Gravitation

Standard difficulty · 20 questions · 40 marks · Time: 36 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. The gravitational force between two bodies is 136 N. If the distance between them is reduced to 1/2, the force becomes:

(a) 34 N **(b)** 272 N **(c)** 136 N **(d)** 544 N

2. A planet has 5 times the mass and the same radius as the earth. The acceleration due to gravity on its surface is (g on earth = 10 m/s^2):

(a) 50 m/s^2 **(b)** 2 m/s^2 **(c)** 51 m/s^2 **(d)** 49 m/s^2

3. A planet has 18 times the mass and 2 times the radius of the earth. Its escape speed is how many times the earth's?

(a) 9 **(b)** 12 **(c)** 36 **(d)** 3

4. Planet B's orbit radius is 9 times planet A's. B's period of revolution is how many times A's?

(a) 3 **(b)** 9 **(c)** 27 **(d)** 81

5. The value of the universal gravitational constant G is about:

(a) 3×10^{8} N m^2 kg^{-2} **(b)** 9.8 N m^2 kg^{-2}
(c) 6.67×10^{11} N m^2 kg^{-2} **(d)** 6.67×10^{-11} N m^2 kg^{-2}

6. Using $g' = g(1 - 2h/R)$, the acceleration due to gravity at a height of 160 km is (g = 10 m/s^2, R = 6400 km):

(a) 9.5 m/s^2 **(b)** 10 m/s^2 **(c)** 9.75 m/s^2 **(d)** 10.5 m/s^2

7. At a depth of 3/8 of the earth's radius, the acceleration due to gravity is (g = 10 m/s^2 at the surface):

(a) 10 m/s^2 **(b)** 3.75 m/s^2 **(c)** 5.29 m/s^2 **(d)** 6.25 m/s^2

8. Assertion (A): A body that weighs 84 N on the earth's surface weighs 21 N at a height equal to the earth's radius.
Reason (R): g decreases in proportion to the distance from the earth's centre.

(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. A body has a mass of 46 kg. Find its mass and its weight on a planet where g is half of the earth's (g there = 5 m/s^2). What is its weight on the earth? (Take g = 10 m/s^2.)

10. At what height above the earth's surface does g become 1/16 of its value at the surface? (R = 6400 km)

11. At what depth below the earth's surface is g reduced by 75%? (R = 6400 km)

12. A 1900 kg satellite moves in a circle just above the surface of a planet with g = 20 m/s^2, whose radius is 5,000 km. Find its orbital speed, its period (π = 22/7) and its kinetic energy.

13. Planet P orbits the sun at 16 times the earth's distance from the sun. Find its period of revolution in earth years.

14. Find the gravitational force between masses of 91 kg and 48 kg placed 1.2 m apart. (G = 6.67 × 10^{-11} N m^2 kg^{-2})

15. How much energy is needed to raise a 300 kg satellite from the earth's surface to a height of 2R? (R = 6.4 × 10^6 m; g = 10 m/s^2)

16. The escape speed from the earth is 11.2 km/s. Find the escape speed from a planet with 4 times the mass and the same radius as the earth.

Section C — Word problems — 4 × 4 = 16 marks

17. A 1900 kg satellite orbits at a height of 24R above the earth's surface (R = 6.4 × 10^6 m, g = 10 m/s^2). Find (a) g at that height, (b) its orbital speed, (c) its period (π = 22/7), (d) its kinetic energy.

18. A body weighs 800 N on the earth's surface. Find its weight (a) at a height of 2R, (b) at a depth of (1/2)R, (c) at the centre of the earth. Explain (c). (Take g = 10 m/s^2.)

19. Two satellites orbit the same planet. The first has a period of 4 hours. The second's orbit radius is 16 times the first's. Find its period. Which law did you use?

20. Two bodies of masses M and 81M are 400,000 km apart. At what point between them is the net gravitational force on a small mass zero?

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Answer key

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Q	Answer	Working
1	**(d) 544 N**	$F \propto 1/r^2$
2	**(a) 50 m/s²**	$g = GM/R^2$, so $g' = g \times m/r^2$
3	**(d) 3**	$v_e = \sqrt{(2GM/R)} \propto \sqrt{(M/R)}$
4	**(c) 27**	$T^2 \propto r^3$, so T ∝ r^(3/2)
5	**(d) 6.67×10^{-11} N m² kg⁻²**	—
6	**(a) 9.5 m/s²**	10 × (1 − 320/6400)
7	**(d) 6.25 m/s²**	$g' = g(1 - d/R)$
8	**(c) A is true, but R is false.**	A is true: g′ = g/4, so the weight is 84 ÷ 4 = 21 N. R is false.
9	**Mass 46 kg; weight 230 N; on the earth 460 N**	mass does not change; weight = mg
10	**19,200 km (= 3R)**	$R^2/(R + h)^2 = 1/16$, so R + h = 4R
11	**4,800 km**	$g' = g(1 - d/R)$; d/R = 75/100
12	**$v = \sqrt{(gR)} = 10000$ m/s; $T = 2\pi R/v$ = 3,142.86 s; KE = 9.50×10^{10} J**	$mg = mv^2/R$
13	**64 years**	$T^2 \propto r^3$: T = 16^(3/2) years
14	**2.02×10^{-7} N**	$F = Gm_1m_2/r^2 = 6.67 \times 10^{-11} \times 91 \times 48 \div 1.44$
15	**1.28×10^{10} J**	$\Delta U = GMm[1/R - 1/(R + h)] = mgR \times 2/3$
16	**22.4 km/s**	$v_e \propto \sqrt{(M/R)}$: 11.2 × √4
17	**(a) 0.016 m/s²; (b) 1,600 m/s; (c) 6.29×10^5 s; (d) 2.43×10^9 J**	$v = \sqrt{(gR^2/(R + h))} = 8000/\sqrt{25}$; $T = 2\pi(R + h)/v$
18	**(a) 88.89 N; (b) 400 N; (c) 0 N, because g is zero at the centre: the earth's mass pulls equally in all directions**	$g' = gR^2/(R + h)^2$; $g' = g(1 - d/R)$
19	**256 hours; Kepler's third law ($T^2 \propto r^3$)**	$T_2 = T_1 \times (16)^{(3/2)}$
20	**360,000 km from the 81M body (40,000 km from M)**	$GM/x^2 = G(81M)/(d - x)^2$, so (d − x)/x = 9

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