Gravitational Fields

Question paper 5

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Gravitational Fields
Sub Topic	
Paper Type	Theory
Booklet	Question paper 5

Time Allowed: **68 minutes**

Score: **/56**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** Define gravitational potential.

....

.... [2]

(b) Explain why values of gravitational potential near to an isolated mass are all negative.

....

....

.... [3]

(c) The Earth may be assumed to be an isolated sphere of radius 6.4×10^3 km with its mass of 6.0×10^{24} kg concentrated at its centre. An object is projected vertically from the surface of the Earth so that it reaches an altitude of 1.3×10^4 km.

Calculate, for this object,

(i) the change in gravitational potential,

change in potential = ... J kg^{-1}

(ii) the speed of projection from the Earth's surface, assuming air resistance is negligible.

speed = ... m s^{-1}
[5]

(d) Suggest why the equation

$$v^2 = u^2 + 2as$$

is not appropriate for the calculation in **(c)(ii)**.

....

.... [1]

2 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) **(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.

(ii) Hence show that

$$v^2 = 2Rg,$$

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

[3]

(b) 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.

Using the equation in **(a)(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 [4]

3 **(a)** A moon is in a circular orbit of radius r about a planet. The angular speed of the moon in its orbit is ω. The planet and its moon may be considered to be point masses that are isolated in space.

Show that r and ω are related by the expression

$$r^3\omega^2 = \text{constant}.$$

Explain your working.

[3]

(b) Phobos and Deimos are moons that are in circular orbits about the planet Mars. Data for Phobos and Deimos are shown in Fig. 1.1.

moon	radius of orbit / m	period of rotation about Mars / hours
Phobos	9.39×10^6	7.65
Deimos	1.99×10^7	

Fig. 1.1

(i) Use data from Fig. 1.1 to determine

1. the mass of Mars,

mass = ... kg [3]

2. the period of Deimos in its orbit about Mars.

period = ... hours [3]

(ii) The period of rotation of Mars about its axis is 24.6 hours.
Deimos is in an equatorial orbit, orbiting in the same direction as the spin of Mars about its axis.

Use your answer in **(i)** to comment on the orbit of Deimos.

....

....[1]

4 **(a)** An amount of 1.00 mol of Helium-4 gas is contained in a cylinder at a pressure of 1.02×10^5 Pa and a temperature of 27 °C.

(i) Calculate the volume of gas in the cylinder.

volume = ... m^3 [2]

(ii) Hence show that the average separation of gas atoms in the cylinder is approximately 3.4×10^{-9} m.

[2]

(b) Calculate

(i) the gravitational force between two Helium-4 atoms that are separated by a distance of 3.4×10^{-9} m,

force = ... N [3]

(ii) the ratio

$$\frac{\text{weight of a Helium-4 atom}}{\text{gravitational force between two Helium-4 atoms with separation } 3.4 \times 10^{-9}\,\text{m}}.$$

ratio = ...[2]

(c) Comment on your answer to **(b)(ii)** with reference to one of the assumptions of the kinetic theory of gases.

....

....

....[2]

5 The orbit of the Earth, mass 6.0×10^{24} kg, may be assumed to be a circle of radius 1.5×10^{11} m with the Sun at its centre, as illustrated in Fig. 1.1.

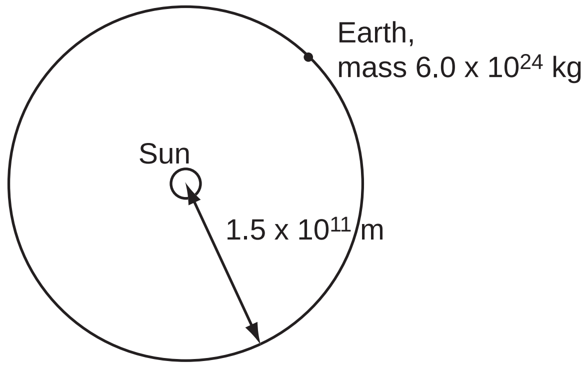

Fig. 1.1

The time taken for one orbit is 3.2×10^{7} s.

(a) Calculate

(i) the magnitude of the angular velocity of the Earth about the Sun,

angular velocity = ... rad s^{-1} [2]

(ii) the magnitude of the centripetal force acting on the Earth.

force = ... N [2]

(b) **(i)** State the origin of the centripetal force calculated in **(a)(ii)**.

....

....[1]

(ii) Determine the mass of the Sun.

mass = ... kg [3]

6 An α- particle ($^{4}_{2}He$) is moving directly towards a stationary gold nucleus ($^{197}_{79}Au$).

The α-particle and the gold nucleus may be considered to be solid spheres with the charge and mass concentrated at the centre of each sphere.

When the two spheres are just touching, the separation of their centres is 9.6×10^{-15} m.

(a) The α-particle and the gold nucleus may be assumed to be an isolated system. Calculate, for the α-particle just in contact with the gold nucleus,

(i) its gravitational potential energy,

gravitational potential energy = ... J [3]

(ii) its electric potential energy.

electric potential energy = ... J [3]

(b) Using your answers in **(a)**, suggest why, when making calculations based on an α-particle scattering experiment, gravitational effects are not considered.

....

....[1]

(c) In the α-particle scattering experiment conducted in 1913, the maximum kinetic energy of the available α-particles was about 6 MeV. Suggest why, in this experiment, the radius of the target nucleus could not be determined.

....

....

....[2]