Indian Institute of Technology, Kharagpur

Name	Roll No.
Department	Section

PHYSICS PH11001 End-Semester Spring 2008-9

Time: 3.00 hrs Full Marks: 50

Paper Setters: Somnath Bharadwaj, Achintya Dhar, Prasanta K. Datta

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The paper has 10 questions, answer all questions

The working should be shown in the answer booklet

The final answers should be entered in the space provided after each question in the question paper

Attach the question paper to the answer booklet and submit it at the end of the exam

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Marks

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Total

Physical Constants

$h = 6.63 \times 10^{-34}$ J/s $\quad e = 1.6 \times 10^{-19}$ C $\quad m_e = 9.1 \times 10^{-31}$ kg

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1 Consider a wave

$$\tilde{A}(x,t) = A[1 + 0.1\cos(\omega_1 t - k_1 x)]\exp[i(\omega_2 t - k_2 x)]$$

with $\omega_1 = 2\pi \times 10\,\mathrm{KHz}$, $k_1 = 2\pi \times 10\,\mathrm{m}^{-1}$, $\omega_2 = 2\pi \times 10\,\mathrm{MHz}$ and $k_2 = \pi \times 10^4\,\mathrm{m}^{-1}$.

Calculate [a.] The frequency of the carrier wave (in Hz) [b.] The frequency of the modulation (in Hz) [c.] The speed of the carrier wave (in m/s) [d.] The speed of the modulation wave (in m/s) [e.] The higher of the two sideband frequencies (in Hz)

Write your answers here

a	b	c	d	e	Marks

2 Consider the wave equation

$$\frac{\partial^2 \xi}{\partial x^2} + \frac{1}{4}\frac{\partial^2 \xi}{\partial y^2} - \frac{1}{c_s^2}\frac{\partial^2 \xi}{\partial t^2} = 0$$

[a.] For what value of p is $\xi_1(x, y, t) = A\sin(px - t)$ a solution? [b.] For what value of q is $\xi_2(x, y, t) = A\exp[-(y - qt)^2]$ a solution? [c.] For what value of g is $\tilde{\xi}_3(x, y, t) = A\exp[i(x - gy - \sqrt{17}c_s t)]$ a solution? [d.] What is the phase velocity of the wave $\tilde{\xi}_3(x, y, t)$? [e.] For what value of h does the wave $\tilde{\xi}_4(x, y, t) = A\exp[i(x - hy - \alpha t)]$ travel in a direction perpendicular to $\tilde{\xi}_3(x, y, t)$?

Write your answers here

a	b	c	d	e	Marks

3 X-ray ($\lambda = 1$ Å) is incident on cubic lattice gold whose spacing 4.1 Å. [a.] What is the inter planar distance $d(h, k, l)$ for $(h, k, l) = (1, 1, 2)$ (in Å)? [b.] What is the diffraction angle for $(1, 1, 2)$ (in degrees)? [c.] What is the wavelength (in Å) of electrons accelerated by a potential difference of 45 KV? [d.] What is the diffraction angle (in degrees) ff these electrons are used instead of the X-ray? [e.] Electrons become relativistic if accelerated through 100 KV instead of 45 KV. What is the momentum of the relativistic electrons (in kg m/s).

Write your answers here

a	b	c	d	e	Marks

4 A particle of mass m, free to move along the x axis is in a potential such that $V(x) = 0$ for $-L/2 \leq x \leq L/2$ and $V(x) = \infty$ elsewhere. For the allowed x range, we write the ground-state (lowest energy) wave-function as

$$\psi(x, t) = \exp(i\omega t)[A\cos(kx) + B\sin(kx)]\,.$$

Determine the values of [a.] k [b.] A [c.] B [d.] the ground state energy [e.] energy of the first excited state.

Write your answers here

a	b	c	d	e	Marks

5 120 radio sources all emitting at $\lambda = 10$m are arranged in a vertical linear array with spacing $\lambda/4$ between successive sources. Each source has a phase lag of $\pi/6$ with respect to the source just above it. . We use θ to denote the angle measured from the vertically upward direction.

[a.] For a distant observer at $\theta = \cos^{-1}(1/3)$, what is the phase difference between the radiation from any two successive sources. [b.] For the same θ, if the amplitude of each source is $10\,\mathrm{V/m}$, what is the resulting total amplitude? [c.] At what θ do we have the $m = 0$ order maxima? [d.] What is the angular width of this maxima? [e.] How many maxima will there be?

Write your answers here

a	b	c	d	e	Marks

6 [a.] For what scattering angle is the scattered light completely linearly polarized? [b.] For what scattering angle is the intensity of the scattered light with linear polarization in the plane of the incident and scattered light rays half the intensity of the perpendicular polarization? [c.] An unpolarized radio wave is incident along the z direction on a metal wire mesh, the wires being aligned with y. In which direction is the transmitted light polarized? [d.] What is the Brewster angle for reflection from a glass ($n = 1.5$) surface to air ($n = 1$)? [e.] A birefringent crystal has $n_e = 1.62$ and $n_o = 1.6$. What should be the thickness for a quarter-wave plate at $\lambda = 5500$ Å?

Write your answers here

a	b	c	d	e	Marks

7 A particle has wave-function

$$\psi(x,t) = A\exp(i\omega t)\exp[-x^2/(4L^2)]$$

L is a constant of dimension length. Given $\int_{-\infty}^{\infty}\exp[-x^2/2]\,dx = \sqrt{2\pi}$. [a.] Determine the normalization constant A. [b.] What is the expectation value $\langle x\rangle$? [c.] How much is Δx, the uncertainty in x? [d.] What is the momentum expectation value $\langle p\rangle$? [e.] How much is Δp, the uncertainty in p?

Write your answers here

a	b	c	d	e	Marks

8 A monochromatic light having $\lambda = 500$nm is normally incident on a screen with two slits of spacing 2 mm. The intensity of the light from the two slits is not the same, and has a ratio $9:1$. [a.] What is the angular separation between to successive maximas (in radians)? [b.] What is the visibility of the fringes? [c.] What is the angular separation between to successive maximas (in radians) if the wavelength is changed to $\lambda = 510$ nm? [d.] Suppose the monochromatic light is replaced by light of two wavelengths (500 and 510 nm). What is the angular spacing (in radians) between two successive maximas? [e.] At what angle (in radians) from the center will we have the first minima?

Write your answers here

a	b	c	d	e	Marks

9 A plane wave of $\lambda = 0.5\,\mu$m is normally incident on a screen with a slit of width $5\,\mu$m. [a.] What is the angle (in radians) of the first minima? [b.] Two more identical slits are introduced on either side of the existing slit, with a separation of $50\,\mu$m between the slits. What is the angle (in radians) of the first minima? [c.] Which is the first missing order in the fringes? [d.] What is the angle (in radians) of the $m = 2$ maxima of this three slit grating. [e.] What is the chromatic resolving power of this grating for $m = 2$? In this problem all angles are measured from the direction of the incident light.

Write your answers here

a	b	c	d	e	Marks

10 The wave functions ψ_1 and ψ_2 are energy eigenfunctions with eigenvalues 1 eV and 2 eV respectively. Consider the wave function

$$\psi = 3\psi_1 + 4\psi_2$$

[a.] Is ψ an energy eigenfunction? For the state ψ, if the energy is measured [b.] what is the probability of getting 1 eV, [c.] what is the probability of getting 2 eV ? [d.] What is the expectation value? [e.] What is the uncertainty ?

Write your answers here

a	b	c	d	e	Marks