersive power of the medium will be

(A) 0.4   (B) 0.3

(C) 0.2   (D) 0.1

Questions based on **Combination of prism**

Q.50 A flint glass prism and a crown glass prism of angles A′ and A respectively are to be combined in such a manner that there is dispersion without deviation. For this to occur the ratio of A′/A must be :

(A) $(\mu_y - 1) / (\mu_y' - 1)$

(B) $(\mu_y' - 1) / (\mu_y - 1)$

(C) $(\mu_y' - 1)$

(D) $(\mu_y - 1)$