**THREE HOURS**

A list of constants is enclosed.

# UNIVERSITY OF MANCHESTER

General Physics

2nd June 2014, 2.00 p.m. - 5.00 p.m.

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

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

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**1.** A car, powered by a 70 kW engine experiences a resistive force of $kv$ where $k = 45\,\mathrm{kg\,s^{-1}}$ and $v$ is the speed of the car. What is the maximum speed that it can achieve in $\mathrm{km\,hr^{-1}}$?

**2.** Estimate the de Broglie wavelength of a nitrogen molecule in air at room temperature.

**3.** A transmission line consists of a pair of wires where each wire has a resistance, $R$. The system is to deliver a power $P$ into a load. Find an expression for $\frac{\Delta P}{P}$ the fraction of power lost in the transmission line in terms of the voltage $V$, the current $I$ and $R$. Hence find the condition on $V$ to minimise this fraction. What practical considerations are there?

**4.** An insulating sphere of radius 3 cm is placed in an evacuated chamber and charged to a potential of $10^3$ V. An electron is then released from rest at a distance of 1 cm from the surface of the sphere. What is the speed of the electron when it hits the sphere?

**5.** Write down an expression for the entropy $S$ of a system in terms of the number of quantum microstates $\Omega$. For a change of entropy $\Delta S$ from state 1 to state 2, what is the ratio of the number of microstates $\Omega_2/\Omega_1$ ? If $\Delta S$ is $1\,\mathrm{J\,K^{-1}}$, what is $\Omega_2/\Omega_1$?

**6.** Find the force on a point charge placed a distance $d$ above an earthed metal plate. Ignoring gravity, what point charge would one need to place at a height $d/2$ above the plate so that the first charge is in equilibrium?

**7.** An electron has a total energy of 100 GeV. Calculate the speed of the electron in terms of the speed of light. A second electron is travelling in the same direction as the first and it has an energy of 97.0 GeV. What is the speed of one electron relative to the other?

**8.** Find the ratio of frequencies for small oscillations in the diatomic molecules $H_2$ and HD where D stands for deuterium, the heavy isotope of hydrogen.

**9.** A particle of mass $m$ moves in an infinitely deep square well of width $a$. What is the normalised wave function for the ground state? The well is suddenly broadened to a width of $2a$. What is the probability that the particle remains in the ground state?

You may wish to use $\sin a \sin b = \frac{1}{2}\left[\cos(a-b) - \cos(a+b)\right]$ .

**10.** An incandescent lamp is powered by an AC current. The average temperature of its filament is 2450 K, and the difference between the peaks and troughs of temperature is 70 K. What is the ratio between the maximum and minimum emitted power during one period of AC current?

**11.** An insulated metal bar of length $L$ and cross-sectional area $A$ has its two ends maintained at temperatures $T_1$ and $T_2$. The thermal conductivity of the bar varies as $K = \alpha + \beta T$ where $T$ is the temperature and $\alpha$ and $\beta$ are constants. What is the rate of flow of heat along the bar? Check your result makes sense when $\beta = 0$.

**12.** The Hubble space telescope has a mirror of diameter $\sim 2$ m and observes at a wavelength of 110 nm. Calculate the resolution at this wavelength in radians. Some people dispute that man actually landed on the Moon. If the lander is $\sim 4$ m in size can the Hubble space telescope see it? The distance from the earth to the moon is 384400 km.

**13.** A ship with an aerial 25 m above sea level is transmitting radio waves to a receiving station located 150 m above sea level at the top of a cliff. As the ship approaches the cliff, destructive interference means that radio contact is lost for the first time when the ship is a distance of 2 km from the base of the cliff. Assuming that the sea reflects radio waves perfectly, determine the wavelength used. You may also assume that the aerial is a point source of electromagnetic waves.

**14.** A projectile explodes into two pieces at the top of its trajectory at a distance $L$ measured horizontally from the launch point. The two fragments carry 1/3 and 2/3 of the original mass and emerge horizontally from the explosion. The smaller fragment lands back at the original launch point. How far from the original launch point does the larger fragment land?

**15.** The density of the atmosphere as a function of height, $z$, above the ground is $\rho(z) = \rho_0 \exp[-z/\ell]$. Calculate the scale-height, $\ell$, if the pressure at $z = 0$ is 102 kPa and the density there is $1.2\,\mathrm{kg\,m^{-3}}$.

END OF EXAMINATION PAPER