Gravitation

2014 Revised AH Physics

Marks

3. A team of astrophysicists from a Scottish University has discovered, orbiting a nearby star, an exoplanet with the same mass as Earth.

   By considering the escape velocity of the exoplanet, the composition of its atmosphere can be predicted.

   (*a*) (i) Explain the term *escape velocity*. **1**

   (ii) Derive the expression for escape velocity in terms of the exoplanet's mass and radius. **2**

   (iii) The radius of this exoplanet is 1·7 times that of the Earth.

   Calculate the escape velocity of the exoplanet. **3**

   (*b*) Astrophysicists consider that a gas will be lost from the atmosphere of a planet if the typical molecular velocity (v_{rms}) is $\frac{1}{6}$ or more of the escape velocity for that planet.

   The table below gives v_{rms} for selected gases at 273 K.

Gas	v_{rms} (m s^{-1})
Hydrogen	1838
Helium	1845
Nitrogen	493
Oxygen	461
Methane	644
Carbon dioxide	393

   The atmospheric temperature of this exoplanet is 273 K.

   Predict which of these gases could be found in its atmosphere. **2**

(8)

3. A spacecraft is orbiting a comet as shown in Figure 3.

The comet can be considered as a sphere with a radius of $2{\cdot}1 \times 10^3$ m and a mass of $9{\cdot}5 \times 10^{12}$ kg.

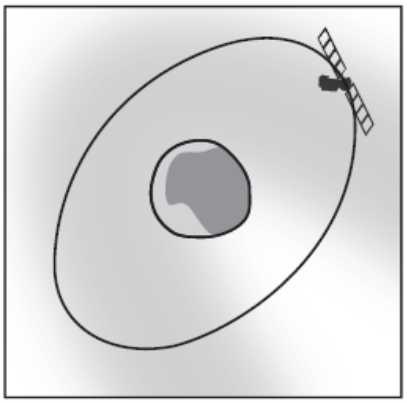

Figure 3 (not to scale)

(a) A lander was released by the spacecraft to land on the surface of the comet. After impact with the comet, the lander bounced back from the surface with an initial upward vertical velocity of $0{\cdot}38\ \text{m s}^{-1}$.

By calculating the escape velocity of the comet, show that the lander returned to the surface for a second time. 4

Space for working and answer

(b) (i) Show that the gravitational field strength at the surface of the comet is $1{\cdot}4 \times 10^{-4}\ \text{N kg}^{-1}$. 3

Space for working and answer

(ii) Using the data from the space mission, a student tries to calculate the maximum height reached by the lander after its first bounce.

The student's working is shown below

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

$$0 = 0{\cdot}38^2 + 2 \times \left(-1{\cdot}4 \times 10^{-4}\right) \times s$$

$$s = 515{\cdot}7\ \text{m}$$

The actual maximum height reached by the lander was not as calculated by the student.

State whether the actual maximum height reached would be greater or smaller than calculated by the student.

You must justify your answer. 3

(Kinematics)

4. The NASA space probe Dawn has travelled to and orbited large asteroids in the solar system. Dawn has a mass of 1240 kg.

The table gives information about two large asteroids orbited by Dawn. Both asteroids can be considered to be spherical and remote from other large objects.

Name	*Mass* ($\times 10^{20}$ kg)	*Radius* (km)
Vesta	2·59	263
Ceres	9·39	473

(a) Dawn began orbiting Vesta, in a circular orbit, at a height of 680 km above the surface of the asteroid. The gravitational force acting on Dawn at this altitude was 24·1 N.

(i) Show that the tangential velocity of Dawn in this orbit is 135 m s^{-1}. 2

Space for working and answer

(ii) Calculate the orbital period of Dawn. 3

Space for working and answer

4. (continued)

(b) Later in its mission, Dawn entered orbit around Ceres. It then moved from a high orbit to a lower orbit around the asteroid.

(i) State what is meant by the *gravitational potential of a point in space*. 1

(ii) Dawn has a gravitational potential of $-1{\cdot}29 \times 10^4$ J kg^{-1} in the high orbit and a gravitational potential of $-3{\cdot}22 \times 10^4$ J kg^{-1} in the lower orbit.

Determine the change in the potential energy of Dawn as a result of this change in orbit. 4

Space for working and answer

5. Two students are discussing objects escaping from the gravitational pull of the Earth. They make the following statements:

Student 1: A rocket has to accelerate until it reaches the escape velocity of the Earth in order to escape its gravitational pull.

Student 2: The moon is travelling slower than the escape velocity of the Earth and yet it has escaped.

Use your knowledge of physics to comment on these statements. 3

SQA Exemplar paper

5. A team of astrophysicists from a Scottish University has discovered, orbiting a nearby star, an exoplanet with the same mass as Earth.

By considering the escape velocity of the exoplanet, the composition of its atmosphere can be predicted.

(a) Explain the term *escape velocity*. 1

(b) Derive the expression for escape velocity in terms of the exoplanet's mass and radius. 3

(c) The radius of the exoplanet is $1{\cdot}09 \times 10^7$ m.

Calculate the escape velocity of the exoplanet. 3

Space for working and answer

3. The International Space Station (ISS) is in orbit around the Earth. MARKS

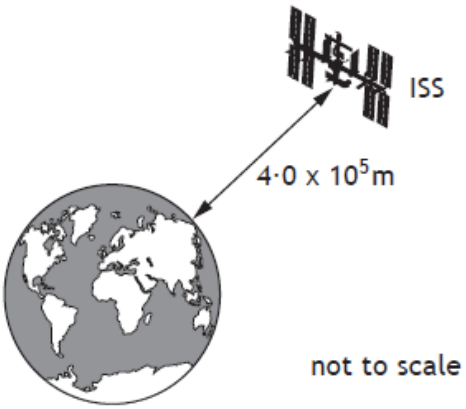

Figure 3A

(a) (i) The gravitational pull of the Earth keeps the ISS in orbit.

Show that for an orbit of radius r the period T is given by the expression

$$T = 2\pi\sqrt{\frac{r^3}{GM_E}}$$

where the symbols have their usual meaning. 2

(ii) Calculate the period of orbit of the ISS when it is at an altitude of $4{\cdot}0 \times 10^5$ m above the surface of the Earth. 2

Space for working and answer

(b) The graph in Figure 3B shows how the altitude of the ISS has varied over time. Reductions in altitude are due to the drag of the Earth's atmosphere acting on the ISS.

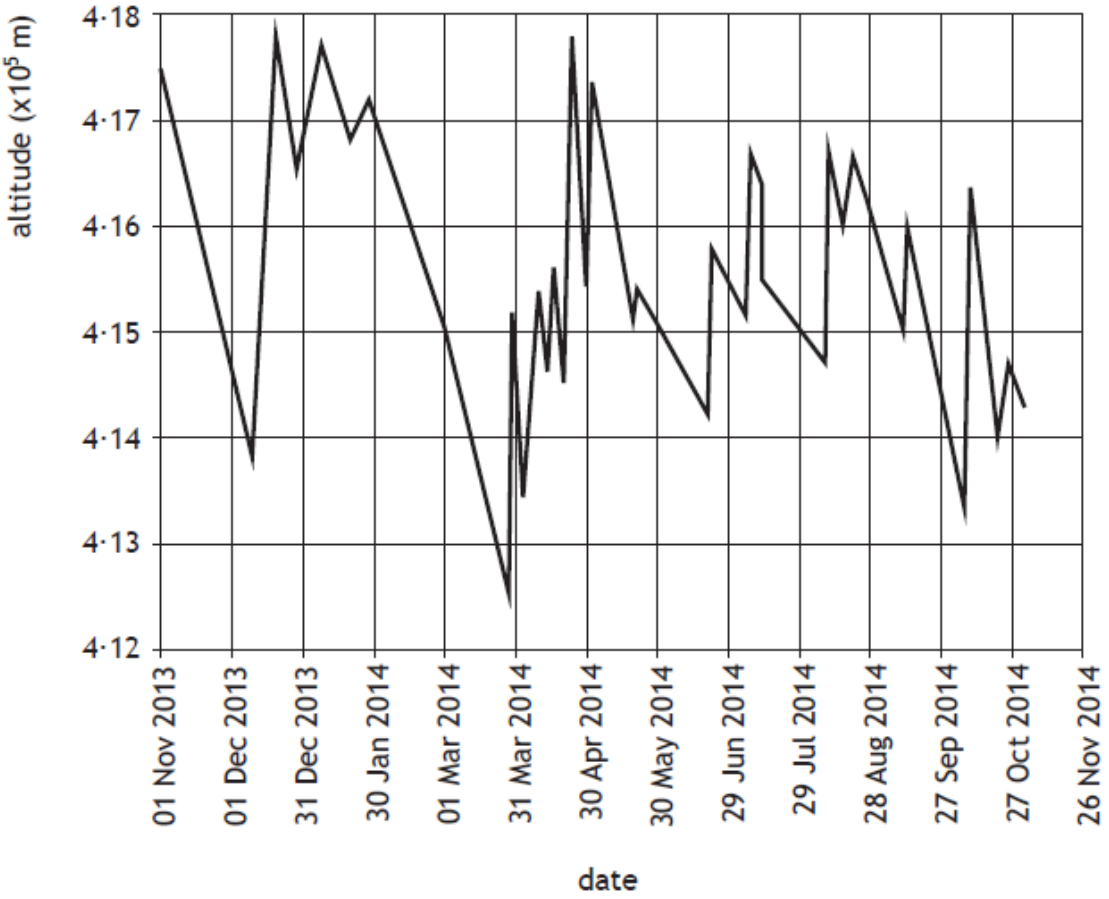

Figure 3B

(i) Determine the value of Earth's gravitational field strength at the ISS on 1 March 2014. 4

Space for working and answer

3. (b) (continued)

(ii) In 2011 the average altitude of the ISS was increased from 350 km to 400 km.

Give an advantage of operating the ISS at this higher altitude. 1