NARAYAN GURUKUL ACADEMY

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Class - 11 Gravitation

90 minutes · 40 marks

Section A — MCQ & VSA (10 × 1 = 10 marks)

1. All planets move in elliptical orbits with the Sun situated at

(A) the centre of the ellipse
(B) one of the two foci of the ellipse
(C) any point inside the ellipse
(D) the edge of the ellipse

2. The value of the universal gravitational constant G (in SI units) is

(A) 6.67×10^{-11} N m^2 kg^{-2}
(B) 6.67×10^{11} N m^2 kg^{-2}
(C) 6.67×10^{-11} N kg^2 m^{-2}
(D) 6.67×10^{-9} N m^2 kg^{-2}

3. The value of acceleration due to gravity is maximum at

(A) the equator
(B) the poles
(C) every point of the surface
(D) a height $h = R$ above the surface

4. The gravitational potential due to a point mass M at a distance r is

(A) $-\frac{GM}{r}$
(B) $+\frac{GM}{r}$
(C) $-\frac{GM}{r^2}$
(D) $+\frac{GM}{r^2}$

5. The escape velocity from the surface of the Earth is

(A) 7.9 km s^{-1}
(B) 11.2 km s^{-1}
(C) 9.8 km s^{-1}
(D) 13.4 km s^{-1}

6. The orbital speed of a satellite revolving close to the Earth's surface ($r \approx R$) is

(A) 11.2 km s^{-1}
(B) 7.9 km s^{-1}
(C) 3.1 km s^{-1}
(D) 24.0 km s^{-1}

7. State Kepler's law of orbits.
8. Define the universal gravitational constant G.
9. Define escape velocity and give its value for the Earth.
10. What is a geostationary (geo-synchronous) satellite?

Section B — Short Answer I (4 × 2 = 8 marks)

11. The areal velocity of a planet is constant. Show what this implies about the angular momentum of the planet.
12. Write the dimensional formula of the universal gravitational constant G.
13. Show that at a height h very much smaller than the Earth's radius R ($h \ll R$), the acceleration due to gravity is approximately $g' \approx g\left(1 - \frac{2h}{R}\right)$.
14. A particle of mass 1 kg is kept on the surface of a uniform sphere of mass 20 kg and radius 1.0 m. Find the work to be done against the gravitational force to take the particle away (to infinity) from the sphere.

Section C — Short Answer II (4 × 3 = 12 marks)

15. The planet Neptune revolves around the Sun with a period of 165 years. Show that the radius of its orbit is approximately thirty times that of the Earth's orbit, taking both orbits as circular.
16. Two spheres of the same material and the same radius r are placed touching each other. Show that the gravitational force between them is directly proportional to r^4.
17. Suppose the Earth increases its speed of rotation. At what new time period will the weight of a body on the equator become zero? Take $g = 10\,\text{m s}^{-2}$ and $R = 6400$ km.
18. An artificial satellite is moving in a circular orbit around the Earth with a speed equal to one-fourth of the escape velocity from the Earth. Determine the height of the satellite above the Earth's surface in terms of R (the Earth's radius).

Section D — Long Answers (2 × 5 = 10 marks)

19. State Newton's universal law of gravitation. Define the universal gravitational constant G, giving its value and dimensions, and derive the relation between g and G.
20. A satellite is so placed that it appears stationary to an observer on Earth and serves as a fixed relay station. Given $R = 6400$ km and $g = 9.8\,\text{m s}^{-2}$, find the height of the satellite above the Earth's surface, the radius of its orbit and its orbital speed.

Answer Key (Marking Scheme)

Q no.	Section	Type	Marks	Answer (with short working hint)
Q1	A	MCQ	1	(B) one of the two foci of the ellipse
Q2	A	MCQ	1	(A) 6.67×10^{-11} N m^2 kg^{-2}
Q3	A	MCQ	1	(B) poles ($g \propto 1/R^2$; $R_{\text{pole}} < R_{\text{eq}}$)
Q4	A	MCQ	1	(A) $V = -GM/r$
Q5	A	MCQ	1	(B) 11.2 km s^{-1} ($v_e = \sqrt{2gR}$)
Q6	A	MCQ	1	(B) 7.9 km s^{-1} ($v_o = \sqrt{gR}$)
Q7	A	VSA	1	Elliptical orbits; Sun at one focus
Q8	A	VSA	1	Force between unit masses at unit distance
Q9	A	VSA	1	Minimum speed to leave Earth's field; 11.2 km s^{-1}
Q10	A	VSA	1	$T = 24$ h, equatorial, west to east, stays over one fixed point
Q11	B	SA-I	2	$\frac{dA}{dt} = \frac{L}{2m}$ = constant ⇒ L constant
Q12	B	SA-I	2	$[M^{-1}L^3T^{-2}]$
Q13	B	SA-I	2	$g' = g(1 + h/R)^{-2} \approx g(1 - 2h/R)$ (binomial, $h \ll R$)
Q14	B	SA-I	2	$V = -GM/R = -1.334 \times 10^{-9}$ J kg^{-1}; $W = 1.334 \times 10^{-9}$ J
Q15	C	SA-II	3	$(T_N/T_E)^{2/3} = (165)^{2/3} \approx 30 \times$
Q16	C	SA-II	3	$m \propto r^3$, $F \propto m^2/r^2 \Rightarrow F \propto r^6/r^2 = r^4$
Q17	C	SA-II	3	$T = 2\pi\sqrt{R/g} \approx 1.4$ h
Q18	C	SA-II	3	$v = v_e/4 \Rightarrow r = 8R \Rightarrow h = 7R$
Q19	D	LA	5	$g = GM/R^2$ derived; $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}, $[M^{-1}L^3T^{-2}]$
Q20	D	LA	5	$r \approx 4.23 \times 10^4$ km, $h \approx 3.6 \times 10^4$ km, $v_o \approx 3.1$ km s^{-1}

Marking Scheme (distribution)

Section	Marks	Q nos.
A — MCQ & VSA	10	1–10
B — Short Answer I	8	11–14
C — Short Answer II	12	15–18
D — Long Answers	10	19–20
Total	**40**	**1–20**