

Chapter 7: Gravitation - NCERT Exercise Solutions

Physics Class 11

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7.1 Gravitational Phenomena

(a) Can you shield a body from gravitational influence by putting it inside a hollow sphere?

Answer: NO. Unlike electric fields, gravitational fields cannot be shielded. A hollow sphere does not block external gravitational forces from acting on objects inside it. Gravitational shielding is impossible.

(b) Can an astronaut in a large space station detect gravity? Answer: YES, potentially. In a small spacecraft, the astronaut and ship fall together (weightlessness). In a very large space station, different parts experience slightly different gravitational forces (tidal effects), which could be detectable.

(c) Why is moon's tidal effect greater than sun's despite sun's stronger gravitational pull?

Answer: Tidal effects depend on the **gradient** of gravitational field, not absolute strength. Moon is much closer to Earth, so the difference in gravitational pull between Earth's near and far sides is greater for the moon than the sun.

7.2 Choose Correct Alternative

(a) Acceleration due to gravity with altitude: DECREASES ($g \propto 1/r^2$) **(b) Acceleration due to gravity with depth:** DECREASES ($g \propto r$ for $r < R_E$) **(c) Acceleration due to gravity is independent of:** MASS OF THE BODY (depends only on Earth's mass and distance) **(d) More**

accurate formula for potential energy difference: $-GMm(1/r_2 - 1/r_1)$ is MORE accurate than $mg(r_2 - r_1)$

7.3 Planet with Double Earth's Orbital Speed

Given: Planet orbits sun twice as fast as Earth **Find:** Orbital size compared to Earth

Solution: Using Kepler's third law: $T^2 \propto r^3$

If $T_{\text{planet}} = T_{\text{Earth}}/2$, then:

$$(T_{\text{planet}})^2 = (T_{\text{Earth}}/2)^2 = T_{\text{Earth}}^2/4$$

$$r_{\text{planet}}^3 = r_{\text{Earth}}^3/4$$

$$r_{\text{planet}} = r_{\text{Earth}}/(4^{1/3}) = r_{\text{Earth}}/1.587$$

Answer: Orbital radius = 0.63 times Earth's orbital radius

7.4 Jupiter's Mass from Io's Data

Given: Io's orbital period $T = 1.769$ days, orbital radius $r = 4.22 \times 10^8$ m

Solution: Using Kepler's third law:

$$T^2 = (4\pi^2/GM)r^3$$

$$M = 4\pi^2 r^3 / (GT^2)$$

$$M = 4\pi^2 \times (4.22 \times 10^8)^3 / [6.67 \times 10^{-11} \times (1.769 \times 24 \times 3600)^2]$$

$$M = 1.90 \times 10^{27} \text{ kg}$$

Sun's mass $\approx 2 \times 10^{30}$ kg Ratio: $M_{\text{Jupiter}}/M_{\text{Sun}} \approx 1/1000$ ✓

7.5 Galactic Revolution Time

Given: 2.5×10^{11} stars, each 1 solar mass, distance = 50,000 ly from center

Solution: Using circular orbital motion:

$$v = \sqrt{GM_{\text{galaxy}}/r}$$

$$T = 2\pi r/v = 2\pi \sqrt{r^3/GM_{\text{galaxy}}}$$

$$T = 2\pi \sqrt{[(5 \times 10^{20})^3 / (6.67 \times 10^{-11} \times 2.5 \times 10^{11} \times 2 \times 10^{30})]}$$

$$T \approx 3 \times 10^8 \text{ years}$$

Answer: About 300 million years

7.6 Satellite Energy

(a) If zero potential at infinity, satellite's total energy is: NEGATIVE of its kinetic energy **(b)**

Energy to launch orbiting satellite vs stationary object: LESS energy needed for orbiting satellite (it already has some kinetic energy)

7.7 Escape Speed Dependencies

(a) Mass of body: NO - escape speed is independent of launched object's mass **(b) Location of**

launch: YES - depends on distance from Earth's center

(c) Direction of projection: NO - escape speed is same in all directions **(d) Height of launch**

location: YES - higher altitude requires less escape speed

7.8 Comet's Orbital Properties

Answer: (a) Linear speed: NOT constant (faster at perihelion, slower at aphelion) **(b) Angular**

speed: NOT constant (Kepler's second law) **(c) Angular momentum:** CONSTANT (no external torque) **(d) Kinetic energy:** NOT constant (varies with speed) **(e) Potential energy:** NOT constant (varies with distance) **(f) Total energy:** CONSTANT (conservative system)

7.9 Astronaut Symptoms in Space

Likely symptoms: **(b) swollen face** and **(d) orientational problems** **Explanation:** Blood shifts toward head in zero gravity causing facial swelling. Lack of gravitational reference causes spatial disorientation.

7.10 Hemispherical Shell Gravitational Intensity

Answer: (iv) 0 **Explanation:** By symmetry, for every mass element pulling in one direction, there's an equal element pulling in the opposite direction. Net gravitational field at the center is zero.

7.11 Arbitrary Point P in Hemisphere

Answer: (ii) e

Explanation: Net gravitational field points toward the hemisphere's base (where most mass is concentrated).

7.12 Zero Gravitational Force Point

Given: $M_{\text{sun}} = 2 \times 10^{30} \text{ kg}$, $M_{\text{earth}} = 6 \times 10^{24} \text{ kg}$, Earth-Sun distance = $1.5 \times 10^{11} \text{ m}$

Solution: At distance x from Earth center:

$$GM_{\text{earth}}/x^2 = GM_{\text{sun}}/(1.5 \times 10^{11} - x)^2$$

$$6 \times 10^{24}/x^2 = 2 \times 10^{30}/(1.5 \times 10^{11} - x)^2$$

Solving: $x = 2.6 \times 10^8$ m from Earth's center

Answer: 260,000 km from Earth's center

7.13 Weighing the Sun

Solution: Use Earth's orbital data:

$$\text{Earth's centripetal force} = \text{Gravitational force}$$

$$mv^2/r = GMm/r^2$$

$$v^2 = GM/r$$

$$M = v^2 r / G = (2\pi r / T)^2 r / G = 4\pi^2 r^3 / (GT^2)$$

With: $r = 1.5 \times 10^8$ km, $T = 1$ year **Answer:** $M_{\text{sun}} \approx 2 \times 10^{30}$ kg

7.14 Saturn's Distance

Given: Saturn year = 29.5 Earth years, Earth distance = 1.5×10^8 km

Solution: Using Kepler's third law:

$$T_{\text{Saturn}}^2 / T_{\text{Earth}}^2 = r_{\text{Saturn}}^3 / r_{\text{Earth}}^3$$

$$(29.5)^2 = (r_{\text{Saturn}} / r_{\text{Earth}})^3$$

$$r_{\text{Saturn}} = r_{\text{Earth}} \times (29.5)^{2/3} = 1.5 \times 10^8 \times 9.54$$

Answer: $r_{\text{Saturn}} \approx 1.43 \times 10^9$ km

7.15 Weight at Height $h = R_E/2$

Given: Weight at surface = 63 N

Solution:

$$g(h) = g/(1 + h/R_E)^2 = g/(1 + 1/2)^2 = g/2.25$$
$$\text{Weight at height} = 63/2.25 = 28 \text{ N}$$

Answer: 28 N

7.16 Weight at Half-way to Center

Given: Surface weight = 250 N

Solution: At depth $d = R_E/2$:

$$g(d) = g(1 - d/R_E) = g(1 - 1/2) = g/2$$
$$\text{Weight} = 250/2 = 125 \text{ N}$$

Answer: 125 N

7.17 Rocket Maximum Height

Given: Initial speed = 5 km/s, $M_E = 6.0 \times 10^{24} \text{ kg}$, $R_E = 6.4 \times 10^6 \text{ m}$

Solution: Using energy conservation:

$$\frac{1}{2}mv^2 - GMm/R_E = -GMm/r_{\max}$$

$$\frac{1}{2}v^2 = GM(1/R_E - 1/r_{\max})$$

$$1/r_{\max} = 1/R_E - v^2/(2GM)$$

$$r_{\max} = 1.6 \times 10^7 \text{ m}$$

Maximum height = $r_{\max} - R_E = 9.6 \times 10^6 \text{ m} = 9,600 \text{ km}$

7.18 Body with 3× Escape Speed

Given: Launched with $v = 3v_{\text{escape}} = 3 \times 11.2 \text{ km/s} = 33.6 \text{ km/s}$

Solution: Using energy conservation:

$$\frac{1}{2}m(33.6 \times 10^3)^2 - GMm/R_E = \frac{1}{2}mv_{\infty}^2$$

$$v_{\infty}^2 = (33.6 \times 10^3)^2 - 2GM/R_E$$

$$v_{\infty}^2 = (33.6 \times 10^3)^2 - (11.2 \times 10^3)^2$$

$$v_{\infty} = \sqrt{[(33.6)^2 - (11.2)^2] \times 10^3} = 31.7 \text{ km/s}$$

Answer: Speed far from Earth = 31.7 km/s

7.19 Satellite Escape Energy

Given: Height = 400 km, $m = 200 \text{ kg}$

Solution:

$$\text{Orbital radius } r = R_E + h = 6.4 \times 10^6 + 4 \times 10^5 = 6.8 \times 10^6 \text{ m}$$

$$\text{Current energy: } E = -GMm/(2r) = -5.88 \times 10^9 \text{ J}$$

$$\text{Energy to escape: } \Delta E = 0 - E = 5.88 \times 10^9 \text{ J}$$

Answer: 5.89 GJ required

7.20 Colliding Stars Speed

Given: Two stars, each mass 2×10^{30} kg, initial separation 10^9 km

Solution: Using energy conservation:

$$\text{Initial energy} = -G(2 \times 10^{30})^2 / (10^{12} \text{ m}) = -2.67 \times 10^{37} \text{ J}$$

At collision (separation = 2×10^7 m):

$$-2.67 \times 10^{37} = 2 \times \frac{1}{2}mv^2 - G(2 \times 10^{30})^2 / (2 \times 10^7)$$

$$\text{Solving: } v = 6.2 \times 10^6 \text{ m/s}$$

Answer: Collision speed = 6,200 km/s each

7.21 Gravitational Force at Midpoint

Given: Two spheres, $m = 100$ kg each, $R = 0.10$ m, separation = 1.0 m

Solution: At midpoint (0.5 m from each center): **Gravitational force:** Net force = 0 (forces cancel)

Gravitational potential:

$$V = -Gm/r_1 - Gm/r_2 = -2Gm/0.5 = -2.67 \times 10^{-8} \text{ J/kg}$$

Equilibrium: Unstable (small displacement leads to net force toward one sphere)

Key Formulas

- **Universal gravitation:** $F = Gm_1m_2/r^2$
- **Escape speed:** $v_e = \sqrt{2GM/R}$
- **Orbital speed:** $v = \sqrt{GM/r}$
- **Kepler's 3rd law:** $T^2 \propto r^3$
- **Gravitational PE:** $U = -GMm/r$

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