Section A

Answer **all** the questions in the spaces provided.

1 If an object is projected vertically upwards from the surface of a planet at a fast enough speed, it can escape the planet's gravitational field. This means that the object can arrive at infinity where it has zero kinetic energy. The speed that is just enough for this to happen is known as the escape speed.

(a) r is the distance from the centre of the planet.
On Fig 1.1, draw the variation with distance r of the kinetic energy E_K, gravitational potential energy E_P and the total energy E_T of this object from the surface of the planet.

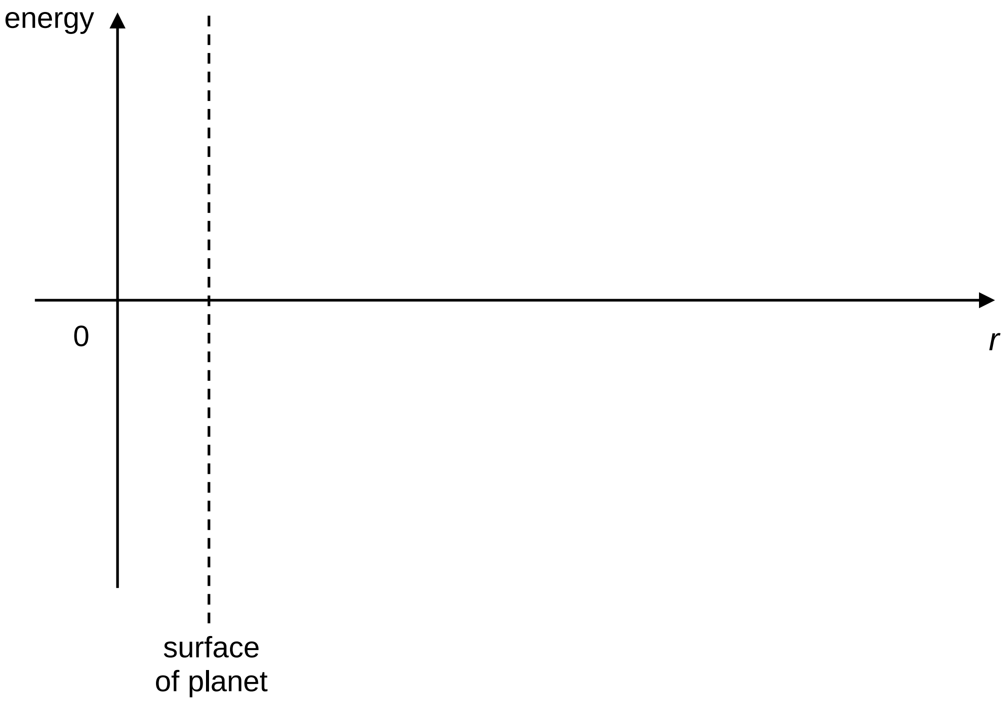

Fig. 1.1

[3]

(b) **(i)** By equating the kinetic energy of the object at the planet's surface to its total gain of potential energy in going to infinity, show that the escape speed v is given by

$$v^2 = \frac{2GM}{R}$$

where R is the radius of the planet and M is its mass.

[1]

(ii) Hence show that

$$v^2 = 2Rg$$

where g is the acceleration of free fall at the planet's surface.

[2]

(c) The mean kinetic energy E_k of an atom of an ideal gas is given by

$$E_k = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

(i) Using the equation in **(b)(ii)**, estimate the temperature at the Earth's surface such that helium atoms of mass 6.6×10^{-27} kg could escape to infinity.

You may assume that helium gas behaves as an ideal gas and that the radius of Earth is 6.4×10^6 m.

temperature = ... K [3]

(ii) The temperature estimated in **(i)** is measured in thermodynamic scale. Explain what is absolute zero in the thermodynamic scale.

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[Total: 10]