I B.Tech. (2023-24) – I Semester - Engineering Physics (PHY 1071)

Mid Term Examination - Scheme of Evaluation

Q1. Resolution of a telescope can be increased by (0.5)

1. ** Increasing the diameter of objective lens
2. Decreasing the diameter of objective lens
3. Increasing the wavelength and decreasing the diameter of objective lens
4. Increasing the wavelength

Q2. The spacing between the rulings in a diffraction grating is 3µm. How many complete primary maxima can be formed from this grating for a wavelength of 550 nm? (0.5)

1. 22
2. 10
3. **11
4. 5

Q3. A beam of x rays of wavelength 1 Å is found to diffract in second order from the face of a LiF crystal at a Bragg angle of 30°. The distance between adjacent crystal planes, in nm, is (0.5)

1. 0.10
2. 0.40
3. **0.20
4. 0.50

Q4. If the Newton's ring set up is immersed in water, then (0.5)

1. ** Ring diameter will decrease
2. Ring diameter will increase.
3. Radius of curvature of the lens will increase.
4. Ring diameter will remain same

Q5. If the amplitude ratio of two interfering beams is 3:2 then the intensity ratio of maxima and minima in the interference pattern will be (0.5)

1. **25:1
2. 9:4
3. 1:0
4. 3:2

Q6. The method of population inversion in the He-Ne laser is (0.5)

1. **He-Ne collisions
2. Direction conversion
3. Optical pumping
4. Electron impact

Q7. The angle of acceptance of an optical fibre is 30 degrees when kept in air. What will be the angle of acceptance when it is in a medium of refractive index 1.33? (0.5)

1. 5 degrees

2. 18 degrees
3. 36 degrees
4. ** 22 degrees

Q8. If the velocity of a charged particle in perpendicular electric and magnetic field is 7.27 X 10^6m/s and the Electric field is 6 X 10^6 N/C, what should be the value of magnetic field? (0.5)

1. 0.45 T
2. 0.70 T
3. **0.83 T
4. 0.94 T

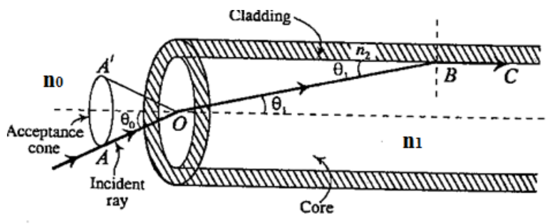
Q9. A blackbody has maximum wavelength λ at 5000 K. Its corresponding wavelength at 4000 K will be (0.5)

1. 2 λ /5
2. ** 5 λ /4
3. λ /4
4. 4 λ /5

Q10. The maximum kinetic energy of a photoelectron when a surface (work function = 4.5 eV) is illuminated by photons with wavelength 400 nm is (0.5)

1. 1.4 eV
2. ** zero
3. −1.4 eV
4. 3.1 eV

Q11. With necessary diagram, derive an expression for angle of acceptance and numerical aperture for an optical fibre. (4)



(1 Marks)

Applying Snell's law of refraction at *O*, we have,

$$\frac{\sin\theta_0}{\sin\theta_1} = \frac{n_1}{n_0}$$

$$\therefore \ \sin\theta_0 = \frac{n_1}{n_0}\sin\theta_1$$ (1 Marks)

Similarly, applying Snell's law at *B*,

$$\frac{\sin(90^\circ - \theta_1)}{\sin 90^\circ} = \frac{n_2}{n_1} \quad \text{or} \quad \cos\theta_1 = \frac{n_2}{n_1}$$

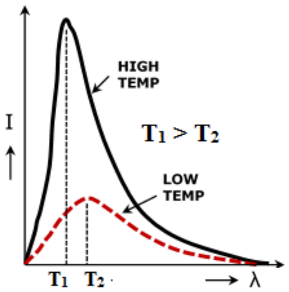
$$\sin\theta_1 = \sqrt{1 - \frac{n_2^2}{n_1^2}}$$ (1 Marks)

$$\sin\theta_0 = \frac{1}{n_0}\sqrt{n_1^2 - n_2^2}$$

θ_0 is called the acceptance angle or half angle of the acceptance cone. The term $n_0 \sin\theta_0$ is called numerical aperture (*NA*). (1 Marks)

Q12. What is a black body? Draw typical black body radiation spectra for two different temperatures T_1 and T_2 ($T_1 > T_2$) and explain Stefan's law and Wien's Displacement law. (4)

A black body is an idealized object that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. It not only absorbs radiation, but can also emit radiation across all frequencies. (1 Marks)



(1 Mark)

Stefan's Law : Hotter objects emit more energy per unit area. Power emitted by a black body is directly proportional to forth power of temperature

$$P = \sigma A e T^4$$

P – Power σ–Stefan Constant, A –Surface area, e–emissivity (1 Mark)

(Mathematical Expression is not necessary if proper explanation is given)

Wien's Displacement Law : The peak of the wavelength distribution shifts to shorter wavelengths as the black body temperature increases

$\lambda_m T$ = constant (1 Mark)

(Mathematical Expression is not necessary if proper explanation is given)

Q13. Obtain an expression for radiation pressure exerted on a perfectly reflecting surface for normal incidence of the wave. (3)
Let us assume the electromagnetic wave strikes the surface at normal incidence and transports a total energy T_{ER} in this time interval (as does a blackbody), the total momentum $\vec{\mathbf{p}}$ transported to the surface has a magnitude

$$p = \frac{T_{ER}}{c}$$

The pressure P exerted on the surface is defined as force per unit area, F/A, which when combined with Newton's second law gives

$$P = \frac{F}{A} = \frac{1}{A}\frac{dp}{dt}$$

$$P = \frac{1}{A}\frac{dp}{dt} = \frac{1}{A}\frac{d}{dt}\left(\frac{T_{ER}}{c}\right) = \frac{1}{c}\left(\frac{dT_{ER}/dt}{c}\right)$$ (2 Marks)

We recognize (dT_{ER}/dt)/A is the rate at which energy is arriving at the surface per unit area, which is the magnitude of the Poynting vector. Therefore, the radiation pressure P exerted on the perfectly absorbing surface is

$P = \frac{S}{c}$ (complete absorption) (0.5 Marks)

If the surface is a perfect reflector (such as a mirror) and the incidence is normal,

$$p = \frac{2T_{ER}}{c}$$

The radiation pressure exerted on a perfectly reflecting surface for normal incidence of the wave is

$$P = \frac{2S}{c}$$ (0.5 Marks)

Q14. A material having an index of refraction of 1.30 is used as an antireflective coating on a piece of glass (n = 1.50). What should the minimum thickness of this film be to minimize reflection of 500-nm light? (3)

$$2nt = \left(m + \frac{1}{2}\right)\lambda \quad \text{so} \quad t = \left(m + \frac{1}{2}\right)\frac{\lambda}{2n}$$

(1+1 Marks)

The minimum thickness of the film is therefore

$$t = \left(\frac{1}{2}\right)\frac{(500 \text{ nm})}{2(1.30)} = \boxed{96.2 \text{ nm}}$$

(1 Marks)

Q15. A pulsed ruby laser emits light at 694.3 nm. For a 14.0-ps pulse containing 3.00 J of energy, find (a) the length of the pulse as it travels through space and (b) the number of photons in it. (3)

a)

$$\Delta L = c\Delta t = (3.00 \times 10^8 \text{ m/s})(14.0 \times 10^{-12} \text{ s}) = \boxed{4.20 \text{ mm}}$$ (1 Marks)

b)

$$E = \frac{hc}{\lambda} = 2.86 \times 10^{-19} \text{ J}$$ (1 Marks)

so the number of photons in the pulse is

$$N = \frac{3.00 \text{ J}}{2.86 \times 10^{-19} \text{ J/photon}} = \boxed{1.05 \times 10^{19} \text{ photons}}$$ (1 Marks)

Q16. The angular resolution of a radio telescope is to be 0.100° when the incident waves have a wavelength of 3.00 mm. What minimum diameter is required for the telescope's receiving dish? (3)

$$\theta_{\min} = 1.22\frac{\lambda}{D} = 0.100°\left(\frac{\pi \text{ rad}}{180°}\right) = 1.75 \times 10^{-3} \text{ rad}$$

$$D = 1.22\left(\frac{\lambda}{\theta_{\min}}\right) = 1.22\left(\frac{3.00 \times 10^{-3} \text{ m}}{\theta_{\min}}\right) = \boxed{2.10 \text{ m}}$$

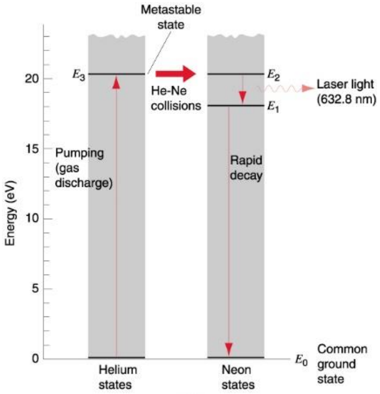
(1.5 Marks)

(1.5 Marks)

Q17. Explain the operation of He-Ne laser with necessary energy level diagrams. (3)

He-Ne Laser has a glass discharge tube filled with He (80%) and Ne (20%) at low pressure. Helium gas is the "pumping" medium and Neon gas is the "lasing" medium (Figure 1). The simplified energy level diagram shows four levels: E_o, E_1, E_2 and E_3. Electrons and ions in the electrical gas discharge occasionally collide with He-atoms, raising them to level E_3 (a metastable state). During collisions between He- and Ne- atoms, the excitation energy of He-atom is transferred to Ne-atom (level E_2), selectively populating E_2 due to resonant energy transfer.

(1.5 Marks)



(Labelling-01 and showing transition-0.5= 1.5 Marks)

Q12. Deviation of violet light is more than red light in case of diffraction grating. State whether this statement is TRUE or FALSE. Justify your answer. (2)

FALSE (1 Marks)

$d \sin\theta = m\lambda$; $\lambda_V < \lambda_R$; $\theta_V < \theta_R$ (1 Marks)