SECTION-01 - BE-01

BASICS OF SCIENCE AND ENGINEERING

PHYSICS

1. Units and Measurements
2. Classical Mechanics
3. Electric Current
4. Heat and Thermometry
5. Weave Motion, Optics and Acoustics

CHEMISTRY

6. Chemical Reactions and Equations
7. Acids, Bases and Salts
8. Metals and Non-Metals

COMPUTER PRACTICE

9. Computer Practice

ENVIRONMENT SCIENCES

10. Environmental Sciences

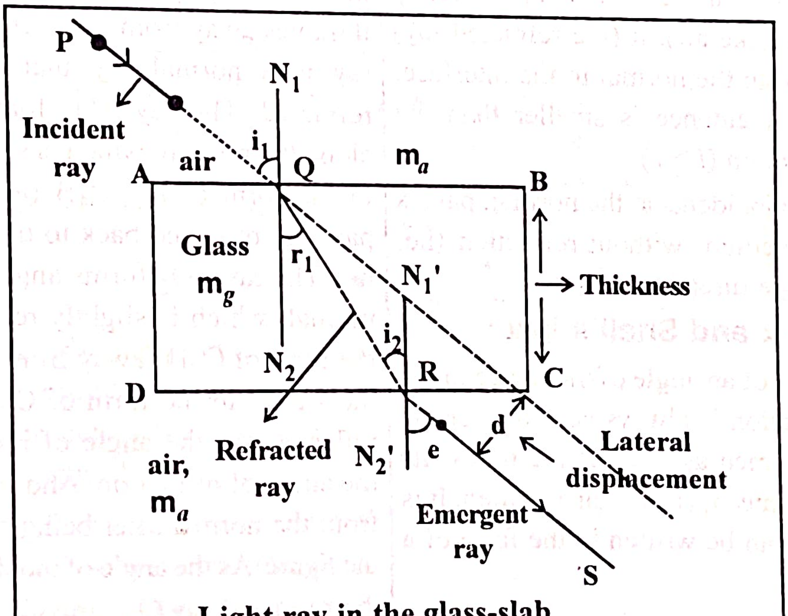
Optics and Acoustics

[1] Refraction :

As we know, the speed of light varies in different mediums. Optically rarer media, such as vacuum or air, have higher velocity, while other denser transparent media have lower velocity. Hence the phenomenon of refraction occurs when a ray of light travels from one medium to another. The ray of refracted light is called a refracted ray.

In the previous standards, you have studied the refraction of light by the experiment with a transparent glass-slab (cuboid). Without repeating that experiment, let us once again understand the same phenomenon of refraction.

As shown in the **figure** PQ is an incident ray. It forms the angle of incident i_1 with the normal. This incident ray PQ travels from the surface AB of the glass slab, from an optically rarer medium like air to an optically denser medium like glass. So its velocity decreases and it bends towards the normal and makes the angle of refraction r_1 where QR is a refracted ray. The refracted ray QR acts as an incident ray for the surface CD of the glass slab and forms an i_2 angle with the normal. Now when a light ray enters from an optically denser medium like glass to an optically rarer medium like air, its velocity increases, and it bends away from the normal. This is how the RS ray exits from the glass slab. That is why it is called an Emergent Ray. In the figure, e is the angle of emergence.



Light ray in the glass-slab

When a light-ray is refracted over two parallel refracting surfaces, the Emergent Ray is shifted from the direction of the incident ray as shown in the figure. Such a transfer of light rays is called the lateral shift.

Due to this lateral shift as a result of refraction, the pencil placed in a glass filled with water appears to be slanted from its surface. Anything placed at the bottom of a vessel filled with water or at the bottom of a swimming pool appears to be slightly upper than its original location. These phenomena are caused by the refraction of light. It is difficult to pierce a fish in a river as its location looks different from where it is due to the refraction of light.

The refractive index of the second medium with respect to that of the first medium (η_{21}) is defined as the ratio of the sine of the angle of incidence in the first medium to the sine of the angle of refraction in the second medium. The Refractive index has no unit as it is the ratio of two similar quantities.

- **Laws of Refraction :**

1. The incident ray PQ, the refracted ray QR and the normal $N_1Q\ N_2$to the interface of two transparent media at the point of incidence, all lie in the same plane.
2. Incident ray and refracted ray both are in different optical media.
3. Incident ray and refracted ray are always on the opposite side of the normal.
4. When a light-ray travels from the optically rarer medium (like air) to an optically denser medium (like glass), it (the refracted ray) bends towards the normal at the interface. Therefore, the angle of the incidence is greater than the angle of refraction ($i > r$).
5. When a light ray enters from an optically denser medium (like glass) to an optically rarer medium (like air), it (the refracted ray) bends away from the normal to the interface. The angle of incidence is smaller than the angle of refraction ($i > r$).
6. The ray which incidents at the normal, passes to the other medium without refraction (i.e. does not change direction).

[2] Refractive Index and Snell's law :

The ratio of the sine of an angle of incidence to the sine of an angle of refraction is always constant for the given two media. It is termed as a refractive index. Its symbol is μ (Mu). Sometimes η (Ita) is also written. It is known as Snell's law. It can be written in the form of a formula as follows :

$$\mu = \eta = \frac{\sin i}{\sin r} = \text{constant} \qquad \ldots (1)$$

Suppose the refractive index of the first medium is η_1 and that of the second medium is η_2. The refractive index of medium-2 relative to medium-1 is denoted by μ_{21} or η_{21}.

$$\mu_{21} = \eta_{21} = \frac{\sin i}{\sin r} = \text{constant} \qquad \ldots (2)$$

The refractive index of light can be represented as the ratio of the velocities of light in its two media. If the velocities of light in medium-1 and medium-2 are v_1 and v_2 respectively, then their ratio is called the refractive index of medium 1 relative to medium 2.

$$\therefore\ \mu_{21} = \eta_{21} = \frac{v_1}{v_2} \qquad \ldots (3)$$

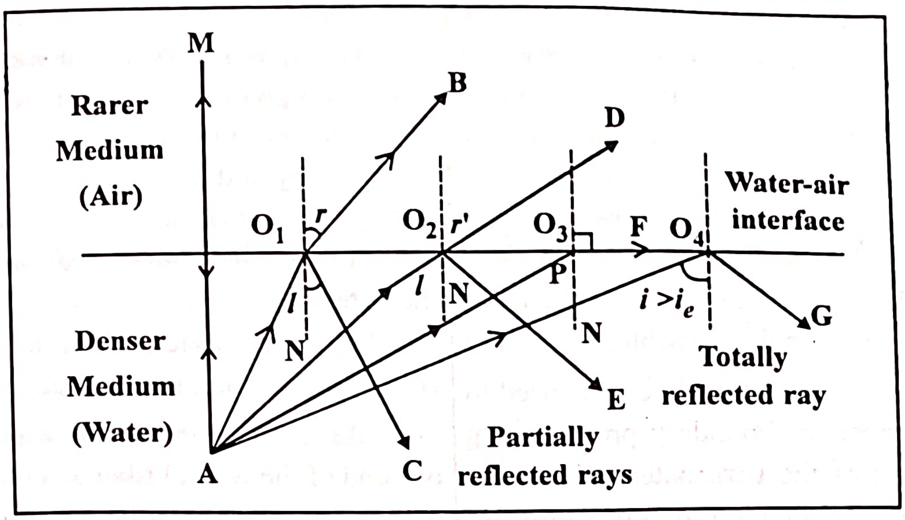
[3] Total Internal reflection and Critical angle :

- **Total Internal Reflection :**

This phenomenon is based on the principle of refraction of light. **The figure** below will be helpful to understand the total internal reflection.

As shown in **figure**, a water container is filled with clear transparent water. A light source, fixed at the bottom of the container emits light rays in all directions. These rays are partially reflected and partially transmitted.

When a ray of light enters from an optically denser medium (here, water) to an optically rarer medium (air), it moves away from the normal at the interface. The AM ray is a normal ray that comes out without being refracted. The ray AO_1 forms the angle of incidence along the normal, which is slightly refracted and emitted in the form of ray O_1B (away from the normal) and partially reflected back to the water in the form of O_1C ray. The ray AO_2 forms angle of incidence (i) with the normal, which is slightly refracted and the ray exits in the form of O_2D (away from the normal) and returns to the water in the form of O_2E ray after being partially reflected. As the angle of incidence increases, so does the angle of refraction. And the ray of light moves away from the normal after being refracted, as can be seen in the figure. As the angle of incidence is increased gradually, the refracted ray O_3F travels in the direction parallel to the interface separating both media for a certain angle of incidence (i) equal to the critical angle (θ_c) . At a particular angle of incidence, refracted ray moves parallel to the surface separating the two media. In this particular case, the angle of refraction becomes 90° for the incidence ray O_3f. The angle of incidence for which the angle of refraction becomes 90° is called the critical angle of the denser medium with respect to the rarer medium. The refracted ray found in the position of a critical angle is called Critical Ray. Here O_3F is that critical ray. In this situation, the surface separating both media appears to be illuminated.



Now, if the angle of incidence (i) is raised even slightly more than the critical angle (θ_c), the incident ray gets completely reflected back into the denser medium (water, in this case). That is, here, as shown in the figure, incident ray, AO_4 is fully reflected and returned back to the water in the form of O_4G. This phenomenon is called total internal reflection.This phenomenon is true for any angle of incidence larger than the critical angle. In this situation, the surface separating both media acts as a perfect mirror. Total Internal reflection also obeys the laws of reflection.

- **Critical Angle :**

In the previous paragraph, the phenomenon of total internal reflection was introduced. Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary.

In our introduction to TIR, we used the example of light traveling through water towards the boundary with a less dense material such as air. When the angle of incidence in water reaches a certain critical value, the refracted ray lies along the boundary, having an angle of refraction of 90-degrees. This angle of incidence is known as the critical angle; it is the largest angle of incidence for which refraction can still occur. For any angle of incidence greater than the critical angle, light will undergo total internal reflection.

So the critical angle is defined as the angle of incidence that provides an angle of refraction of 90-degrees. Make particular note that the critical angle is an angle of incidence value. For the water-air boundary, the critical angle is 48.6-degrees. For the crown glass-water boundary, the critical angle is 61.0-degrees. The actual value of the critical angle is dependent upon the combination of materials present on each side of the boundary.

Let's consider two different media - creatively named medium i (incident medium) and medium r (refractive medium). The critical angle is the θ_i that gives a θ_r value of 90-degrees. If this information is substituted into Snell's Law equation, a generic equation for predicting the critical angle can be derived. The derivation is shown below.

$$\eta_i \sin\theta_i = \eta_r \sin\theta_r$$

$$\eta_i \sin\theta_c = \eta_r \sin 90^o$$

$$\eta_i \sin\theta_c = \eta_r \qquad (\sin 90^o = 1)$$

$$\sin\theta_c = \frac{\eta_r}{\eta_i}$$

$$\theta_c = \sin^{-1}\frac{\eta_r}{\eta_i}$$

The critical angle can be calculated by taking the inverse-sine of the ratio of the indices of refraction. The ratio of $\frac{\eta_r}{\eta_i}$ is a value less than 1.0. In fact, for the equation to even give a correct answer, the ratio of $\frac{\eta_r}{\eta_i}$ must be less than 1.0. Since TIR only occurs if the refractive medium is less dense than the incident medium, the va[...] of η_i must be grea[...]r than the value of η_r. If at any ti[...] he values for the numerator and denominator become [...]ccidentally switched, the critical angle value cannot be calculated. Mathematically, this would involve finding the inverse-sine of a number greater than 1.00, which is not possible. Physically, this would involve finding the critical angle for a situation in which the light is traveling from the less dense medium into the more dense medium, which again, is not possible.

This equation for the critical angle can be used to predict the critical angle for any boundary, provided that the indices of refraction of the two materials on each side of the boundary are known. Examples of its use are shown below :

- **Necessary Conditions for Total Internal Reflection :**

The two necessary conditions for the total internal reflection are :

(i) The light must travel from an optically denser medium to an optically rarer medium.

(ii) The angle of incidence in denser medium must be greater than the critical angle for the pair of media.

[4] Applications of Total Internal Reflection in Optical Fibers :

The bright glitter and sparkling of Crystal glass and diamond glitter are attributed to the total internal reflection. A total internal reflection in nature gives the illusion of a mirage in the desert. Similarly, looming occurs due to total internal reflection in the polar or extremely cold regions. That means sailors see the steamer or ship hanging upside down in the air. The optical fibres used in communication and the medical field works on the principle of total internal reflection.

One thing to note here is that the total internal reflection does not occur when any light ray enters from an optically rarer medium to an optically denser medium. For objects with a large refractive index, the critical angle is less. For example, the critical angle for the light ray going from diamond to air is $\theta_c = 24^\circ$. This phenomenon is the reason for sparkling glitter seen in diamonds and crystal glass.

Optical fibres are now widely used to send audio or video signals over long distances. Optical fibres can transmit signals from one place to another using the phenomenon of total internal reflection. They are in the form of long and thin fibres of high-quality glass, quartz and plastic materials. Its diameter is about 0.0001 centimetres. The central-axial part of this fibre is called the core while the core is surrounded by the layer called cladding. In an optical fiber, the refractive index of the core is higher than that of cladding material.

As shown in the figure, when a light ray enters into one end of the optical fiber at a proper acceptance angle, it undergoes multiple total internal reflections and finally emerges out from the other end of the optical fiber. Even if the optical fiber is curved or twisted, the ray of light undergoes total internal reflection and passes through it.

Optical fiber is widely used in communication. In addition, it has various uses in various fields such as engineering field, medical, military field, etc.

[5] LASER :

- **Introduction to LASER :**

The year 2020 marks the 60th anniversary of the invention of the laser, the Diamond Jubilee of the laser. We don't even know and we have used laser technology unknowingly. When we shop in a big shopping mall, the laser-based bar code gun/scanner is used. The optical mouse, connected to a computer, is also an example of a laser device. The read/write process of the CDs/DVDs used in a music system is done by a laser beam only. When we send an e-mail, the worldwide fiber optic network based on laser starts working. Laser technology has numerous applications in the present and is likely to lead to many more revolutionary discoveries in the future. What is this laser ?

LASER is the abbreviation of "**Light Amplification by Stimulated Emission of Radiation**".

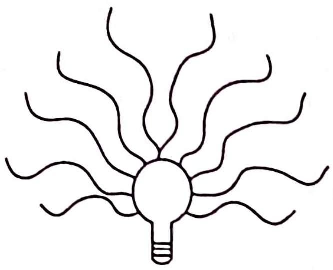
L – Light

A – Amplification

S – Stimulated

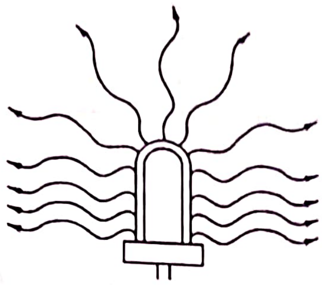
E – Emission

R – Radiation



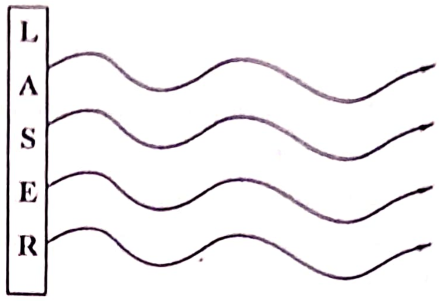
Electric Bulb

(1) Ordinary light



Sodium Lamp

(2) Sodium lamp



(3) Laser beam

A laser is an electromagnetic, visible or invisible, ray of monochromatic light that consists of an extremely powerful, intense, bright, focused and coherent unidirectional beam of light rays that travels by tremendous velocity in air or vacuum. A laser beam is highly energetic and has unique properties over conventional ordinary light rays. The light of a normal bulb has all the wavelengths, as shown in **figure 1,** which propagates in all directions. The monochromatic (single wavelength) light of a sodium lamp has only one wavelength which spreads in all directions (**Figure 2**), while the laser light has only one wavelength, as shown in **figure 3**, which propagates in one direction.

- **Characteristics of Laser :**

(1) A laser is an intense, powerful and coherent beam of light rays that travel at a tremendous speed.

(2) The laser light is highly directional, which means laser light is emitted as a relatively narrow beam in a specific direction.

(3) In a laser beam, the rays are parallel to each other.

(4) The laser beam propagates in only one straight direction without angular divergence, so even after reaching very long distances, there is hardly any change in the cross-section of its beam.

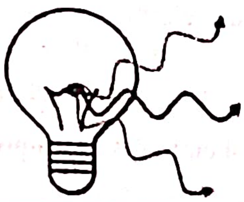
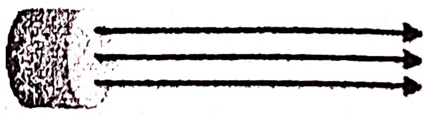
(5) Laser is a strong, concentrated and highly focused beam. It can deposit a lot of energy within a small area.

(6) Laser light is coherent, i.e. All photons in a laser beam are in the same phase.

(7) A laser beam contains only monochromatic light (Single wavelength).

(8) Laser light is usually emitted by intense pulses. Ruby and other solid crystal diodes produce lasers through pulses. But, a gas laser can emit continuous waves.

- **The differences between LASER and ordinary light :**

Ordinary Light Beam	LASER Light Beam
1. Spreads in all directions from the place of origin. (Divergent)	1. Spreads in the same direction. (Non-divergent; Unidirectional)
2. Intensity decreases gradually as it travels long distances and spread with the distance.	2. Even travelling long distances rarely changes its cross-section.
3. A convex lens or a concave mirror is needed to convert ordinary light into a parallel beam. However, its divergence is greater than that of laser light.	3. Laser light is made up of parallel rays.
4. Has low intensity and low brightness.	4. Has more intensity and has more brightness.
5. Not coherent, that is, the phase of all photons is different as it is a mixture of many wavelengths.	5. Coherent, meaning that all photons have the same phase.
6. It may be Monochromatic or Polychromatic. Ordinary white light is a combination of many colours (frequencies).	6. A Laser beam is monochromatic as it is composed of a single colour (frequency).
7. Example 	7. Example 

Multiple Choice Questions (MCQs)

1. Amongst which of the following cases, the total internal reflection of light happens ?
   (A) The angle of incidence is smaller than the critical angle
   (B) The angle of incidence is equal to the critical angle
   (C) The angle of incidence is greater than the critical angle
   (D) The angle of incidence is equal to the angle of refraction

Ans. : (C)

2. What is the phenomenon called when a light ray changes its path when passing through one medium to another ?
   (A) Reflection (B) Refraction
   (C) Dispersion (D) Total internal reflection

Ans. : (B)

3. What happens when a light ray enters from water into the air ?
   (A) bends towards normal
   (B) bends away from normal
   (C) not refracted
   (D) reflected in back

Ans. : (A)

4. Which sign is used for the refractive index ?
   (A) μ (B) η
   (C) both (D) None of this

Ans. : (C)

5. At what angle of incidence, the light ray that incident on a glass slab, does not get refracted ?
   (A) 0^o (B) 45^o
   (C) 60^o (D) = Critical Angle (θ_c)

Ans. : (A)

6. Which of the following has the highest refractive index ?
   (A) Glass (B) Water
   (C) Pearl (D) Diamond

Ans. : (D)

7. The velocity of light in the medium........with increase its refractive index.

(A) decreases (B) increases

(C) Becomes zero (D) Remains constant

Ans. : (A)

8. When a light ray travels from transparent glass medium to the medium of water, its velocity..........

(A) decreases (B) increases

(C) Becomes zero (D) Remains constant

Ans. : (B)

9. According to Snell's Law, the Refractive index (μ) = ...

(A) $\frac{\sin i}{\sin r}$ = Constant

(B) $\frac{\sin r}{\sin i}$ = Constant

(C) $\sin i \times \sin r$ = Constant

(D) $\sin i + \sin r$ = Constant

Ans. : (A)

10. Absolute refractive indices of glass (μ_g) and (μ_d) diamond are respectively.......

(A) 0.52 &1.42 (B) 1.42 &2.42

(C) –1.52 & –2.42 (D) 1.52 & 2.42

Ans. : (D)

11. Due to .... illusion of mirage happens.

(A) Dispersion (B) polarisation

(C) refraction (D) Total Internal reflection

Ans. : (D)

12. A signal of light propagates through optical fibers due to ....phenomenon.

(A) dispersion (B) polarisation

(C) refraction (D) total Internal reflection

Ans. : (D)

13. Absolute refractive indices of water and ice are respectively .....

(A) 1.33 and1.31 (B) 0.33 and 0.31

(C) –1.33 and –1.31 (D) 2.33 and 2.31

Ans. : (A)

14. The critical angle of crown glass with respect to air is Refractive index of crown glass (u) = 1.52

(A) 48.75° (B) 37.31°

(C) 24.41° (D) 41.14°

Ans. : (D)

15. The Laser is _____radiation.

(A) Extremely monochromatic

(B) Partially monochromatic

(C) White light

(D) None of above

Ans. : (A)

16. Laser is a/an extremely _____radiation.

(A) unidirectional

(B) focused

(C) coherent and stimulated

(D) All of above

Ans. : (D)

17. In the conventional energy sources...

(A) Different atoms emit radiation at different times.

(B) There is no phase relationship between the emitted photons.

(C) Different molecules emit photons in different directions.

(D) All of above

Ans. : (D)

18. In the laser source ...

(A) The photons emitted by different atoms are either in the same phase or maintain the constant phase difference.

(B) Different atoms emit photons in the same direction.

(C) Both (A) and (B)

(D) None of these.

Ans. : (C)

19. Lasers are used in ...

(A) Metal cutting and hole drilling

(B) Welding

(C) Testing of physical and chemical properties of the material

(D) All of the above.

Ans. : (D)

20. Laser means light amplification by .... of light radiation.
(A) Stimulated (B) Spontaneous
(C) Absorption (D) Both (A) & (B)

Ans. : (A)

21. LASER is abbreviations used for
(A) Name of scientist
(B) Light amplification by stimulated emission of radiation
(C) Light amplification by spontaneous emission of radiation
(D) Light absorption by sun and earth radiation

Ans. : (B)

22. A Laser beam is monochromatic. It means it has
(A) Single Frequency (B) Wide Width
(C) Narrow Width (D) Several Colours

Ans. : (A)

23. Directionality property of iaser can be used in ....
(A) surveying (B) remote sensing
(C) Lidar (D) All of the above

Ans. : (D)

24. Which of the following is not the property of laser ?
(A) Coherence
(B) High direction
(C) Extreme brightness
(D) Divergence

Ans. : (D)

25. Light sources used in fiber optic communication
(A) LEDs (B) Semiconductor lasers
(C) Phototransistors (D) Both (A) and (B)

Ans. : (D)

26. The light ray propagating (without leakage) through the optical fiber making an angle up to ......value with its axis is called acceptance angle.
(A) maximum (B) minimum
(C) Both (A) & (B) (D) None

Ans. : (A)

27. The core diameter of a single-mode step-index fiber is approximately....
(A) 60 μm -70 μm (B) 8 μm -10 μm
(C) 100 μm -250 μm (D) 50 μm -200 μm

Ans. : (B)

28. The light ray in the optical fiber is transmitted by the phenomenon called....of waves.
(A) interference (B) diffraction
(C) polarization (D) total internal reflection

Ans. : (D)

29. If η_1 and η_2 are the refractive indices of core and cladding respectively, the condition for propagation of light from optical fiber is...
(A) $\eta_1 = \eta_2$ (B) $\eta_1 > \eta_2$
(C) $\eta_1 < \eta_2$ (D) None

Ans. : (B)

30. The phenomenon responsible for the loss of light intensity in an optical fiber is.....
(A) absorption (B) scattering
(C) reflection (D) Both (A) & (B)

Ans. : (D)

31. If η_1 and η_2 are the refractive indices of core and cladding respectively, the Numerical Aperture (NA) of an optical fiber is given by,
(A) $\eta_1 2 - \eta_2 2$ (B) $\eta_2 2 - \eta_1 2$
(C) $(\eta_1 2 - \eta_2 2)^{1/2}$ (D) $(\eta_2 2 - \eta_1 2)^{1/2}$

Ans. : (C)

32. The estimated lifespan of optical fiber is........
(A) 40 to 50 years (B) About 100 years
(C) 20 to 30 years (D) Less than 10 years

Ans. : (C)

33. The total internal reflection occurs when an angle of incidence is ..... critical angle.
(A) greater than (B) less than
(C) equal to (D) both (A) and (B)

Ans. : (A)

34. The numerical aperture (NA), indicates the .... capacity of the optical fiber.
(A) light gathering (B) light consuming
(C) heat consuming (D) magnetic lines gathering

Ans. : (A)

35. The core refractive index profile of the graded-index fibers is ....
(A) Spherically symmetric
(B) Nonlinear
(C) Step index
(D) None

Ans. : (A)

36. The most widely used optical fibers in the world are ....

(A) multimode step index fibers

(B) multimode graded index fibers

(C) single-mode step-index fibers

(D) None

Ans. : (C)

37. If the value of the critical angle is .... then the acceptance angle is maximum.

(A) maximum (B) minimum

(C) (A) or (B) (D) None

Ans. : (A)

38. Optical fibers are made of .... material.

(A) semiconductor (B) metallic

(C) conductor (D) dielectric

Ans. : (D)

39. If the angle of incidence is greater than the acceptance angle, the light-ray inserted at one end of the optical fiber will ....

(A) not propagate in the optical fiber

(B) propagate in the optical fiber

(C) (A) or (B)

(D) None of these

Ans. : (A)

40. Optical fibers can carry more information than simple conventional copper wire because ......of the fiber.

(A) more thickness

(B) too wide bandwidth

(C) too little bandwidth

(D) None of the these

Ans. : (B)

★★★