Unit 7 · Gravitation

HARDER PRACTICE QUESTIONS

Full marks 29

Write your answers on separate paper. Show your working. Take $g = 9.8\ m/s^2$ at the Earth's surface, the Earth's radius $R = 6400$ km and $G = 6.67 \times 10^{-11}\ N\ m^2/kg^2$.

1 Spot the error [3]

Find the mistake and correct it.

To find g at a height of 3200 km, Rabin writes:
"$g' = g(1 - 2h/R) = 9.8 \times (1 - 2 \times 3200 \div 6400) = \mathbf{0\ m/s^2}$: a satellite there would feel no gravity."

2 Predict, then explain [4]

Write your prediction first, then explain it.

Bina goes 100 km down a (very deep, imaginary) mine. Sanjay goes 100 km up in a balloon. Treat the Earth as a uniform sphere.

i. Predict: whose weight drops more?
ii. Find the fraction of the surface weight each keeps.

3 Read the data [4]

A table gives g at heights above the Earth's surface:

Height h (km)	0	640	3200	6400
g (m/s^2)	9.80	8.10	4.36	2.45

i. Show that $g \times (R + h)^2$ is the same in every column.
ii. Ayush claims: "g falls by the same amount for every 640 km you go up." Use the table to show he is wrong.
iii. Predict g at 12 800 km above the surface.

4 Launch costs [4]

The numbers are made up.

A 1000 kg satellite is to be put into a circular orbit of radius 2R (one Earth radius above the surface).

i. Find its total energy in the orbit, and its potential energy on the ground (use $GM = gR^2$).
ii. Find the least energy the launch must give it (ignore the air and the Earth's spin).

5 Show that [3]

Show that the escape velocity from the Earth's surface is $\sqrt{2}$ times the orbital velocity of a satellite skimming the surface. If a satellite skimming the surface (ignoring the air) were given 41% more speed, what would happen?

6 Estimate it [3]

Use the numbers given.

Using $M = gR^2/G$, estimate the average density of the Earth. The rocks at the surface have a density of about $2700\ kg/m^3$. What does your answer tell you about the inside of the Earth?

7 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

> Nirmala wrote: “A heavy satellite must move faster than a light one in the same orbit, to stay up. At the center of a uniform Earth, gravity is strongest, because all the mass is around you. And the potential energy of a satellite is positive, since it is high above the ground.”

8 Think [3]

A satellite in a low orbit feels a little drag from the thin air there. Pranisha says it must slow down. In fact it speeds up as it sinks lower. Explain how, using its energies.

9 Make your own [2]

Make up a planet whose escape velocity is the same as the Earth’s, but whose surface gravity is different. Give its mass and radius as multiples of the Earth’s, and its g.