

**THREE HOURS OR TWO HOURS**

A list of constants is enclosed.

**UNIVERSITY OF MANCHESTER**

General Physics I - SNSF

17th May 2001, 9.45 a.m. - 12.45 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.

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

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

PC3012 June 2001 continued...

1. Calculate the root mean square velocity of the helium atoms in gaseous  $\text{He}^4$  at a temperature of 300K.
  
2. What is the frequency of the photons produced when an electron ( $e^-$ ) and a positron ( $e^+$ ) annihilate at rest?
  
3. Explain what is meant by the terms *nuclear fusion* and *nuclear fission*. Explain why it is energetically favoured for very light nuclei to undergo fusion to form heavier nuclei, whereas it is energetically favoured for very heavy nuclei to undergo fission to form lighter nuclei.
  
4. A thundercloud holds a negative charge of 100 C at a mean height of 5 km and a positive charge of 100 C at a mean height of 9 km. Estimate the electric field at the ground directly below the thundercloud. (The ground can be regarded as a surface of constant potential.)
  
5. A diffraction grating has a total width of  $D$ , a slit width of  $w$  and a slit spacing of  $d$ . The grating is illuminated normally by plane monochromatic waves of wavelength  $\lambda$ . Sketch, taking care to mark all the relevant angular scales, the diffraction pattern (in intensity) as seen on a distant screen.
  
6. A sieve is moving up and down with an amplitude of  $x_0 = 50$  mm. If sand grains lying on the sieve are supposed to become detached from the sieve during the harmonic oscillation, what is the maximum vibration period?
  
7. Show that the function

$$\Psi(x, t) = A e^{-\frac{\sqrt{Cm}}{2\hbar} x^2} e^{-\frac{i}{2} \sqrt{\frac{C}{m}} t}$$

is an eigenfunction of the Schrödinger equation for a particle of mass  $m$  moving under the influence of a one-dimensional potential,  $V(x)$ . Thus find an expression for the appropriate  $V(x)$ .

PC3012 June 2001 continued...

8. A two-level system has energies which differ by  $\epsilon$ . The upper level is doubly degenerate and the lower level is singly degenerate. Calculate its average energy at temperature  $T$  and its specific heat in the limit when  $kT \gg \epsilon$ .

9. A pair of crossed polarisers, with axes vertical and horizontal respectively, is placed in a beam of unpolarised light with intensity  $I_0$ . What is the light intensity: (a) after passing through the vertical polarizer and then (b) through the horizontal polariser? A third polarizer is placed between the crossed pair with its axis at an angle  $\theta$  to the vertical. Show that after passing through the horizontal polariser the light intensity is given by:

$$I = \frac{I_0 \sin^2 2\theta}{8}.$$

10. When a beam of neutrons with kinetic energy 0.025 eV is directed at a crystal, a reflection is observed at  $30^\circ$  to a set of lattice planes. Calculate the spacing of the planes assuming a first order reflection.

11. One mole of a perfect gas undergoes a reversible, isothermal expansion from a volume of 4 litres to a volume of 8 litres at 300K. Calculate the work done by the gas and the change in its entropy.

12. The  $K_S^0$  meson has a mass of 500 MeV/c<sup>2</sup> and a mean lifetime of  $0.89 \times 10^{-10}$  s. What is the mean distance travelled by  $K_S^0$  mesons before they decay, if they are produced with an energy of 1 GeV?

13. Consider a pulse of duration  $b$  represented by the 'top-hat' function

$$\begin{aligned} f(t) &= h \text{ for } -0.5b < t < 0.5b \\ f(t) &= 0 \text{ elsewhere.} \end{aligned}$$

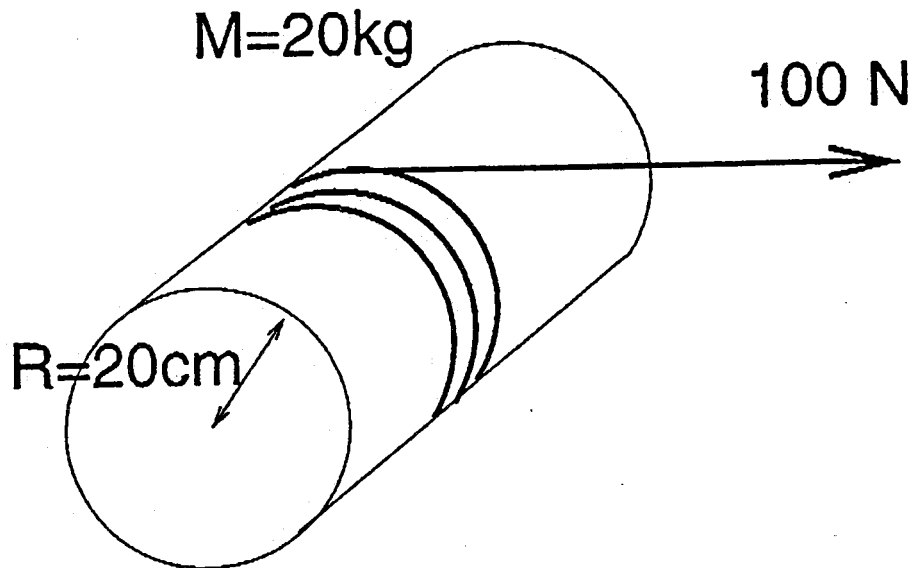
Show that its Fourier transform is proportional to

$$hb \frac{\sin \pi \nu b}{\pi \nu b}$$

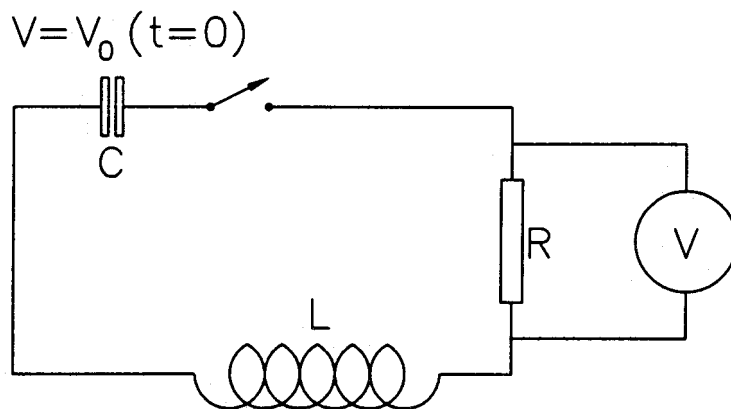
where  $\nu$  denotes a frequency of oscillation.

PC3012 June 2001 continued...

14. A massless rope is wrapped several times around a solid cylinder of radius  $R = 20 \text{ cm}$  and mass  $M = 20 \text{ kg}$ , which is at rest on a horizontal surface. Someone pulls  $1 \text{ m}$  of the rope with a constant force of  $100 \text{ N}$ , setting the cylinder in motion. Assuming that the rope neither stretches nor slips and that the cylinder rolls without slipping, what is the final angular velocity of the cylinder and the speed at its surface?



15.



Consider the circuit shown above where the capacitor  $C$  is charged to a voltage  $V_0$  at  $t < 0$ . At a time  $t = 0$  the switch is closed. Given that  $R \ll X_C$  and  $R \ll X_L$ , describe, using a diagram, the voltage  $V$  that appears across the resistor as a function of time.

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