PC3010

THREE HOURS OR TWO HOURS

A list of constants is enclosed.

UNIVERSITY OF MANCHESTER

General Paper 1

26th May 2004, 2.00 p.m. - 5.00 p.m.

THREE HOUR CANDIDATES
(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.

TWO HOUR CANDIDATES
(Maths/Physics, 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.

PC3010 June 2004 continued...

1. X-rays with a wavelength of 0.16 nm are reflected off a crystal of silicon. The first interference peak is observed at an angle of 36°. Find the spacing of the atoms in silicon. [10 marks]

2. Gravity Probe B has just been lauched into a circular orbit round the Earth at a height of 650 km. Estimate the time it takes to complete one orbit. [10 marks]

3. The note from a tuning fork of unknown frequency makes three beats per second with the note from a standard fork of frequency 440 Hz. The beat frequency increases when a small piece of wax is put on a prong of the first (unknown-frequency) fork. What is the frequency of this fork?

[10 marks]

4. A wire loop of resistance 0.1 Ω has an area of 2.5×10^{-3} m^2. It is initially in a uniform magnetic field of 1 T, which is normal to the plane of the loop. How much charge flows round the loop when it is removed to a region of zero magnetic field? [10 marks]

5. A container holds 10 litres of an ideal gas at 20°C and atmospheric pressure. It is kept at a constant temperature while the gas is slowly compressed to one third of its original volume. How much work is done on the gas during this process? [10 marks]

6. Use the Uncertainty Principle to estimate the momentum of a quark confined within a hydrogen nucleus. [10 marks]

7. Assuming that the largest electric field that can be sustained in air is 10^6 V m^{-1}, calculate the maximum electric energy density that can be created in air. [10 marks]

8. Protons are scattered from iron nuclei, which have $Z = 26$. Estimate the maximum energy, in MeV, of the protons for which no deviation from Rutherford (i.e. Coulomb) scattering is observed. You may assume that an iron nucleus may be approximated by a sphere of radius 5 fm. [10 marks]

9. A gas container is divided into two equal parts by a removable partition. One part contains one mole of helium, the other one mole of neon, both at STP. Calculate the change ΔS in the entropy when the partition is removed and both gases are allowed to mix completely. [10 marks]

10. A particle of mass m moves in one dimension in a potential $V(x)$. The ground state energy is zero and the ground state wave function is $\psi(x) = Ae^{-bx^4}$, where A and b are constants. Determine the potential $V(x)$. [10 marks]

11. In the classic experiment to measure the gravitational constant, the balance consists of two equal masses of 0.025 kg connected by a rod of length 0.4 m and negligible mass, suspended on a long fibre. If the balance oscillates with a period of 3.8 minutes, estimate the torsional constant, in $\mathrm{N\,m\,rad^{-1}}$, of the fibre. [10 marks]

12. The viscosity, η, of a gas is given by $\eta = kc\lambda n$, where k is a constant, c is the mean molecular speed, λ is the mean free path and n is the number density of the molecules. How does η depend on (i) the mass of the molecules, (ii) the linear size of the molecules, (iii) the temperature of the gas, and (iv) the number density of the molecules? [10 marks]

13. Perfectly monochromatic light of wavelength 550 nm is chopped by a shutter into a pulse of duration 2.5×10^{-8} s. Estimate the spread in wavelength of the resulting light. [10 marks]

14. In 2003, the 76 m diameter Lovell radio telescope was used to search for a signal at 401 MHz from the Beagle Mars lander. Estimate the angular resolution of the telescope at this frequency. [10 marks]

15. A 1.022 MeV photon is Compton scattered through 90° by an electron and emerges with an energy of 0.341 MeV. What is the speed of the recoiling electron? [10 marks]
