

THREE HOURS

A list of constants is enclosed.

UNIVERSITY OF MANCHESTER

General Physics

5th June 2009, 9.45 a.m. - 12.45 p.m.

(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.

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

P.T.O.

1. A compressor for a cryostat reduces the volume of 1 m^3 of helium gas initially at atmospheric pressure to one tenth of its original volume at constant temperature. What is the work done on the gas?
2. A neutron has a kinetic energy of 1 GeV . What is its velocity?
3. Car wheels, supported by springs attached to the car, are found to be vertically displaced by 10 cm when the weight of the car is shared amongst the four wheels. Assuming that the weight of the car results in a load of 250 kg on each wheel, calculate the spring constant for each spring. If the mass of a wheel is 20 kg , what is the period of oscillation of the wheel?
4. Patients suffering from an over-active thyroid can be treated by partial removal of the thyroid by injection of a compound containing radioactive iodine. This concentrates in the thyroid and kills cells. A medical physicist estimates that a sample with an initial activity of 0.05 Ci is required. How many grams of ^{131}I should be injected ?

The half-life of ^{131}I is 8 days. 1 Ci is 3.7×10^{10} disintegrations/sec.

5. A 1 kg block of copper, with a specific heat capacity of $385 \text{ J kg}^{-1} \text{ K}^{-1}$, at a temperature of 90°C is thrown into a lake at 10°C . Calculate the change of entropy of the lake.
6. $\psi_1(x)$ and $\psi_2(x)$ are two normalized eigenfunctions of the Hamiltonian operator, \hat{H} . The corresponding eigenvalues are E_1 and E_2 . The system is in an initial state with wavefunction

$$\phi(x, 0) = \frac{1}{2}\psi_1(x) + \frac{\sqrt{3}}{2}\psi_2(x).$$

Compute the average value of the energy and its uncertainty ΔE . What values of the energy could one measure in an experiment?

P.T.O.

7. Show, for a dispersive medium where the phase velocity c of a wave is proportional to k^{-p} where k is the wavenumber, that the group velocity is equal to $(1 - p)c$. What is the value of p for a surface wave in deep water where the dispersion relation is $\omega^2 = gk$?

8. An astronomer observes that the blue Balmer line ($\lambda = 434.2 \text{ nm}$) has a Zeeman splitting of 0.004 nm for sunlight coming from a sunspot region of the Sun's surface. Give a rough estimate of the magnetic field at the sunspot.

9. A simple parallel plate capacitor has an area of 10^{-4} m^2 and separation of 0.1 mm in air. What is its capacitance?

10. A research balloon floats at equilibrium when it reaches an altitude of 40 km . At this altitude the air pressure is 300 Nm^{-2} and the temperature is -13°C . The volume of the helium filled balloon is $8.5 \times 10^5 \text{ m}^3$. The atomic weight of helium is 4. The mean molecular mass of air is 29 g . What is the payload of the balloon?

Treat air and helium as ideal gases.

11. A square flag with side 1 m was left on the Moon in 1969. What is the angular size of the flag when observed from Earth? If we wanted to confound conspiracy theorists, who claim the landings never took place, by creating a map of 100 pixels of the flag, what diameter telescope would one need to perform this task for light of wavelength 600 nm ? Assume that the telescope has a circular aperture and ignore any effects of the Earth's atmosphere. The distance to the Moon is 384400 km .

12. A long bar magnet is bent into the form of a closed ring. If the intensity of magnetisation is \underline{M} , and ignoring any end effects due to the join, find the magnetic field \underline{H} and the induction \underline{B} , (a) inside the material of the magnet, and (b) just outside.

P.T.O.

13. A spectrometer uses a diffraction grating ruled at 1000 lines per mm and operates in first order. A spectral line is found to be diffracted by 30 degrees to the normal to the grating. What is the angular separation in minutes of arc to a further line if its wavelength is 5 Å longer?

14. A stone is tied to a string of length l . Someone whirls this stone in a vertical circle. Assume that the energy of the stone remains constant as it moves around the circle. Calculate the minimum speed the stone must have at the bottom of the circle, if the string is to remain taut at the top of the circle.

15. A galaxy cluster of mass $10^{14}M_{\odot}$ is made of dark matter. The dark matter particle can spontaneously decay into photons. The lifetime of dark matter particles is 10^{24} sec. Estimate the luminosity of (power emitted by) the cluster. What will be the incident flux measured on the Earth if the cluster is 100Mpc away?

END OF EXAMINATION PAPER