## 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 |



1 (a) Define gravitational potential.
$\qquad$
$\qquad$
(b) Explain why values of gravitational potential near to an isolated mass are all negative.
$\qquad$
$\qquad$
$\qquad$
(c) The Earth may be assumed to be an isolated sphere of radius $6.4 \times 10^{3} \mathrm{~km}$ with its mass of $6.0 \times 10^{24} \mathrm{~kg}$ concentrated at its centre. An object is projected vertically from the surface of the Earth so that it reaches an altitude of $1.3 \times 10^{4} \mathrm{~km}$.

Calculate, for this object,
(i) the change in gravitational potential,
change in potential =
$\mathrm{Jkg}^{-1}$
(ii) the speed of projection from the Earth's surface, assuming air resistance is negligible.
speed =
$\qquad$
(d) Suggest why the equation

$$
v^{2}=u^{2}+2 a s
$$

is not appropriate for the calculation in (c)(ii).
$\qquad$

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

$$
v^{2}=\frac{2 G M}{R}
$$

where $R$ is the radius of the planet and $M$ is its mass.
(ii) Hence show that

$$
v^{2}=2 R g
$$

where $g$ is the acceleration of free fall at the planet's surface.
(b) The mean kinetic energy $E_{\mathrm{k}}$ of an atom of an ideal gas is given by

$$
E_{\mathrm{k}}=\frac{3}{2} k T \text {, }
$$

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 $6.6 \times 10^{-27} \mathrm{~kg}$ could escape to infinity.

You may assume that helium gas behaves as an ideal gas and that the radius of Earth is $6.4 \times 10^{6} \mathrm{~m}$.
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 $\omega$. The planet and its moon may be considered to be point masses that are isolated in space.

Show that $r$ and $\omega$ are related by the expression

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

Explain your working.
(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 <br> $/ \mathrm{m}$ | period of rotation <br> about Mars <br> $/$ hours |
| :---: | :---: | :---: |
| Phobos <br> Deimos | $9.39 \times 10^{6}$ <br> $1.99 \times 10^{7}$ | 7.65 |

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 =
$\qquad$ 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.
$\qquad$

4 (a) An amount of 1.00 mol of Helium-4 gas is contained in a cylinder at a pressure of $1.02 \times 10^{5} \mathrm{~Pa}$ and a temperature of $27^{\circ} \mathrm{C}$.
(i) Calculate the volume of gas in the cylinder.
volume $=$ $\mathrm{m}^{3} \quad[2]$
(ii) Hence show that the average separation of gas atoms in the cylinder is approximately $3.4 \times 10^{-9} \mathrm{~m}$.
(b) Calculate
(i) the gravitational force between two Helium-4 atoms that are separated by a distance of $3.4 \times 10^{-9} \mathrm{~m}$,
(ii) the ratio
weight of a Helium-4 atom
gravitational force between two Helium-4 atoms with separation $3.4 \times 10^{-9} \mathrm{~m}$

$$
\begin{equation*}
\text { ratio }= \tag{2}
\end{equation*}
$$

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

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


Fig. 1.1
The time taken for one orbit is $3.2 \times 10^{7} \mathrm{~s}$.
(a) Calculate
(i) the magnitude of the angular velocity of the Earth about the Sun,
angular velocity $=$ $\qquad$ $\operatorname{rads}^{-1} \quad[2]$
(ii) the magnitude of the centripetal force acting on the Earth.

$$
\text { force }=
$$

$\qquad$
(b) (i) State the origin of the centripetal force calculated in (a)(ii).
$\qquad$
(ii) Determine the mass of the Sun.
mass = kg [3]

6 An $\alpha$ - particle $\left({ }_{2}^{4} \mathrm{He}\right)$ is moving directly towards a stationary gold nucleus ( ${ }_{79}^{197} \mathrm{Au}$ ).
The $\alpha$-particle and the gold nucleus may be considered to be solid spheres with the charge and mass concentrated the centre of each sphere.

When the two spheres are just touching, the separation of their centres is $9.6 \times 10^{-15} \mathrm{~m}$.
(a) The $\alpha$-particle and the gold nucleus may be assumed to be an isolated system. Calculate, for the $\alpha$-particle just in contact with the gold nucleus,
(i) its gravitational potential energy,
gravitational potential energy $=$
(ii) its electric potential energy.
electric potential energy $=$ J [3]
(b) Using your answers in (a), suggest why, when making calculations based on an $\alpha$-particle scattering experiment, gravitational effects are not considered.
$\qquad$
$\qquad$
(c) In the $\alpha$-particle scattering experiment conducted in 1913, the maximum kinetic energy of the available $\alpha$-particles was about 6 MeV . Suggest why, in this experiment, the radius of the target nucleus could not be determined.
$\qquad$
$\qquad$

