Engineering Daily Exam 10 [Set 03] EV

Work, Energy & Power + Gravitation & Gravity

Total Marks: 50 **Negative Marks:** 0.25 **Time:** 1 Hour

MCQ 50 marks

1. Find the gravitational self-energy (binding energy) of a uniform solid sphere of mass $M = 6 \times 10^{24}\,\text{kg}$ and radius $R = 6.4 \times 10^{6}\,\text{m}$.

   (A) $-2.253 \times 10^{32}\,\text{J}$ (B) $-1.877 \times 10^{32}\,\text{J}$
   (C) $-3.754 \times 10^{32}\,\text{J}$ (D) $+2.253 \times 10^{32}\,\text{J}$

2. What will be the weight of a 50 kg person in a spacecraft located at a height of 1200 km above the Earth's surface?

   (A) 412.4 N (B) 347.5 N (C) 691.2 N (D) 490 N

3. A 500 g rubber ball hits a wall perpendicularly at $15\,\text{ms}^{-1}$ and rebounds at $9\,\text{ms}^{-1}$. How much kinetic energy (in Joules) was converted to heat and sound in the collision?

   (A) 56.25 J (B) 13.5 J (C) 20.25 J (D) 36 J

4. A 3 kg block is pushed 8 m across a frictionless table by a constant 25 N horizontal force, then the force is removed and the block enters a rough section ($\mu = 0.2$). Find the block's speed at the instant it enters the rough section.

   (A) $13.33\,\text{ms}^{-1}$ (B) $5.77\,\text{ms}^{-1}$
   (C) $8.16\,\text{ms}^{-1}$ (D) $11.55\,\text{ms}^{-1}$

5. Find the (idealized, ignoring air resistance) orbital period of a satellite orbiting at a height of 10 km above Earth's surface.

   (A) 5078 s (B) 3.26×10^{10} s
   (C) 5090 s (D) 2.01 s

6. Point masses of 2 kg, 3 kg, and 4 kg are placed at the vertices of an equilateral triangle of side 0.5 m. Find the total gravitational potential energy of the system.

   (A) $-6.938 \times 10^{-9}\,\text{J}$ (B) $-3.469 \times 10^{-9}\,\text{J}$
   (C) $-8.008 \times 10^{-10}\,\text{J}$ (D) $+3.469 \times 10^{-9}\,\text{J}$

7. Water is lifted from a well 125 m deep at a rate of 100 kg per minute using an engine. If 35% of the engine's power is lost while lifting this water, find the engine's power in horsepower.

   (A) 2.11 HP (B) 7.82 HP
   (C) 3.70 HP (D) 2.74 HP

8. In a right-angled triangle ABC with the right angle at A, $AB = 3\,\text{m}$ and $AC = 4\,\text{m}$. Point masses of 2 kg , 3 kg, and 5 kg are placed at A, B, and C respectively. Find the magnitude of the net gravitational force on the mass at A due to the masses at B and C.

   (A) 6.10×10^{-11} N (B) 8.62×10^{-11} N
   (C) 4.45×10^{-11} N (D) 2.78×10^{-12} N

9. A 1500 kg vehicle starts from rest and reaches a height of 500 m ($g = 9.8\,\text{ms}^{-2}$ taken as constant) with a speed of $80\,\text{ms}^{-1}$. If the engine's efficiency is 60%, find the total (input) energy consumed by the engine.

   (A) 12.15 MJ (B) 20.25 MJ
   (C) 7.29 MJ (D) 33.75 MJ

10. If the gravitational constant G were suddenly doubled (with Earth's orbital radius and the Sun's mass unchanged), how would Earth's orbital period change?

    (A) $\frac{T}{\sqrt{2}}$ (B) 0.5T (C) T (D) 2T

11. A child on a swing (rope length 3 m, treated as a simple pendulum) is pulled back so the seat rises 0.8 m above its lowest point, then released. Air resistance dissipates 10% of the potential energy as heat before it reaches the lowest point. Find the child's speed at the lowest point.

    (A) $3.756\,\text{ms}^{-1}$ (B) $3.96\,\text{ms}^{-1}$
    (C) $3.564\,\text{ms}^{-1}$ (D) $4.153\,\text{ms}^{-1}$

12. A solid rubber ball is dropped from 5 m onto a hard floor and rebounds to 3.2 m. What percentage of its kinetic energy is lost in the collision?

    (A) 56.25% (B) 64% (C) 36% (D) 20%

13. A thin, uniform spherical shell of mass $M_1 = 5 \times 10^{24}\,\text{kg}$ and radius $R_1 = 8 \times 10^{6}\,\text{m}$ has, concentric with it, a smaller thin uniform spherical shell of mass $M_2 = 2 \times 10^{24}\,\text{kg}$ and radius $R_2 = 3 \times 10^{6}\,\text{m}$ inside it. Find the gravitational potential at a point at distance $r = 5 \times 10^{6}\,\text{m}$ from the common center (i.e., between the two shells, $R_2 < r < R_1$).

    (A) $-4.17 \times 10^{7}\,\text{Jkg}^{-1}$ (B) $-2.67 \times 10^{7}\,\text{Jkg}^{-1}$
    (C) $-1.084 \times 10^{8}\,\text{Jkg}^{-1}$ (D) $-6.84 \times 10^{7}\,\text{Jkg}^{-1}$

14. A vertical spring ($k = 2000\,\text{Nm}^{-1}$) is compressed 20 cm by a 0.4 kg ball and released. How much higher does the ball rise above the point where the spring returns to its natural length? (Ignore spring mass and air resistance.)

    (A) 10.20 m (B) 20.41 m (C) 51.02 m (D) 10.00 m

15. Planet A orbits planet B once every 70 days in an orbit of radius 3×10^{5} km. If planet C also orbits the same planet B once every 135 days, find the orbital radius of C.

    (A) 5.79×10^{5} km (B) 11.16×10^{5} km
    (C) 1.94×10^{5} km (D) 4.65×10^{5} km

16. A 0.5 kg projectile is launched at $40\,\text{ms}^{-1}$ at 30° above the horizontal. Find its kinetic energy at the highest point (ignore air resistance).

    (A) 300 J (B) 400 J (C) 100 J (D) 8.66 J

17. A $6\,\text{kg}$ block on a frictionless horizontal table is connected via a frictionless pulley at the table's edge to a hanging $4\,\text{kg}$ mass. Released from rest, find the speed of the blocks after the hanging mass has descended $1.5\,\text{m}$ (use energy methods).

(A) $5.42\,\text{ms}^{-1}$ (B) $3.43\,\text{ms}^{-1}$ (C) $4.20\,\text{ms}^{-1}$ (D) $2.42\,\text{ms}^{-1}$

18. A planet's density varies with distance r from the center as $\varrho(r) = \varrho_0\left(1 - \frac{r}{R}\right)$, where ϱ_0 is a constant and R is the planet's radius. At what distance from the center (in terms of R) will the acceleration due to gravity g be maximum?

(A) $r = \frac{2R}{3}$ (B) $r = \frac{R}{2}$ (C) $r = \frac{R}{3}$ (D) $r = \frac{3R}{4}$

19. An object is thrown straight up with the same kinetic energy from the surfaces of planets X and Y. Planet X's surface gravity is 3 times Y's, and both have equal radii. Find $h_x : h_y$ (assume height is small compared to radius).

(A) $1:1.732$ (B) $1:3$ (C) $1:1$ (D) $3:1$

20. Two identical stars (each $2 \times 10^{30}\,\text{kg}$) orbit their common center of mass at a separation of $4 \times 10^{11}\,\text{m}$. Find the orbital speed of each star.

(A) $9.13\,\text{kms}^{-1}$ (B) $18.27\,\text{kms}^{-1}$

(C) $12.92\,\text{kms}^{-1}$ (D) $25.83\,\text{kms}^{-1}$

21. A small ball is released from height h above the bottom of a smooth circular loop-track of radius R. When the ball reaches the top of the loop, the track exerts a normal force on it equal to twice its own weight. Find the relation between h and R.

(A) $h = 5R$ (B) $h = 2.5R$ (C) $h = 3.5R$ (D) $h = 3R$

22. A planet has mass $7 \times 10^{25}\,\text{kg}$ and radius $7000\,\text{km}$, and rotates once every 24 hours on its own axis. Find how much the weight of a $10\,\text{kg}$ object, positioned at 30° from the rotation axis, decreases due to this rotation.

(A) $0.0925\,\text{N}$ (B) $0.370\,\text{N}$

(C) $0.1851\,\text{N}$ (D) $0.2776\,\text{N}$

23. At what speed must an object be launched from Earth's surface so that it follows a bound, elliptical orbital path (and does not escape)?

(A) $v > 11.2\,\text{kms}^{-1}$

(B) $v < 11.2\,\text{kms}^{-1}$

(C) $v = 7.9\,\text{kms}^{-1}$ (only this one value)

(D) $v = 11.2\,\text{kms}^{-1}$ (exactly escape velocity)

24. A $2\,\text{kg}$ block starts from rest at the top of a frictionless $8\,\text{m}$ high incline (angle 37°), slides down, crosses a short frictionless flat section, and goes up a second frictionless incline of angle 53°. How far along the surface of the second incline does the block travel?

(A) $10.02\,\text{m}$ (B) $5.01\,\text{m}$

(C) $8.00\,\text{m}$ (D) $13.29\,\text{m}$

25. A rocket is launched vertically from a planet's surface ($R = 6400\,\text{km}$, $g = 9.8\,\text{ms}^{-2}$) at $8\,\text{kms}^{-1}$. Using exact energy conservation (accounting for the variation of g with height), find the maximum height it reaches.

(A) $13066\,\text{km}$ (B) It escapes to infinity

(C) $6666\,\text{km}$ (D) $3265\,\text{km}$

26. A rectangular water tank has length, width and height of $3\,\text{m}$, $4\,\text{m}$ and $5\,\text{m}$ respectively (full of water). Find the power (in HP) of a 55%-efficient motor needed to completely empty it in 15 minutes.

(A) $7.96\,\text{HP}$ (B) $2.19\,\text{HP}$

(C) $238.9\,\text{HP}$ (D) $3.98\,\text{HP}$

27. An escalator moves at $0.75\,\text{ms}^{-1}$ along a 30° incline. A $70\,\text{kg}$ person stands still on it and is carried up to a vertical height of $6\,\text{m}$. Find the power the escalator motor spends lifting this person.

(A) $445.6\,\text{W}$ (B) $514.5\,\text{W}$

(C) $1.23\,\text{W}$ (D) $257.25\,\text{W}$

28. A uniform sphere has mass $2 \times 10^4\,\text{kg}$ and radius $2.5\,\text{m}$. Find the gravitational field intensity at a point $0.7\,\text{m}$ from the sphere's center.

(A) $4.186 \times 10^{-8}\,\text{Nkg}^{-1}$ (B) $2.724 \times 10^{-6}\,\text{Nkg}^{-1}$

(C) $1.495 \times 10^{-7}\,\text{Nkg}^{-1}$ (D) $5.98 \times 10^{-8}\,\text{Nkg}^{-1}$

29. If the mass of planet A is 36 times the mass of planet B, and the distance between them is $40 \times 10^9\,\text{km}$, at what point on the line joining them (measured from A) will the gravitational pull of both planets on an object be equal?

(A) $20.00 \times 10^9\,\text{km}$ (B) $34.29 \times 10^9\,\text{km}$

(C) $5.71 \times 10^9\,\text{km}$ (D) $38.92 \times 10^9\,\text{km}$

30. A satellite moves in a circular orbit $1600\,\text{km}$ above Earth's surface. An instantaneous tangential speed increase makes its new orbit have an apogee $3600\,\text{km}$ above Earth's surface. By how much was the satellite's speed increased relative to its initial speed? ($R = 6400\,\text{km}$, $g = 9.8\,\text{ms}^{-2}$)

(A) $192\,\text{ms}^{-1}$ (B) $383\,\text{ms}^{-1}$

(C) $1360\,\text{ms}^{-1}$ (D) $766\,\text{ms}^{-1}$

31. Earth's mass is $5.97 \times 10^{24}\,\text{kg}$, the Moon's mass is $7.35 \times 10^{22}\,\text{kg}$, and the distance between them is $3.84 \times 10^5\,\text{km}$. At what distance from Earth is the net gravitational field zero?

(A) $38400\,\text{km}$ (B) $379300\,\text{km}$

(C) $192000\,\text{km}$ (D) $345600\,\text{km}$

32. The Sun's mass is $1.989 \times 10^{30}\,\text{kg}$ and radius $6.96 \times 10^8\,\text{m}$. Find the escape velocity from the Sun's surface.

(A) $617.6\,\text{kms}^{-1}$ (B) $436.7\,\text{kms}^{-1}$

(C) $19531\,\text{kms}^{-1}$ (D) $0.0234\,\text{kms}^{-1}$

33. **A pump lifts water from a lower reservoir to a higher one $35\,\text{m}$ above, at a rate of 15000 litres per hour. If overall efficiency is 70%, find the pump motor's power rating in kW. (1 litre $= 1\,\text{kg}$)**

(A) $1.429\,\text{kW}$ (B) $7350\,\text{kW}$

(C) $2.042\,\text{kW}$ (D) $1.0\,\text{kW}$

34. **A tunnel is dug straight through the Earth's diameter, and an object is dropped into it from the surface. When the object reaches the Earth's center, find the ratio of its speed to the escape velocity.**

(A) $1:\sqrt{2}$ (B) $1:2$

(C) $\sqrt{2}:1$ (D) $1:1$

35. **A hollow spherical shell has a radius of $0.5\,\text{m}$. Find the ratio of gravitational field intensities ($g_{0.2} : g_{0.8}$) at points $0.2\,\text{m}$ and $0.8\,\text{m}$ from the center.**

(A) $16:1$ (B) $1.024:1$

(C) 0 (D) Infinite

36. **A planet's mass suddenly increases by 50%, while its radius simultaneously decreases by 20%. Find the percentage change in the planet's escape velocity.**

(A) Increases by 134.4%

(B) Increases by 87.5%

(C) Decreases by 13.3%

(D) Increases by 36.9%

37. **A $0.3\,\text{kg}$ block slides at $4\,\text{ms}^{-1}$ across a frictionless horizontal table and strikes a horizontal spring ($k = 800\,\text{Nm}^{-1}$). Find the maximum compression of the spring.**

(A) $0.1549\,\text{m}$ (B) $0.1095\,\text{m}$

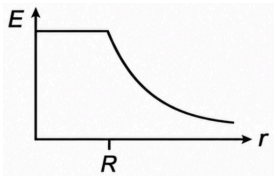
(C) $0.0775\,\text{m}$ (D) $0.0387\,\text{m}$

38. **A satellite orbits close to Earth's surface (radius $\approx R$) with period T_0. Another satellite is placed at height R above Earth's surface. What is its period?**

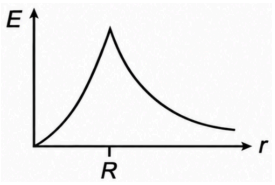
(A) T_0 (B) $\sqrt{2}\,T_0$ (C) $2\sqrt{2}\,T_0$ (D) $4T_0$

39. **For a solid, uniform-density sphere of radius R, which graph correctly shows gravitational field intensity E versus distance r from the center?**

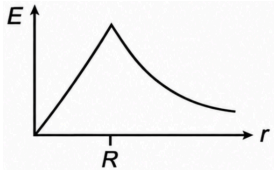
(A)



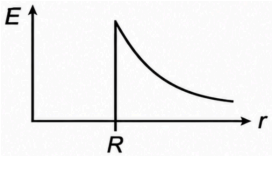
(B)



(C)



(D)



40. **A crane lifts a $250\,\text{kg}$ iron block upward at constant velocity. If the crane applies $7\,\text{HP}$ of power at 66% efficiency, at what speed will the block rise?**

(A) $1.41\,\text{ms}^{-1}$ (B) $2.13\,\text{ms}^{-1}$

(C) $0.0019\,\text{ms}^{-1}$ (D) $3.23\,\text{ms}^{-1}$

41. **A wind turbine's blades sweep a circular area of radius $25\,\text{m}$. Wind blows at $12\,\text{ms}^{-1}$ (air density $1.2\,\text{kgm}^{-3}$). If the turbine extracts 40% of the kinetic energy of the wind passing through, find the electrical output power (in kW).**

(A) $201.28\,\text{kW}$ (B) $2035.76\,\text{kW}$

(C) $67.86\,\text{kW}$ (D) $814.3\,\text{kW}$

42. **For an object of mass m falling freely from rest under gravity, find the expression for the amount of potential energy lost (equivalently, kinetic energy gained) during the n-th second.**

(A) mg^2n^2 (B) $\frac{1}{2}\text{mg}^2(2\text{n}+1)$

(C) $\text{mg}^2(2\text{n}-1)$ (D) $\frac{1}{2}\text{mg}^2(2\text{n}-1)$

43. **A $1000\,\text{kg}$ car moving at $25\,\text{ms}^{-1}$ brakes and comes to a stop. If the coefficient of kinetic friction between the tyres and the road is 0.6, find the stopping distance.**

(A) $106.29\,\text{m}$ (B) $4.25\,\text{m}$

(C) $53.15\,\text{m}$ (D) $31.89\,\text{m}$

44. **A person takes 2 minutes to climb stairs to the 5th floor. The number of steps on each floor $= 5\text{n}+2$, where $\text{n} =$ floor number $(1, 2, \ldots, 5)$, and the height of each step is $13\,\text{cm}$. If the person's mass is $65\,\text{kg}$, find his power in horsepower.**

(A) $58.66\,\text{HP}$ (B) $0.0786\,\text{HP}$

(C) $0.0139\,\text{HP}$ (D) $4.72\,\text{HP}$

45. **A satellite's orbital radius is reduced to $\frac{1}{4}$ of its original value (same central planet). By what factor does its orbital period change?**

(A) $\frac{1}{2}$ (B) $\frac{1}{16}$

(C) $\frac{1}{4}$ (D) $\frac{1}{8}$

46. **Planet A's mass is 7 times planet B's mass, and the distance between them is $10^5\,\text{km}$. Assume only these two planets exist in this universe. Find the distance between the point where the gravitational field intensity is zero and the point where the gravitational potential is at its extremum (minimum).**

(A) $27440\,\text{km}$ (B) $72560\,\text{km}$

(C) 0 (same point) (D) $50000\,\text{km}$

47. **The momentum of a $4\,\text{kg}$ object varies with time as $p(t) = 3t^2 + 2t$ (SI units). Using the work-energy theorem, find the total work done on the object from $t = 1\,\text{s}$ to $t = 3\,\text{s}$.**

(A) $133\,\text{J}$ (B) $118.25\,\text{J}$

(C) $68.5\,\text{J}$ (D) $236\,\text{J}$

48. In a hydroelectric plant, water falls through $45\,\text{m}$ at a rate of $200000\,\text{kg}$ per minute. The turbine converts water power to mechanical power at 88% efficiency, and the generator converts that to electrical power at 95% efficiency. Find the electrical output power in MW.

(A) $73.66\,\text{MW}$ (B) $1.220\,\text{MW}$

(C) $1.229\,\text{MW}$ (D) $1.294\,\text{MW}$

49. A worker pushes a $25\,\text{kg}$ crate up a rough ramp (angle 15°, length $6\,\text{m}$, $\mu = 0.3$) with a constant force along the ramp. Starting from rest, the crate reaches the top at $2\,\text{ms}^{-1}$. Using the work-energy theorem, find the work done by the worker's applied force.

(A) $856.32\,\text{J}$ (B) $430.44\,\text{J}$

(C) $475.88\,\text{J}$ (D) $1584.1\,\text{J}$

50. A solid wooden cylindrical log (density $600\,\text{kgm}^{-3}$), diameter $0.6\,\text{m}$ and length $7\,\text{m}$, lies flat on the ground. How much work must be done to tilt it up, about one end resting on the ground, until it makes a 30° angle with the ground?

(A) $40.73\,\text{kJ}$ (B) $10.54\,\text{kJ}$

(C) $20.37\,\text{kJ}$ (D) $35.27\,\text{kJ}$