31

Spectrum of Light and Photometry

BRIEF REVIEW

Spectrum A collection of dispersed light giving its wavelength composition is called a spectrum. For example, when a white light is incident on a prism a spectrum of different colours from red to violet is observed.

Pure and Impure Spectrum If each colour gives its sharp impression in the spectrum, i.e., a well defined line spectrum is obtained, then such a spectrum is called pure spectrum. To achieve pure spectrum — (i) The beam of light incident on the dispersing element (prism or diffraction grating) should be parallel or collimated. (ii) The dispersed light should be focussed in such a way that all the rays of a particular wavelength are collected at a place.

Note: These two points list the requirements of a spectrometer.

If the slit is wide, different points of the slit produce separate spectra which overlap each other. Thus colour impression gets diffused due to overlap resulting into an **impure spectrum.**

Kinds of spectra Broadly speaking spectra can be of two types – **emission spectrum** and **absorption spectrum**.

Light emitted by an object when it is suitably excited by heating or by passing an electric discharge etc. When this light is passed through a dispersing element to get a spectrum, **emission spectrum** is obtained. It reveals the information about the source material. Emission spectrum may be of three types:

Continuous Spectrum If the source is a hot solid such as bulb filament or liquid, the spectrum is continuous. Light emitted by a bulb, candle or red hot iron has continuously varying wavelengths. Even X-ray spectrum is continuous.

Line Spectrum When substances in its atomic state (gaseous or vapour state) de-excite, they produce bright colour lines. For example when common salt is thrown in a campfire, only a few colours appear in the form of isolated sharp parallel lines. Each line is the image of spectrograph slit deviated through an angle that depends upon the wavelength. A spectrum of this sort is called a line spectrum. For example sodium gives D_1 and D_2 doublet (589 and 589.6 nm). Hydrogen spectrum is well studied and so on.

Band Spectrum The molecular energy levels are generally grouped into several bunches, each bunch widely separated from the other but levels in a bunch are close to each other. The wavelengths emitted by such molecules are also grouped. Each group retains its identity (is separated from the other). The wavelengths in a group being close to each other and appear as continuous. The spectrum looks like a band of colours.

Absorption Spectrum When white light having all the wavelengths is passed through an absorbing material, the material may absorb certain wavelengths selectively (to get excited). These wavelengths will disappear when the transmitted light is dispersed (passed through a prism or grating). Dark lines or bands at the missing wavelengths appear on an otherwise bright continuous coloured background. Such a spectrum is called absorption spectrum. It is of two types line absorption spectrum and band absorption spectrum. When sunlight is dispersed certain sharply defined dark lines are seen. These lines are called **Fraunhoffer lines**. Fig 31.1(a) and Fig 31.1(b) illustrate emission and absorption process.

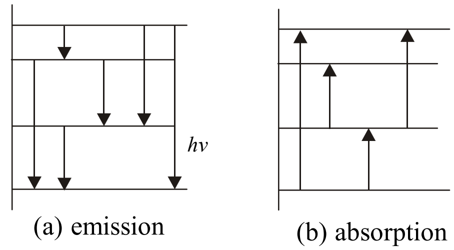

Fig. 31.1

Speed of light using Fizeau method

$c = \dfrac{2Dn\omega}{\pi} = 4\,Dnf$ where D is distance from the rotating wheel of the mirror ω is angular speed of rotation of the wheel when image is completely unseen for the first time and n is number of teeth in the wheel or number of rotations per second. $\omega = 2\pi f$ where f is linear frequency.

Foucault's method to find speed of light $c = \dfrac{4R^2\omega a}{S(R+b)}$ where R is the radius of concave mirror, a is distance between lens and source, b is distance between plane mirror and lens and S is shift in image.

Michelson method to find speed of light $c = \dfrac{DN\omega}{2\pi} = DfN$ where N is number of faces in a polygonal mirror, ω is angular speed of rotation and D is the distance travelled by light on reflections from polygonal mirror. $f = \dfrac{\omega}{2\pi}$ is the linear frequency.

Fresnel distance $Z_f = \dfrac{a^2}{\lambda}$ where a is slit width. Z_f describes the distance travelled by a beam without appreciable broadening of the beam.

Lambert's Cosine Law The surfaces which radiate according to the Lambert's Cosine Law are called perfectly diffused. $I = I_0 \cos\theta$.

Luminous flux Radiation emitted by a source has components corresponding to a wide range of wavelengths. Different component wavelengths have different energies and different brightness. The luminous flux is a quantity directly representing the total brightness producing capacity of the source. Its unit is lumen. Luminous flux of a source of $\dfrac{1}{685}$ W emitting monochromatic light of wavelength 555 *nm* is called 1 lumen. That is, a 1 watt source emitting a monochromatic light of wavelength 555 *nm* emits 685 lumen.

Relative Luminosity =

$$\frac{\text{Luminous flux of a source of given wavelength}}{\text{Luminous flux of a 555 nm source of same power}}$$

$$\text{Luminous efficiency} = \frac{\text{Total luminous flux}}{\text{Total radiant flux}}$$

$$= \frac{\text{Luminous flux emitted}}{\text{Power input to the source}}$$

Luminous Intensity or illuminating power (I) Luminous flux per unit solid angle is defined as luminous intensity. Its unit is candela (cd).

$I = \dfrac{dF}{d\Omega} = \dfrac{F}{4\pi}$ where F is luminous flux and Ω is solid angle.

1 Candela is the luminous intensity of a black body of surface area $\dfrac{1}{60}$ cm^2 placed at the freezing temperature of platinum at a pressure of 101.325 N m^{-2}.

Illuminance (E) is the luminous flux incident per unit area. E = $\dfrac{dF}{dA}$ units lumen m^{-2} or Lux. CGS unit is Phot.

Law of photometery A photometer is used to compare intensities of two sources $\dfrac{I_1}{I_2} = \left(\dfrac{d_1}{d_2}\right)^2$ where d_1 and d_2 are distances of the source from photometer.

SHORT CUTS AND POINTS TO NOTE

1. In pure spectrum each colour has its sharp impression. Pure spectrum is achieved if

(a) incident radiation (light beam) on dispersing element is parallel.

(b) light dispersed by it is collected in such a way that all the rays of a particular colour are collected at a plane.

(c) slit width should be as small as possible.

If the slit is wide, different parts of the slit produce different spectra which overlap resulting in impure spectrum.

2. Solid and liquid sources normally produce continuous spectrum. For example, a bulb, a candle, red hot iron etc. produce continuous spectrum. Even X-ray spectrum is continuous.

3. Line spectrum is obtained when atoms in their atomic state (gaseous or vapour form) de-excite; bright coloured lines are produced.

Band spectrum is produced due to de-excitation of molecules as their energy levels are grouped into several bunches. The wavelength in a bunch are close to each other.

Absorption spectrum is obtained when atoms/molecules select particular wavelengths to get excited from the incident continuous light. These wavelengths are missing (form dark lines or bands) from the incident light when transmitted light is dispersed.

4. Speed of light is measured using:

Fizeau method $c = \dfrac{2Dn\omega}{\pi} = 4\,Dnf$

Foucault method $c = \dfrac{4R^2\omega a}{S(R+b)}$

Michelson method $c = \dfrac{D\omega N}{2\pi} = DfN$

5. Radiant flux = input power.

Luminosity of radiant flux produces a sensation of brightness in the eye.

6. Luminous flux of a 1 W source emitting wavelength 555 *nm* is 685 lumen.

7. Relative luminosity =

$$\frac{\text{Luminous flux of a source of given wavelength}}{\text{Luminous flux of a 555 } nm \text{ source of same power}}$$

8. Luminous efficiency $= \dfrac{\text{Total luminous flux}}{\text{Total radiant flux}}$

$$= \frac{\text{Luminous flux emitted}}{\text{Power input to the source}}$$

9. Luminous intensity or illuminating power is luminous flux per unit solid angle, unit is *cd.*

$$I = \frac{F}{4\pi} = \frac{dF}{d\Omega}.$$

10. Illuminance $E = \dfrac{dF}{dA} = \dfrac{I\cos\theta}{r^2}$ and follows inverse square law for a point source. In SI system it is measured in Lux. 1Lux = 1*lm* m^{-2}

CGS unit is Phot.

11. Lamberts Cosine Law. An ideal source shall emit light radiations uniformly in all possible directions. But actual sources are extended and have a different luminous intensity in different directions given by $I = I_0 \cos\theta$.

12. **Law of Photometery** $\dfrac{I_1}{I_2} = \left(\dfrac{d_1}{d_2}\right)^2$

13. The total energy of radiations emitted per unit time is called total radiant flux. Unit is watt.

Note: It includes components of wavelengths beyond the visible region.

14. Luminosity of radiant flux measures the capacity to produce the sensation of brightness in the eye. A relative comparison of radiant flux of different relative intensities can be made by the curve shown in Fig. 31.2.

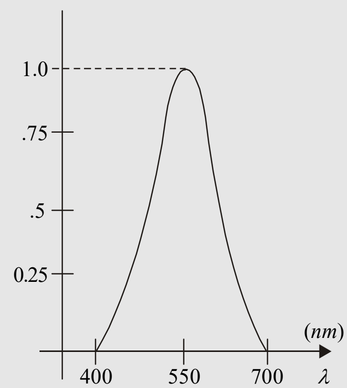

Fig. 31.2 **Response of eye to different wavelengths of equal brightness**

15. Inverse Square Law. Illuminance at a point distant r from the source is given by $E = \dfrac{I\cos\theta}{r^2}$.

16. Photoluminescence. Phenomenon of emission of visible light is called photoluminiscence. It is of two types **Florescence** and **Phosphorescence**. If light continues to emit for a **time > $10^8 s$** after removal of the source, the phenomenon is called **phosphorescence** otherwise it is florescence.

17. Persistence of vision: If our eye sees an object its impression does not fade out instantaneously. Rather, it takes $1/16$ second for image in the eye to completely fade out. This phenomenon is called persistence of vision. T.V., cinema make use of this fact.

18. Light is absorbed according to the law $I = I_0\, e^{-\alpha x}$ where x is the thickness it has passed and α is absorption coefficient.

CAUTION

1. Using same luminosity, i.e., 685 lumen W^{-1} for all wavelengths.

⇒ 685 lumen W^{-1} is only for 555 nm. Multiply with relative luminosity for other wavelengths.

2. Assuming all types of light polarised or unpolarised vary as $\cos^2 \theta$, i.e., $I = I_0 \cos^2 \theta$.

⇒ Polarised light follow $I = I_0 \cos^2 \theta$ (Malus Law) while unpolarised light for a diffused source follows Lamberts Law, i.e., $I = I_0 \cos \theta$.

3. Assume light intensity follows inverse square law.

⇒ For **diffused (point) source** it varies as $E = \dfrac{I_0 \cos\theta}{r^2}$

or amplitude of light reaches $\propto \dfrac{1}{r}$.

For **cylindrical source** intensity varies inversely with distance, i.e., $I \propto \dfrac{1}{r}$ or amplitude $a \propto \dfrac{1}{\sqrt{r}}$.

4. Not considering time for equally satisfying points in case of camera.

⇒ Use $E_1 t_1 = E_2 t_2$ or $\dfrac{I_1 t_1}{r_1^2} = \dfrac{I_2 t_2}{r_2^2}$ for equally satisfactory points.

5. Considering light is absorbed only in opaque medium.

⇒ Light is absorbed even in transparent medium. Coefficient of absorption depends upon the nature of material. Law of absorption is $I = I_0 e^{-\alpha x}$

SOLVED PROBLEMS

1. A 100 W lamp is rated 0.8W per candela; the luminous flux of the source is nearly

(a) 1571.4 *lm* (b) 1603.4 *lm*
(c) 1501.3 *lm* (d) 1481.6 *lm*

Solution (a) $I = \dfrac{100}{0.8} = 125\ cd.$

Luminous flux $F = 4\pi$ I

$= 4 \times \dfrac{22}{7} \times 125 = 1571.4\ lm$

2. A lamp placed 60 cm from a screen produces the same illumination as a standard 100 W lamp placed 90 cm away on the other side of the screen. The luminous intensity of the first lamp is

(a) 49.44 W (b) 44.44 W
(c) 54.44 W (d) 34.44 W

Solution (b) $P_1 = \dfrac{r_1^2}{r_2^2} P_2 = \dfrac{60 \times 60}{90 \times 90} \times 100$

$= \dfrac{400}{9} = 44.44$ W

3. The time of exposure is 4 *s* to print a photograph from a negative when source is 1 m away. If the source is placed 0.5 m away the time of exposure will be

(a) 4 *s* (b) 2 *s*
(c) 1 *s* (d) 0.5 *s*

Solution (c) $\dfrac{I_1}{r_1^2} t_1 = \dfrac{I_2 t_2}{r_2^2}$ or

$$t_2 = \frac{t_1 r_2^2}{r_1^2} = \frac{10.51^2 \times 4}{1^2} = 1\ s$$

4. If relative luminosity is 0.65 then the luminous flux of a 10 W source is

(a) 12130.6 (b) 4125.5
(c) 4352.5 (d) 4452.5

Solution (d) $10 \times 685\ (0.65)$

5. The luminous intensity of a small plane source of light along the forward normal is 160 *cd*. Assuming the source to be perfectly diffused, the luminous flux emitted into a cone of solid angle 0.04 str around a line making 60° with forward normal is

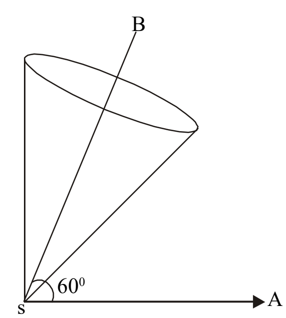

Fig. 31.3

(a) 3.2 *lm* (b) 0.8 *lm*
(c) 16 *lm* (d) 1.6 *lm*

Solution (a) $I = I_0 \cos 60 = 160 \times \dfrac{1}{2} = 80\ cd$

flux $= I\,\Delta\Omega$

$= 80 \times 0.04 = 3.2\ lm$

6. An illuminance of $2.56 \times 10^5\ lm/m^2$ is produced by the sun on the earth. The luminous flux of the sun is

(a) 5.625×10^{28} *lm* (b) 7.2×10^{28} *lm*
(c) 7.2×10^{27} *lm* (d) 5.625×10^{27} *lm*

Solution (b) $E = I/r^2$ and

flux $= 4\pi I = 4\pi E r^2$

$= 4 \times \frac{22}{7} \times 2.56 \times 10^5 (1.5 \times 10^{11})^2$

$= 7.2 \times 10^{28}$ *lm*.

7. Fig 31.4 shows a florescent lamp. The intensities at points *A*, *B* and *C* are related.

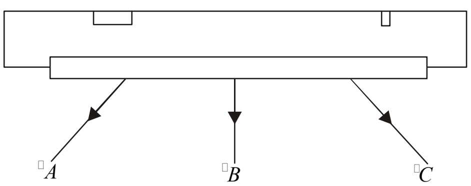

Fig. 31.4

(a) $I_A = I_B = I_C$ (b) $I_B > I_A > I_C$
(c) $I_A = I_C < I_B$ (d) $I_B = I_A > I_C$

Solution (c) Apply $I = \frac{I_0 \cos\theta}{r}$

8. A battery operated torch is adjusted to give parallel beam of light. It produces illuminance of 60 *lux* on a wall 2 m away. The illuminance produced 3 *m* away is

(a) 60 *lux* (b) $\frac{80}{3}$ *lux*
(c) 40 *lux* (d) none of these

Solution (a) $\frac{dF}{dA}$ is const.

9. A circular area of radius 1 cm is placed 2 m away from a point source. The source emits light uniformly in all directions. The source is on the line of the normal from the centre of the area. 2×10^{-3} *lm* flux is incident on the area. Find the total flux emitted by the source.

(a) 250 *lm* (b) 320 *lm*
(c) 285 *lm* (d) 355 *lm*

Solution (b) $\Delta\Omega = \frac{\pi \times 1 \times 10^{-4}}{2^2} = \frac{\pi}{4} \times 10^{-4}$ str.

Total flux $F = \frac{2 \times 10^{-3} \times 4\pi}{\frac{\pi}{4} \times 10^{-4}} = 320$ lm

10. A point source emitting uniformly in all directions is placed 0.5 m above a table top. The luminous flux of the source is 500 π lumen. Find the illuminance at a small surface area of the table top 0.8 m from the source.

(a) 125 *lux* (b) 122 *lux*
(c) 118 *lux* (c) 115 *lux*

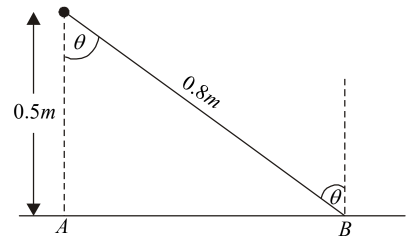

Fig. 31.5

Solution (b) $I = \frac{500\pi}{4\pi} = 125\ cd$

$$E = \frac{I\cos\theta}{r^2} = \frac{125 \times 5}{(.8)^2 \times 8}$$

$= 122$ *lux*

11. The brightness producing power of a source
(a) does not depend on the power
(b) does not depend upon wavelength emitted
(c) depends on power
(d) none of these

Solution (c)

12. As the wavelength is increased from violet to red, the luminosity
(a) increases continuously
(b) decreases continuously
(c) first increases then decreases
(d) first decreases then increases

Solution (c)

13. The parameter that determines the brightness of a light source sensed by an eye is
(a) energy of light entering the eye per second
(b) wavelength of the light
(c) total radiant flux entering the eye
(d) total luminous flux entering the eye

Solution (d)

14. Light from a point source falls on a screen. If the separation between the source and the screen is increased by 1%, the illuminance will decrease

(a) 0.5% (b) 1%
(c) 2% (d) 4%

Solution (c) $E \propto \frac{1}{r^2}$

$$\frac{\Delta E}{E} = \frac{2\Delta r}{r} \Rightarrow 2\,(1\%) = 2\%$$

15. A room is illuminated by an extended source. The illuminance at a particular portion can be increased by

(a) moving the source

(b) rotating the source

(c) changing the colour of the source

(d) placing mirrors at proper positions

(e) all of these

Solution (e)

TYPICAL PROBLEMS

16. A photographic plate records sufficiently intense image when exposed with 10 W source for 12 *s*. How much time it will take if exposed with 12 W source

(a) 12 *s* (b) 10 *s*

(c) 8 *s* (d) 9 *s*

Solution (b) Energy be equal $P_1 t_1 = P_2 t_2$

or $t_2 = \dfrac{12\times 10}{12} = 10\ s$

17. A source emits 31.4 W of radiant flux distributed uniformly in all directions. The luminous efficiency is 60 lumen/W. Find the luminous intensity of the source.

(a) 600 π *Cd* (b) 600 *Cd*

(c) 150 *Cd* (d) 100 *Cd*

Solution (c) $F = 31.4 \times 60\ lm$,

$$I = \frac{F}{4\pi} = \frac{31.4\times 60}{4\pi} = 150\ Cd.$$

18. Two light sources of 8 and 12 *Cd* are placed on the same side of the photometer screen at a distance of 40 cm from it. Where should a 80 *Cd* source be placed to balance the illuminance?

(a) 40 cm (b) 60 cm

(c) 20 cm (d) 80 cm

Solution (d) $\dfrac{(8+12)}{40^2} = \dfrac{80}{d^2}$

or $d = 80$ cm

19. A student is studying a book placed at the edge of a circular table of radius *R*. A point source of light is suspended directly above the centre of the table. What should be the height of the lamp so that maximum illuminance is produced at the position of the book?

(a) R (b) $R/2$

(c) $R/\sqrt{2}$ (d) $R/\sqrt{3}$

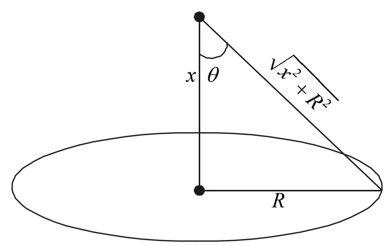

Fig. 31.6

Solution (c) $I = \dfrac{I_0 \cos\theta}{(x^2+R^2)} = \dfrac{I_0 x}{(x^2+R^2)^{3/2}}$.

For I to be maximum $\dfrac{dI}{dx} = 0$ or

$$\frac{I_0}{(x^2+R^2)^{3/2}} - \frac{x\left(3/2\right)(2x)}{\left(x^2+R^2\right)^{5/2}} = 0$$ or

$R^2 - 2x^2 = 0$ or

$x = R/\sqrt{2}$

20. An electric lamp and a candle produce equal illuminance on a screen when placed 80 cm and 20 cm from the screen respectivley. The lamp is now covered with a thin paper which transmit 49% of the luminous flux. By what distance the lamp be moved to balance the intensities at the screen again?

(a) 24 *cm* (b) 12 *cm*

(c) 18 *cm* (d) 56 *cm*

Solution (a) Case (i) $\dfrac{I_1}{I_2} = \left(\dfrac{80}{20}\right)^2$

Case (ii) $\dfrac{.49 I_1}{I_2} = \left(\dfrac{d}{20}\right)^2$ or

$d = 20\sqrt{.49(16)} = 20\,(2.8)$

$= 56\ cm$

Lamp be moved by $80 - 56 = 24\ cm$

21. In the Foucault's method, the distance from the rotating mirror to concave mirror is 20 m. Lens is placed mid way between the illuminated slit and the rotating mirror which are 2 m apart. If the rotating mirror makes 438 revolutions per second and the deflection of the image is 0.7 mm calculate the velocity of light.

(a) $2.847 \times 10^8\ ms^{-1}$ (b) $2.927 \times 10^8\ ms^{-1}$

(c) $2.649 \times 10^8\ ms^{-1}$ (d) $2.992 \times 10^8\ ms^{-1}$.

Solution (d) $C = \dfrac{4\omega R^2 a}{S(R+b)} = \dfrac{4(2\pi \times 438)\times(20)^2 \times 1}{.7\times10^{-3}(20+1)}$

$= 2.992 \times 10^8\ ms^{-1}$

22. The illumination produced by A is balanced by B on the screen when B is 60 cm apart from the screen. A smoked glass plate is placed in front of A and to balance the illumination B is to move 15 cm further away. Find the transmission coefficient of the smoked glass.

(a) 0.36 (b) 0.64

(c) 0.49 (d) 0.51

Solution (b) $\alpha = \dfrac{I_2}{I_1} = \left(\dfrac{60}{75}\right)^2 = \left(\dfrac{4}{5}\right)^2 = \dfrac{16}{25} = 0.64$

23. Which of the following is the method used to measure the speed of light in laboratory

(a) Fizeau method (b) Roemer method

(c) Michelson method (d) Foucault's method

Solution (d)

24. In Michelson method distance travelled by light between two reflection is 4.8 km. The shape of rotating mirror is regular octagon. At what minimum speed (other than zero) is the image formed at the position where non rotating mirror forms it?

(a) 780 *rev/s* (b) 7800 *rev/s*

(c) 690 *rev/s* (d) 7500 *rev/s*

Solution (b) $C = Dfn \quad f = \dfrac{C}{DN}$

$= \dfrac{3\times10^8}{4.8\times10^3}\times 8 = \dfrac{10^5}{12.6}$

PASSAGE 1

Read the following passage and answer the questions given at the end.

Herring and related fish have a brilliant silvery appearance that camouflages them while swimming in a sunlit ocean. The silveriness is due to platelets attached to the surfaces of these fish. Each platelet is made up of several alternating layers of crystalline guanine (n = 1.8) and of cytoplasm layers ($n = 4/3$) with a guanine layer on the outside in contact with the surrounding water. In one typical platelet guanine layers are 74 nm thick and cytoplasm layers are 100 nm thick. Light is striking platelet surface at normal incidence for which vacuum wavelengths of visible light reflections are R_1, R_2, R_3, R_4 and R_5 as shown in Figure 31.7.

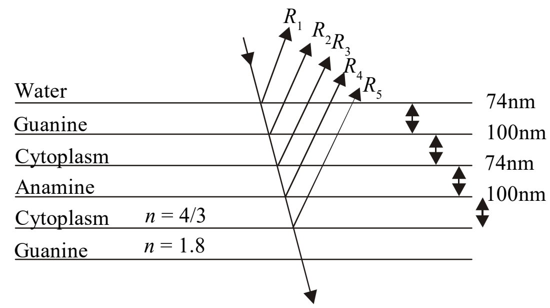

Fig. 31.7

1. Are R_1, R_2, R_3, R_4 and R_5 nearly in phase?

(a) yes (b) no

(c) maintain a constant phase (d) insufficient data to reply

2. If white light is incident on this platelet which colour will be strongly reflected?

(a) Red (b) blue

(c) green (d) voilet

3. Does the colour most reflected depends on the angle at which it is viewed?

(a) yes

(b) No, it depends only on refractive index of the substance

(c) No, it depends on the thickness of the layers only.

(d) No, it depends on the refractive index of the medium.

Solution **1.** (a), (c)

Solution **2.** (c) Voilet $\dfrac{\lambda}{4} = 100\text{ nm or } \lambda = 400\text{ nm}$

Solution **3.** (a).

QUESTIONS FOR PRACTICE

1. 1% of light of a source with luminous intensity 50 candela is incident on a circular surface of radius 10 cm. The average illuminace of the surface is

(a) 100 lux (b) 200 lux

(c) 300 lux (d) 400 lux

2. The illuminace of a surface is 10 lux. If the total area of the surface is 30 cm^2, then the luminous flux incident on it will be

(a) 3×10^{-4} 1m (b) 3×10^{-3} 1m

(c) 3×10^{-2} 1m (d) 3×10^{-1} 1m

3. The luminous efficiency of a lamp is 51mW^{-1} and its luminous intensity is 35Cd. The power of the lamp is

(a) 11W (b) 22W

(c) 44W (d) 88W

4. The luminous intensity of a light source is 500 Cd. The illuminace of a surface distant 10 m from it, will be if light falls normally on it

(a) 5 lux (b) 10 lux

(c) 20 lux (d) 40 lux

5. The luminous intensity of a light source is 300 Cd. The illuminance of a surface lying at a distance of 10 m from it will be if light falls normally on it

(a) 30 lux (b) 3 lux

(c) 0.3 lux (d) 0.03 lux

6. In the above problem, if light falls on the surface at an angle of 60°, then illuminance will be—

(a) 12 lux (b) 6 lux

(c) 3 lux (d) 1.5 lux

7. A lamp is hanging at a height of 4 m above a table. The lamp is lowered by 1m. The percentage increase in illuminace will be

(a) 40% (b) 64%

(c) 78% (d) 92%

8. At what distance should a book be placed from a 50 Cd bulb so that the illuminace on the book becomes $2\, l\, \text{m}\, \text{m}^{-2}$

(a) 1m (b) 5m

(c) 10m (d) 50m

9. Two light sources with equal luminous intensity are lying at a distance of 1.2 m from each other. Where should a screen be placed between them such that the illuminace on one of its faces is four times that on the another face?

(a) 0.2m (b) 0.4m

(c) 0.8m (d) 1.6m

10. Two lamps of luminous intensity of 8 Cd and 32 Cd respectively are lying at a distance of 1.2 m from each other. Where should a screen be placed between two lamps such that its two faces are equally illuminated due to the two sources?

(a) 10cm from 8 Cd lamp (b) 10cm from 32 Cd lamp

(c) 40cm from 8 Cd lamp (d) 40 cm from 32 Cd lamp

11. In the above problem, another position of the screen where its one face will be equally illuminated by the two sources will be

(a) 60 cm from 8 Cd lamp

(b) 120 cm from 8Cd tamp

(c) 60 cm from 32Cd lamp

(d) 120 cm from 32 Cd lamp

12. A photoprint is required to be placed in front of 100 Cd lamp at a distance of 0.5 m for 25 sec for good impression. If it is to be placed in front of a 400 Cd lamp for 36 sec for the same impression then the distance of the print from the lamp will be

(a) 0.5m (b) 1.0m

(c) 1.2m (d) 1,5m

13. A lamp is hanging along the axis of a circular table of radius r. At what height should the lamp be placed above the table, so that the illuminace at the edge of the table is $\frac{3}{8}$ of that at its center?

(a) $\frac{r}{2}$ (b) $\frac{r}{\sqrt{2}}$

(c) $\frac{r}{3}$ (d) $\frac{r}{\sqrt{3}}$

14. Two small lamps A and B, the first placed 60cm to the left of a Bunsen photometer and the second placed 100 cm to the right of the same photometer, produce equal illuminance at the photometer. A large perfectly reflecting mirror is then placed 20 cm to the left of A with its reflecting surface normal to the axis of the bench. The llluminance on two sides of the photometer become unequal. Through what distance must the lamp B be moved in order to restore equality of illuminance on the photometer?

(a) 0.143 m (b) 0.234 m

(c) 0.369 m (d) 0.457 m

15. A photographic print was found to be satisfactory when the exposure was for 20 s at a distance of 0.6 m from a 40 W lamp. At what distance must the same paper be held from a 60W lamp in order that an exposure of 36 s may give the same result?

(a) 1.2 m (b) 0.98 m

(c) 0.72 m (d) 0.66 m

16. A screen receives 3 watt of radiant flux of wavelength 6000 Å. One lumen is equivalent to 1.5×10^{-3} watt of monochromatic light of wavelength 5550 Å. If relative luminosity for 6000Å is 0.685 while that for 5550Å is 1.00, then the luminous flux of the source is—

(a) 4×10^3 1m (b) 3×10^3 1m

(c) 2×10^3 1m (d) 1.37×10^3 1m

17. A point source of 100 candela is held 5m above a sheet of blotting paper which reflects 75% of light incident upon it. The illuminance of blotting paper is

(a) 4 phot (b) 4 lux

(c) 3 phot (d) 3 lux

18. In the above problem, the luminance of blotting paper is

(a) 3 phot (b) 3 lux

(c) 4 phot (d) 4 lux

19. A fluorescent tube which is equivalent to a line source of 100 candela per meter is hung horizontally 5 meters above the table. The illuminance at a point vertically below the tube will be

(a) 8 lux (b) 8 phot
(c) 40 lux (d) 40 phot

20. A source of light emits a continuous stream of light energy which falls on a given area. Luminous intensity is defined as

(a) luminous energy emitted by the source per second.
(b) luminous flux emitted by the source per unit solid angle
(c) luminous flux falling per unit area of a given surface.
(d) luminous flux coming per unit area of an illuminated surface.

21. Inverse square law for illuminace is valid for

(a) isotropic point source
(b) cylindrical source
(c) search light
(d) all types of sources

22. The distance between a point source of light and a screen is doubled. The intensity will be

(a) four times the original value
(b) two times the original value
(c) half the original value
(d) one quarter of the original value

23. The unit of luminous efficiency of electric bulb is—

(a) Watt (b) Lumen
(c) Lumen/watt (d) Lux

24. Candela is a unit of

(a) accoustic intensity (b) electric intensity
(c) luminous intensity (d) magnetic intensity

25. The luminous intensity of a 100 W unidirectional bulb is 100 candela. The total luminous flux emitted from the bulb will be—

(a) 100π lumen (b) 200π lumen
(c) 300π lumen (d) 400π lumen

26. In the above problem the luminous efficiency of the bulb in lumen/watt will be—

(a) 4π (b) 37π
(c) 2π (d) π

27. When sunlight falls normally on earth, a luminous flux of 1.57×10^5 lumen/m^2 is produced on earth. The distance of earth from sun is 1.5×10^8 Km. The luminous intensity of sun in candela will be

(a) 3.53×10^{27} (b) 3.53×10^{25}
(c) 3.53×10^{29} (d) 3.53×10^{21}

28. In the above problem, the luminous flux emitted by sun will be

(a) 4.43×10^{25} 1m (b) 4.43×10^{26} 1m
(c) 4.43×10^{27} 1m (d) 4.43×10^{28} 1m

29. An electric bulb of luminous intensity I is suspended at a height h from the center of the table having a circular surface diameter $2r$, The illuminace at the center of the circular disc will be

(a) $\frac{I}{r^2}$ (b) $\frac{I}{r}$
(c) $\frac{I}{h^2}$ (d) $\frac{I}{h}$

30. A lamp of 250 candle power is hanging at a distance of 6m from a wall. The illuminace at a point on the wall at a minimum distance from the lamp will be

(a) 9.64 lux (b) 4.69 lux
(c) 6.94 lux (d) none of these

31. In the above problem, the illuminace at a point on the wall at a distance 8 m below the previous point will be

(a) 2.5 lux (b) 1.5 lux
(c) 0.5 lux (d) none of these

32. If the distance of a surface from light source is doubled, then the illuminace will become

(a) $\frac{1}{2}$ times (b) 2 times
(c) $\frac{1}{4}$ times (d) 4 times

33. The luminous flux of a 60 W power bulb is 600 lumen. The luminous efficiency of the bulb will be

(a) 60 lmW^{-1} (b) 600 lmW^{-1}
(c) 0.1 lmW^{-1} (d) 10 lmW^{-1}

34. The luminous efficiency of a lamp is 5 1mW^{-1} and its luminous intensity is 30 candela. The power of the lamp will be

(a) 6πW (b) 12πW
(c) 24πW (d) 48πW

35. The luminous efficiency of a lamp is 8.8 lumen/watt and its luminous intensity is 700 Cd. The power of the lamp will be

(a) 10^1W (b) 10^2W
(c) 10^3W (d) 10^4W

36. The light from an electric bulb is normally incident on a small surface. If the surface is tilted to 60° from this position, then the illuminace of the surface will become

(a) half (b) one fourth
(c) double (d) four times

37. The illuminace of a surface distant 10 m from a light source is 10 lux. The luminous intensity of the source for normal incidence will be

(a) 10^1 Cd (b) 10^2 Cd

(c) 10^3 Cd (d) none of these

38. Light from a lamp is falling normally on a surface distant 10 m from the lamp and the luminous intensity on it is 10 lux. In order to increase the intensity 9 times, the surface will have to be placed at a distance of

(a) 10 m (b) $\frac{10}{3}$ m

(c) $\frac{10}{9}$ m (d) 10×9 m

39. The illuminace on screen distant 3 m from a 100 W lamp is 25 1m/m^2. Presuming normal incidence, the luminous intensity of the bulb will be

(a) 100 Cd (b) 25 Cd

(c) 225 Cd (d) none of these

40. In a grease spot photometer, light from a lamp with dirty chimney is exactly balanced by a point source distant 10 cm from the grease spot. On clearing the chimney, the point source is moved 2 cm to obtain balance again, The percentage of light absorbed by dirty chimney is nearly

(a) 56% (b) 44%

(c) 36% (d) 64%

41. A screen is illuminated by two point sources A and B. Another source C sends a parallel beam of light towards point P on the screen. The lines AP, BP and CP are 3m, 1.5 m and 1.5 m respectively. The radiant power of the sources A and B are 90 W and 180 W respectively. The beam coming from C is of intensity 20 W/m^2 . The intensity at point P on the screen due to the source A will be

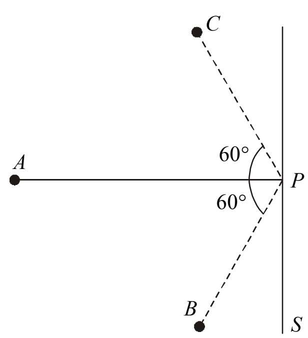

Fig. 31.8

(a) $\frac{1.25}{p}$ (b) $\frac{2.5}{p}$ W/m^2

(c) $\frac{5}{p}$ W/m^2 (d) $\frac{10}{p}$ W/m^2

42. In the above problem, the intensity at point P due to the source B will be

(a) $\frac{1.25}{p}$ W/m^2 (b) $\frac{2.5}{p}$ W/m^2

(c) $\frac{5}{p}$ W/m^2 (d) $\frac{10}{p}$ W/m^2

43. In Q. 41, the intensity at point P due to the source C will be

(a) 5 W/m^2 (b) 10 W/m^2

(c) 15 W/m^2 (d) 20W/m^2

44. In Q. 41, the total intensity at point P due to the source A, B and C will be

(a) 10W/m^2 (b) 20W/m^2

(c) 14 W/m^2 (d) 28W/m^2

45. A point source of light is situated at a distance of 5 cm from a screen. There is a hole of diameter 7 cm in the screen and light of luminous intensity 15.4 lumen passes through it. The solid angle subtended by the hole at the source will be (in str)

(a) 1.54 (b) 2.27

(c) 3.14 (d) 4.7

46. In the above problem, the luminous intensity of the source in the direction of hole will be

(a) 40 Cd (b) 30 Cd

(c) 20 Cd (d) 10 Cd

47. In Q45, the luminous flux emitted by the source, will be—

(a) 10p lumen (b) 20p lumen

(c) 30p lumen (d) 40p lumen

48. In the adjoining figure is shown a circular cross-section of tunnel. A bulb of 100W is lighting at the highest point S of the tunnel. The diameter of the tunnel is 4m. The illuminance at point Q will be

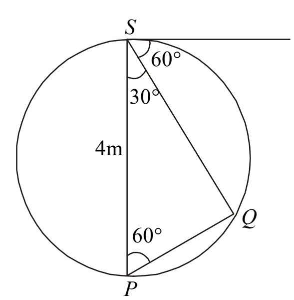

Fig. 31.9

(a) $\frac{25\sqrt{3}}{6} W/m^2$ (b) $\frac{25}{4} W/m^2$

(c) $\frac{25\sqrt{3}}{4} W/m^2$ (d) $\frac{25}{6} W/m^2$

49. In the above problem, the ratio of illuminace, at points Q and P will be

(a) $\frac{\sqrt{3}}{2}$ (b) $\frac{2}{\sqrt{3}}$

(c) $\frac{3}{2}$ (d) $\frac{2}{3}$

50. A lamp of luminous intensity 20 Cd is hanging at a height of 40 cm from the center of a square table of side 60 cm. The illuminance at the centre of the table will be

(a) 100 Lux (b) 125 Lux

(c) 150 Lux (d) none of these

51. In the above problem, the illuminance at the mid-point of the side of the table will be

(a) 125 Lux (b) 100 Lux

(c) 64 Lux (d) 32 Lux

52. In Q 50, the illuminance at the corner of the table will be

(a) 125 Lux (b) 64 Lux

(c) 72 Lux (d) 40.35 Lux

PASSAGE 1

Read the following passage and answer the questions given at the end

Youngs double slit experiment is valid for any type of wave. Two sources S_1 and S_2 are effective point sources of radiation excited by the same oscillator. S_1 and S_2 are along y axis distance d apart. They are coherent and in phase with each other. They emit equal amount of power in the forms of 1 m wavelength electromagnetic radiation. A detector is moved along OX. The source S_1 and S_2 are 4 m apart.

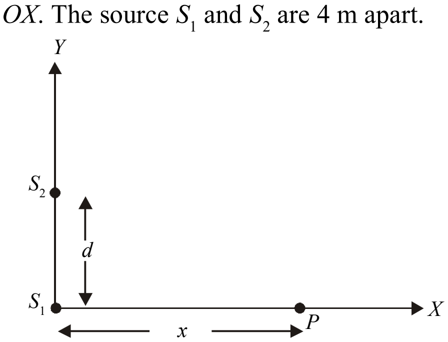

Fig. 31.10

1. Find the position where intensity is maximum closest to source S_1.

(a) 5 m (b) 6 m

(c) 7.5 m (d) 9 m

2. The minimum intensity will be

(a) zero at all minima

(b) nonzero at some minima

(c) cannot be determined.

(d) different at different minima but not zero

Solution **1.** (c) condition for obtanining a maxima is path difference $\Delta x = n\lambda$

$$\sqrt{(d^2 + x^2)} - x = n\lambda$$

or $d^2 + x^2 = (n\lambda + x)^2$

$d^2 + x^2 = n^2\lambda^2 + x^2 + 2n\lambda x$

$4^2 = n^2(1)^2 + 2n(1)x$ for $n = 1$ $x = 7.5$ m

Solution **2.** (d) $I = (\sqrt{I_1})^2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$

The minima will be obtained when $\phi = (2n + 1/2)\lambda$

$$\sqrt{(d^2 + x^2)} - x = (2n + 1/2)\lambda \text{ or } d^2 + x^2 = \frac{\lambda^2}{4} + x^2 + x\lambda$$

$$x = 16 - \frac{1}{4} = 15.75 \text{ m.}$$

$$I_1 = \frac{P}{4\pi(15.75)^4}, I_2 = \frac{P}{4\pi(17.1)^2} \text{ since } I_1 \neq I_2$$

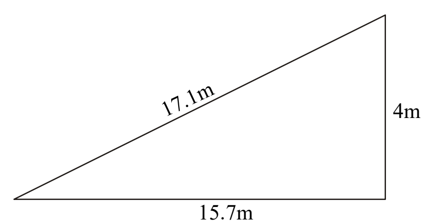

Fig. 31.11

$\therefore$ intensity cannot be zero at minima.

Answers to Questions for Practice

1.	(b)	2.	(c)	3.	(d)	4.	(a)	5.	(b)	6.	(d)	7.	(c)
8.	(b)	9.	(b)	10.	(c)	11.	(b)	12.	(c)	13.	(d)	14.	(a)
15.	(b)	16.	(d)	17.	(b)	18.	(b)	19.	(c)	20.	(b)	21.	(d)
22.	(d)	23.	(c)	24.	(c)	25.	(d)	26.	(a)	27.	(a)	28.	(d)
29.	(c)	30.	(c)	31.	(b)	32.	(c)	33.	(d)	34.	(c)	35.	(c)
36.	(a)	37.	(c)	38.	(b)	39.	(c)	40.	(c)	41.	(b)	42.	(d)
43.	(b)	44.	(c)	45.	(a)	46.	(d)	47.	(d)	48.	(a)	49.	(b)
50.	(b)	51.	(c)	52.	(d)								