COVENANT UNIVERSITY
NIGERIA

TUTORIAL KIT
OMEGA SEMESTER

PROGRAMME: PHYSICS

COURSE: PHY 223

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PHY 223: Waves and Optics

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1. An outside loudspeaker emits sound waves with a power output of 600 W.
(i) Find the intensity 30.0 m from the source
(ii) Find the intensity level in decibels, at this distance (Take reference intensity $I_0 = 1.00 \times 10^{-12} \, W/m^2$)

SOLUTION

(i) $I = \dfrac{P}{4\pi r^2}$

Intensity I = ?
Power (P) = 900W
Radius (r) = 30.0 m

$$I = \frac{900}{4\pi (30.0)^2}$$

$$= \frac{600}{4 \times 3.14 \times 900}$$

$$= \frac{600}{11304}$$

$$= 0.05 \, W/m^2$$

(ii) $\beta = 10 \log\left(\dfrac{I}{I_0}\right)$

Sound level (β)=?

Intensity (I) =0.05 W/m^2

Reference intensity $I_0 = 1.00 \times 10^{-12} \, W/m^2$

$$\beta = 10 \log\left(\frac{0.05}{1.00 \times 10^{-12}}\right)$$

$$= 10 \log\left(5.0 \times 10^{10}\right)$$

$$= 106.98 dB$$

2. Derive an expression for the velocity of longitudinal waves in metal rod.
3. A 200 g mass vibrates horizontally without friction at the end of a horizontal spring for k=7.0 N/m. The mass is displaced 5.0 cm from equilibrium and released. Find
   (i) its maximum speed
   (ii) its speed when it is 3.0cm from equilibrium

SOLUTION
(i)

$$V = \sqrt{\frac{k}{m}\left(x_0^2 - x^2\right)}$$

$$k = 7.0\,{}^{N}\!/_{m}$$

$$x_0 = 0.050m$$

$$m = 0.200kg$$

$$x = 0$$

$$V = x_0\sqrt{\frac{k}{m}}$$

$$= (0.050)\sqrt{\frac{7.0}{0.200}}$$

$$= 3.30\,{}^{m}\!/_{s}$$

(ii)

when x = 0.030m

$$V = \sqrt{\frac{k}{m}\left(x_0^2 - x^2\right)}$$

$$V = \sqrt{\frac{7.0}{0.200}\left((0.050)^2 - (0.030)^2\right)}$$

$$= 0.24\,{}^{m}\!/_{s}$$

4. Show that the energy of a harmonic oscillator is 

5. Compute the acceleration due to gravity at a place where a simple pendulum 150.3 cm long makes 100.0 cycles in 246.7 s

SOLUTION

Length of the thread (L) =1.503m

Acceleration due to gravity (g) = ?

Period (T) = $\frac{246.7}{100}$

T = 2.467s

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$g = \frac{4\pi^2}{T^2}l$$

$$= \frac{4\times(3.14)^2\times 1.503}{(2.467)^2}$$

$$g = 9.749\,{}^{m}\!/_{s^2}$$

6. Show the relationship between group velocity and phase velocity.

7. A whistle producing sound of frequency 1000 Hz moves with a velocity of 50 m . An observer also moves in the same direction with a velocity of 25 m . If the speed of sound in air is 350 m , what is the frequency of the sound as heard by the observer?

SOLUTION

(i)

$$= \frac{}{}$$

$$= \frac{}{}$$

$$= \frac{350 + 25}{350 + 50} \times 1000$$

$$= 938$$

$$= \frac{}{}$$

$$= \frac{350 - 25}{350 - 50} \times 1000$$

$$= \frac{325}{300} \times 1000$$

$$= 1.08333 * 1000$$

$$= 1083$$

8. A uniform cord has a mass of 0.3Kg and a length of 6.0m. The cord passes over a pulley and supports a 2.00 kg. Find the speed of a pulse travelling along this cord.

9. A 20 kg electric motor is mounted on four vertical springs, each having a spring constant of 30 N/cm. Find the period with which the motor vibrates vertically.

SOLUTION

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$= 2\pi\sqrt{\frac{20}{1200}}$$

$$T = 0.26s$$

10. A taut string for which is under a tension of 80.0 N. How much power must be supplied to the string to generate sinusoidal waves at a frequency of 60.0 Hz and amplitude of 6.00 cm

11. With reference to lens system define the following parameters

a) Principal plane

b) Focal point

c) Nodal point

SOLUTION

a. Principal plane**:** this is a perpendicular plane in a lens system at which all the refraction can be considered to happen.

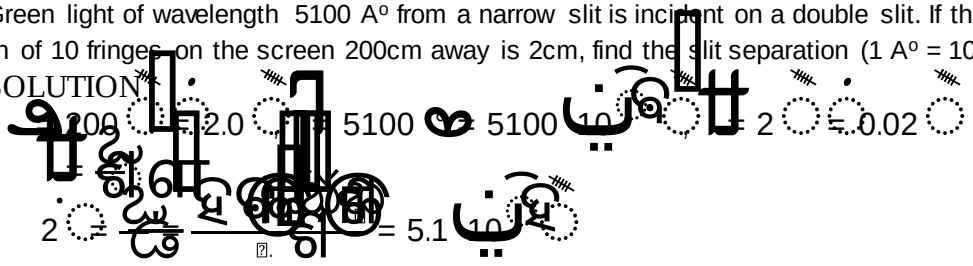
b. Focal point**:** it is a point through which any ray that passes through it will travel parallel to the optical axis after refraction from the lens system.

c. Nodal point: this is the point which describes the paths of rays that are not refracted, but are translated down the optical axis.

12. Using Snell's law prove that the reflected and refracted rays are perpendicular to each other.

13. Green light of wavelength 5100 A^o from a narrow slit is incident on a double slit. If the overall separation of 10 fringes on the screen 200cm away is 2cm, find the slit separation (1 $A^o = 10^{-10}$m)

SOLUTION



14. What is holography? State three of its application

15. List and explain three types of scattering

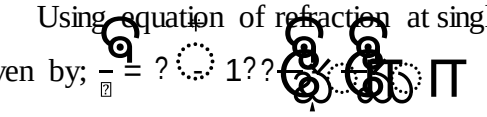
SOLUTION

a. Rayleigh Scattering: It refers to the scattering of light off the molecules of the air to about a tenth (< 1 /10 wavelengths) of the wavelength of the light. It increases with the fourth power of the frequency and is more effective at short wavelengths. This type of scattering is elastic in nature and is responsible for the blue colour of the sky.

b. Raman Scattering: It is an inelastic type of scattering. It occurs when incident photons interact with the air molecules in such a way that energy is either gained or lost so that the scattered photons are shifted in frequency.

c. Mie Scattering: It is a scattering that takes place in air molecules with particle sizes larger than a wavelength. It produces a pattern like an antenna lobe, with a sharper and more intense forward lobe for larger particles. Mie scattering is not strongly wavelength dependent and produces the almost white glare around the sun when a lot of particulate material is present in the air. It is responsible for the white light from mist and fog.

16. State the difference between Polaroid and polarimeter

17. Using equation of refraction at single spherical surface show that the lensmaker equation is given by; 

SOLUTION

Using single-surface equation, twice, one for each surface. The resulting equations are;

$$\frac{n_1}{s_1} + \frac{n_2}{i_1} = \frac{n_2 - n_1}{R_1} \quad 1$$

$$-\frac{n_2}{s_2} + \frac{n_3}{i_2} = \frac{n_3 - n_2}{R_2} \quad 2$$

Note; image point i_1 acts as the source point s_2 for the interaction with the second surface of the lens, thus eqn. 2 becomes

$$-\frac{n_2}{i_1 - t} + \frac{n_3}{i_2} = \frac{n_3 - n_2}{R_2} \quad 3$$

Since n_1 is index in air, let $n_1 = 1$

$$\frac{1}{s_1} + \frac{n_2}{i_1} = \frac{n_2 - 1}{R_1} \quad 4$$

$$-\frac{n_2}{i_1 - t} + \frac{n_3}{i_2} = \frac{n_3 - n_2}{R_2} \quad 5$$

Add eqns. 4 and 5

Eqn. 6 can be written in the form

$$\frac{1}{f} = (n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad 7$$

Eqn.7 gives the lensmaker equation as

$$\frac{1}{f} = (n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad 8$$

Where f = focal length; $\frac{1}{f} = \frac{1}{s} + \frac{1}{i}$; s = object distance, i = image distance, n = index of refraction, R_1 = radius of surface 1, R_2 = radius of surface 2.

18. Calculate the thickness of (i) a quarter-wave plate and (ii) half-wave plate, given that n_e = 1.533, n_o = 1.544 λ = 5000 Å

19. An equiconvex lens located in air has radii of 5.0cm, an index of 1.56, and a thickness of 3.70cm. Calculate the focal length and the power of the lens.

SOLUTION

R_1 = 5.0 cm, R_2 = -5.0 cm, n_2 = 1.56, t = 3.70 cm

$\frac{1}{f} = (n_2 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ 1mk

$\frac{1}{f} = (1.56 - 1)\left(\frac{1}{5.0} - \frac{1}{-5.0}\right) = 0.56\left(\frac{2}{5.0}\right)$

$f = \frac{5.0}{1.12} = 4.46$ cm

P = $\frac{1}{f(m)}$ = 19.43 D

20. State three differences between diffraction and interference