THREE HOURS

A list of constants is enclosed

UNIVERSITY OF MANCHESTER

General Physics

21 May 2010

09:45 – 12:45

(Physics, Physics with Astrophysics, Physics with Theoretical Physics, Physics with Technological Physics)

Answer as many questions as you can.
Marks will be awarded for your **THIRTEEN** best answers.

Each question is worth 10 marks

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

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1. In June 1960, a car on the M1 managed to skid 290 meters before coming to rest. It produced the longest recorded skid marks on a public road. Assume that the wheels were locked and assume a coefficient of kinetic friction between the road and the wheels of $\mu = 0.8$. Calculate the initial velocity of the car in km/hr.

2. A room has a volume of 100 m^3, what is the weight of the air within it? If the air were to be liquefied what, approximately, would you expect its volume to be?

3. An astronaut makes a pendulum from a 1 m length of string and a small weight. What is the period of the pendulum if the astronaut is standing on the surface of the moon? Assume that the moon has a radius of 1740 km and a mass of 7.4×10^{22} kg.

4. Positronium is a bound state of an electron and positron.

a) Estimate the ionisation energy of positronium.

b) An argon atom collides with positronium which is in an excited state for which the principal quantum number n is 2. If 10 eV is transferred to the electron, what velocity does it have after the collision ?

c) Describe quantitatively the decay products arising from the annihilation of the electron and positron.

5. An electron with kinetic energy of 10 eV moves in a circular orbit of radius 0.1 mm . What is the magnitude and direction of the magnetic field?

6. A convex lens is required to focus the light from a lamp onto the slit of a spectroscope. If the lamp is situated 10 cm from the lens, and the lens is 20 cm from the slit, what is the required focal length of the lens? If the diameter of the lens is 5 cm, estimate the fraction of light emitted by the lamp falling on the slit, assuming the lamp radiates isotropically.

7. X-rays whose energy is 25 keV exhibit first order Bragg diffraction from a crystal at an angle of incidence 10 degrees to the reflecting plane. Neutrons of energy 0.025 eV are then directed onto the same crystal, for what angle of incidence does reflection of the neutrons take place?

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8. When a high-energy cosmic ray hits the upper atmosphere, at an altitude of 80 km, the collision energy produces showers of pions and muons. Pions and muons have a decay time of $\tau = 2.6 \times 10^{-8}$ s and $\tau = 2.2 \times 10^{-8}$ s respectively. The rest mass of the muon and pion are 105.7 MeV/c^2 and 139.6 MeV/c^2 respectively. Calculate the minimum velocity relative to the speed of light (v/c) and the minimum energy for each of these particles in order for them to reach the Earth's surface.

9. State the efficiency of the Carnot cycle in terms of the higher temperature, T_h , and the lower temperature, T_c. For a given small shift of ΔT, either raising T_h or lowering T_c, which gives the greater increase in efficiency?

10. A copper wire is carrying a current of 45 A. The wire has 2.7×10^{23} free electrons per meter of length, and the same number of positive (fixed) nuclei. The current is carried by the electrons.

(a) What is the average velocity of the electrons?

(b) What are the negative and positive charges per unit length on the wire in the reference frame in which the wire is at rest?

(c) What are the negative and positive charges per unit length, in the reference frame that has a velocity equal to the average velocity of the electrons? Calculate the net charge per unit length in this reference frame.

11. Hydrogen atoms fall from a large distance into the gravitational potential well of a bound cluster of 1000 galaxies whose diameter is 4 Megaparsec. Assuming that each galaxy has a mass 10^{11} times that of the Sun calculate the kinetic energy acquired by the atoms and hence estimate their effective temperature. Assuming that the atoms become ionized, in which region of the EM spectrum (i.e. radio, infra-red, visible, ultra-violet, X-ray or gamma-ray) might you expect the plasma to radiate?

12. A bullet is fired from a gun with velocity v_o at 45° to the ground. The ground is defined as the x-axis. It lands a distance v_0^2/g from the firing position after a time $(\sqrt{2})v_0/g$. Using the uncertainty principle derive a formula for the error in the landing position (δx). Estimate this error for a bullet of mass 10 g fired with an exit velocity of 1000 ms^{-1}. Comment on your answer. Assume g is 9.81 ms^{-2}.

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13. The resolution of a radio telescope array depends on the total aperture size. The field of view is the resolution of a single element. The SKA array will use elements each of 15 m diameter, spread over a total aperture size of 150 km. What is the width of the field of view (in degrees) and what is the resolution (in arc seconds) of the instrument if the SKA is operated at a frequency of 1 GHz?

14. Suppose that a uniform spring with spring constant k = 120 N/m, is cut into two pieces, one twice as the long as the other. What are the spring constants of the two pieces?

15. Starting with Maxwell's equations in the vacuum, show that:

$$\nabla^2 \underline{E} = \mu_0 \varepsilon_0 \frac{\partial^2 \underline{E}}{\partial t^2}.$$

What is this equation and identify the value of $\mu_0 \varepsilon_0$?

You may find the identity $\nabla x \nabla x \underline{E} = \nabla(\nabla . \underline{E}) - \nabla^2 \underline{E}$ useful.

END OF EXAMINATION PAPER

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