Department of Physics, MIT Manipal University, Manipal
II Semester B.Tech. - Test 1 Engineering Physics [PHY1001] Date 14-02-2017
Time: 8.00-9.00 pm Max Marks: 15

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Note: Answer all the questions.
Draw neat sketches wherever necessary with axes shown properly.

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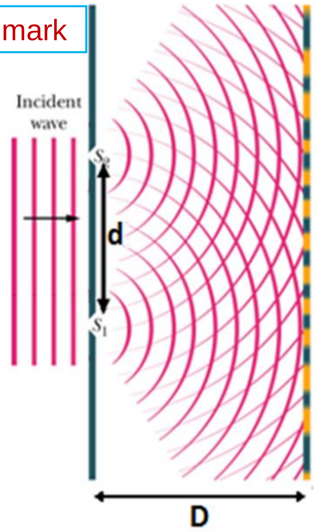
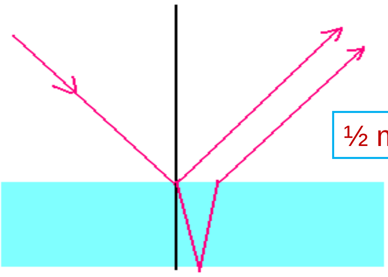
1. Illustrate with figure how coherent waves are produced? [2]

½ mark



Two methods of producing coherent waves:
Division of wave front: For example, Young double slit experiment: Here, two different portions of a same wave front is made to pass through two narrow slits separated by large distance d (d>>λ). ½ mark

Division of amplitude: For example, in Newton rings experiment this mechanism is used. Light waves reflected from front and rear surfaces of a thin film are perfectly coherent (Figure 1.3). ½ mark



½ mark

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2. Define fractional refractive index change Δ and obtain the relation between Δ & numerical aperture NA. [2]

Fractional refractive index change (Δ): It is the ratio of the difference in the refractive indices $(n_1 - n_2)$ between the core & the cladding to the refractive index n_1 of the core. $\Delta = \frac{(n_1 - n_2)}{n_1}$ 1 mark

Since $n_1 > n_2$, Δ is always positive.
Relation between *NA* & Δ :
Assuming $n_0 = 1$, $NA = \sqrt{n_1^2 - n_2^2} = \sqrt{(n_1 - n_2)(n_1 + n_2)}$
$(n_1 - n_2) = n_1 \Delta$ and since $n_1 \approx n_2$, we can approximate $(n_1 + n_2) \approx 2\, n_1$.
Therefore, $NA = \sqrt{(n_1 \Delta)(2n_1)} = n_1 \sqrt{2\Delta}$ 1 mark

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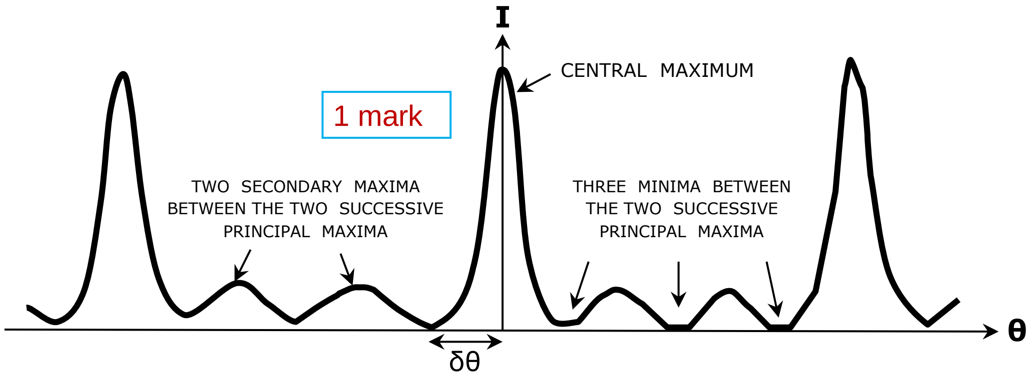
3. Draw a schematic graph of diffraction pattern due to 4 slits.
Calculate the angular half width of the central maximum in the diffraction pattern due to 4 slits (for normal incidence) when the separation between the adjacent slits is ten times the wavelength of the light. [2]



$$\delta\theta = \frac{\lambda}{Nd} = \frac{1}{N\left(\frac{d}{\lambda}\right)} = \frac{1}{4\times10} = \boxed{0.025\ \mathrm{rad}} = 1.43^\circ$$ 1 mark

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4. HRK E 48-33

An atom has two energy levels with a transition wavelength of 582 nm. At 300 K, 4.0×10^{20} atoms are in the lower state. How many occupy the upper state under conditions of thermal equilibrium ? Boltzmann constant = 1.38×10^{-23} J/K, Planck's constant = 6.63×10^{-34} Js, speed of light in vacuum = 3.00×10^{8} m/s [2]

$$E_2 - E_1 = \frac{hc}{\lambda} = 3.41 \times 10^{-19}\ \mathrm{J}$$ ½ mark

$$\frac{N_2}{N_1} = \exp\left(-\frac{(E_2-E_1)}{kT}\right) = e^{-82.5} = 1.5\times10^{-36}$$ 1 mark

$$N_2 = N_1 \times \left(1.48\times10^{-36}\right) = \boxed{6 \times 10^{-16}} \approx 0$$ ½ mark

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5. LAB Problem

A Newton's rings apparatus is used to determine the radius of curvature of a lens. The radii of the mTH and the (m+10)TH dark rings are measured and found to be 0.410 cm and 0.672 cm, respectively, in light of wavelength 589 nm. Calculate the radius of curvature of the lower surface of the lens. [2]

r_m = 0.410 cm, r_{m+10} = 0.672 cm, λ = 589 nm

$r_m^2 = m\lambda R$ ½ mark $r_{m+10}^2 = (m+10)\lambda R$

$\therefore\ r_{m+10}^2 - r_m^2 = 10\lambda R$

$R = (r_{m+10}^2 - r_m^2)/(10\lambda)$ ½ mark

$= \boxed{4.81\ \mathrm{m}}$ 1 mark

6. Choose the most appropriate answer for the following out of the options given.
WRITE THE FULL SENTENCE WITH THE RIGHT OPTION UNDERLINED: **[1x5]**

(A) Which of the following is essential for the laser action to occur between two energy levels of an atom?

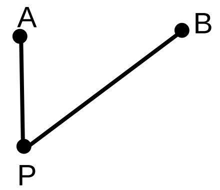
HRW MCQ41-68

- the lower level should be metastable
- **there should be more atoms in the upper level than in the lower level Ans**
- there should be more atoms in the lower level than in the upper level
- the lower level should be the ground state

(B) The figure shows two point sources of light, A and B. B emits light waves that are $+\pi$ radians out of phase with the waves from A. A is at a distance of 3λ from P. B is at a distance of 5λ from P. (λ is the wavelength.) The phase difference between waves arriving at P from A and B is

SJ MCQ37-25

- 0 rad
- 2π rad
- **3π rad Ans**
- 4π rad



(C) A film (t = thickness) of index of refraction n_1 coats a surface with index of refraction n_2. When, $n_1 > n_2$ the condition for constructive interference for reflected monochromatic light of wavelength λ in air is

SJ MCQ37-33

- $t = m\,\frac{\lambda}{n_1}$
- $t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n_1}$
- $2t = m\,\frac{\lambda}{n_1}$
- $\mathbf{2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n_1}}$ **Ans**

(D) A radar installation operates at 9000 MHz with an antenna (dish) that is 15 meters across. Determine the maximum distance (in kilometers) for which this system can distinguish two aircraft 100 meters apart. Speed of radio waves = 3.00×10^8 m/s

SJ MCQ38-10

- 7.4 km
- 370 km
- 3.7 km
- **37 km Ans**

(E) Monochromatic light from a He-Ne laser (wavelength = 632.8 nm) is incident on a diffraction grating containing 5000 lines/cm. Determine the angle of the first-order maximum.

SJ MCQ38-11

- **18.4° Ans**
- 39.2°
- 14.6°
- 27.7°

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