PC3010

THREE HOURS OR TWO HOURS

A list of constants is enclosed.

UNIVERSITY OF MANCHESTER

General Physics (snsf)

15th May 2002, 2.00 p.m. - 5.00 p.m.

THREE HOUR CANDIDATES

Answer as many questions as you can.

Marks will be awarded for your **THIRTEEN** best answers.

TWO HOUR CANDIDATES
(Maths/Physics and Physics with Business and Management)

Answer as many questions as you can from questions 1-10 inclusive.

Marks will be awarded for your **NINE** best answers.

Electronic calculators may be used, provided that they cannot store text.

The numbers are given as a guide to the relative weights of the different parts of each question.

P.T.O.

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1. Photoelectrons with a maximum energy of 0.4 eV are observed when light of wavelength 450 nm is incident on a surface. Calculate the maximum wavelength of light which will produce photoelectrons from this surface.

2. Sketch the field distributions round (a) an electric dipole and (b) a current loop, both situated in free space. Show the field line directions both near and far from the dipole and the loop, indicating the polarity of the charges on the dipole and the current direction in the loop.

3. Sunlight at the Earth's surface has an intensity of approximately 1 kW m^{-2} on a plane perpendicular to the direction of the Sun. What is the photon pressure exerted on a perfectly reflecting mirror of area 1 m^2 held perpendicular to the direction of the Sun? If the mean wavelength of the light is 550 nm estimate the number of photons hitting the mirror per second.

4. An intrepid Australian digs a hole through the centre of the Earth from Queensland to Spain and then drops a small object of mass m down the hole. Assuming that the Earth is of uniform density, calculate the gravitational force acting on the mass at a distance r from the centre of the Earth.

Describe the motion of the mass.

5. A moving neutral π meson is observed to decay into two photons each with energy 80 MeV, there being an angle of 120° between their trajectories. Calculate:

(i) The total energy of the meson.

(ii) The momentum of the meson.

(iii) The rest mass of the meson.

6. Two guitars have been tuned independently and produce beats when the A-strings are played together. The time dependence of the two sound waves at a point in space can be described by $y_1 = A\sin(\omega_1 t)$ and $y_2 = A\sin(\omega_2 t)$. The resultant sound wave can be written as $y = 2A\cos\left(\frac{\Delta\omega t}{2}\right)\sin(\overline{\omega}t)$, where $\Delta\omega$ is the angular frequency difference and $\overline{\omega}$ the average angular frequency of the two waves.

One guitar is tuned correctly so the A-string oscillates at a frequency of 110 Hz. If the beat frequency is $\frac{3}{4}$ Hz, what are the possible frequencies of the other A-string vibration?

The frequency of oscillation of a string is proportional to the square root of the string tension. By what fraction must the tension in the out of tune guitar string be changed to bring it in tune?

7. Air at S.T.P. is heated to 800 K by an adiabatic compression. What is the final pressure in atmospheres which must be applied? The ratio of specific heats of air is $C_p/C_v = 1.4$.

8. A two-level system has one energy level at zero energy and the other at 0.025 eV. Calculate its average energy at a temperature 290 K.

9. Two narrow slits separated by 0.3 mm are illuminated by light of wavelength $\lambda = 600$ nm. Calculate the separation of the fringes (in mm) on a screen 2 m from the slits. By how many fringes would the pattern move if transparent film of thickness 30 μm and refractive index 1.33 were placed over one of the slits?

10. The construction of a coaxial cable is that of a long inner conducting solid wire of radius a and an outer conductor in the shape of a thin cylindrical tube of radius b coaxial with the wire. The annular space between the two conductors is filled with a dielectric of relative permittivity ϵ. Use Gauss' law to calculate the capacitance per unit length of cable.

11. Write down a general equation of motion for an undriven damped harmonic oscillator and derive the condition for critical damping.

12. Consider a gas of degenerate massless neutrinos with Fermi temperature 10^8 K. Calculate the number of neutrinos per unit volume.

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13. Assuming that the surface of the Sun is at 6000 K and that both Earth and Sun are black bodies and that the Earth has a uniform temperature T^* at its surface, calculate the value of T^* in degrees K.

14. The skin of a drum is a circular membrane with surface tension γ. Use a dimensional argument to determine how the fundamental frequency of the drum depends on γ, the radius R of the drum and the mass ρ per unit area of the membrane.

15. The normalised energy eigenfunctions and corresponding eigenvalues for a particle in an infinite square well are given by

$$\phi_n(x) = \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right)$$

and

$$E_n = \frac{n^2\pi^2\hbar^2}{2ma^2} \quad .$$

If the wavefunction before an energy measurement is given by

$$\psi(x) = \frac{3}{5}\sqrt{\frac{2}{a}} \sin\left(\frac{\pi x}{a}\right) + \frac{4}{5}\sqrt{\frac{2}{a}} \sin\left(\frac{3\pi x}{a}\right)$$

calculate the energies you expect to measure and their respective probabilities.
