Engineering Daily Exam 10 [Set 04] EV

Work, Energy & Power + Gravitation & Gravity

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

MCQ 50 marks

1. Planet P has the same mass as Earth, but only $\frac{1}{8}$ of Earth's average density. A narrow tunnel is drilled straight to the center of planet P (assumed uniform density), and a ball is released from the surface into it. Find the ball's speed at the center of P, in terms of Earth's escape velocity v_e.

   (A) $\frac{v_e}{4}$ (B) $\frac{v_e}{\sqrt{2}}$

   (C) $\frac{v_e}{2}$ (D) v_e

2. A satellite rotates once on its own axis every 13 h and has a diameter of 15×10^5 km. If a spacecraft of mass 10^9 kg lands on it at the equator, how much does the spacecraft's weight decrease due to the body's own rotation?

   (A) 1.352×10^{10} N (B) 2.704×10^{10} N

   (C) 1.007×10^{14} N (D) 1.752×10^{17} N

3. A 45 m long ladder is set against the roof of a building, making a 55° angle with the ground. A 60 kg person carrying a 10 kg object climbs the ladder and reaches the roof in 5 min. Find the person's power in horsepower (HP).

   (A) 0.079 HP (B) 6.78 HP

   (C) 0.113 HP (D) 0.097 HP

4. A 15 g bullet moving at 400 ms^{-1} strikes a wooden block and penetrates 12 cm before stopping. Find the average resisting force exerted by the wood.

   (A) 10, 000 N (B) 10, 000, 000 N

   (C) 20, 000 N (D) 100 N

5. A body is thrown vertically downward with a velocity of 51.8 m/s from a height of 137m. At what height above the ground will its kinetic energy be $\frac{3}{5}$ of its potential energy?

   (A) 82.2 m (B) 51.375 m

   (C) 85.625 m (D) 54.8 m

6. Two spherical masses, 2×10^{27} kg and 5×10^7 kg, with radii 3×10^4 km and 4×10^3 km respectively, start approaching each other essentially from rest under mutual gravity alone. Find the ratio of their speeds ($v_1 : v_2$) at the instant their surfaces touch (collision).

   (A) $4 \times 10^{19} : 1$ (B) $1 : 4 \times 10^{19}$

   (C) 1 : 1 (D) 1 : 7.5

7. At what height above Earth's surface will an object's weight be reduced to 1% of its surface weight?

   (A) 64 km (B) 633, 600 km

   (C) 64, 000 km (D) 57, 600 km

8. A 20 kg block is pulled across a rough floor (μ = 0.25) through 12 m by a 150 N force applied at 40° above the horizontal. Find the net work done on the block.

   (A) 501.5 J (B) 1080.06 J

   (C) 790.8 J (D) 1378.8 J

9. A straight, frictionless tunnel is dug through the Earth NOT through the center, but along a chord. Compared to a tunnel through the center, the period of oscillation of a ball dropped into this chord tunnel is:

   (A) Cannot be determined without knowing the exact chord length

   (B) Shorter, proportional to the chord length

   (C) Exactly the same

   (D) Longer, inversely proportional to the chord length

10. At a height of 3000 km above the surface of a planet, g is measured to be 3.728 ms^{-2}. At a height of 2000 km above the surface, g is measured to be 4.9 ms^{-2}. Find the radius of the planet.

    (A) 8000 km (B) 2000 km

    (C) 4828 km (D) 6000 km

11. Two stars, of mass 3×10^{30} kg and 5×10^{30} kg, orbit their common center of mass at a separation of 2×10^{11} m. Find the orbital period of this binary system.

    (A) 54.4 s (B) 2.432×10^7 s

    (C) 4.864×10^7 s (D) 3.076×10^7 s

12. A person lifts a 20 kg dumbbell from the floor to a height of 1.6 m, 25 times (lowering it slowly is taken to require no work). If all 25 repetitions take total 2 min, find the person's average power output.

    (A) 3920 W (B) 130.67 W

    (C) 2.61 W (D) 65.33 W

13. A brick has dimensions 0.45 m × 0.55 m × 0.75 m (density 1800 kgm^{-3}). It initially rests on its 0.75 m × 0.55 m face (so the 0.45 m edge is vertical). Find the work needed to tip it up so it stands on its 0.45 m × 0.55 m face (so the 0.75 m edge becomes vertical).

    (A) 491.16 J (B) 272.87 J

    (C) 982.33 J (D) 245.58 J

14. A conveyor belt lifts sand at a rate of 50 kgs^{-1} from ground level to a height of 4 m, and also gives it a horizontal speed of 3 ms^{-1} at the top. Find the power required to run the belt (considering only the energy given to the sand).

    (A) 2185 W (B) 225 W (C) 2410 W (D) 1960 W

15. A cyclist pedals up a 5° incline at a constant speed of 4 ms^{-1}. The combined mass of cyclist and bike is 80 kg, and a constant resistive force (friction + air drag) of 20 N opposes the motion. Find the power the cyclist must produce.

(A) 273.44 W (B) 3204 W

(C) 353.44 W (D) 80 W

16. Water flows through a pipe of cross-section 0.02 m^2 at 3 ms^{-1} and is pumped to a height of 25 m. Ignoring losses, find the power required. (Density of water = 1000 kgm^{-3})

(A) 270 W (B) 14700 W

(C) 14970 W (D) 14.97 W

17. A pile-driver hammer (mass 800 kg) falls from 2 m onto a pile, driving it 8 cm into the ground. If 20% of the hammer's kinetic energy is lost as heat and sound on impact, find the ground's average resisting force.

(A) 1,568 N (B) 156,800 N

(C) 235,200 N (D) 196,000 N

18. An object weighs 47 N on Earth and 35 N on Mars. If Mars's radius is 1.25 times Earth's radius, find the escape velocity of Mars.

(A) 9.665 kms^{-1} (B) 14.51 kms^{-1}

(C) 12.52 kms^{-1} (D) 10.81 kms^{-1}

19. A satellite of mass 800 kg orbits a planet of mass 4×10^{24} kg in a circular orbit. If the satellite's kinetic energy is 1.2×10^{10} J, find the orbital period.

(A) 5105 s (B) 20,420 s

(C) 2.84×10^4 s (D) 10,210 s

20. At what depth below Earth's surface will the acceleration due to gravity equal half of the acceleration due to gravity at the same (numerical) height above the surface?

(A) 5470 km (B) 6400 km

(C) 5000 km (D) 3200 km

21. A simple pendulum of length 0.5 m swings through a semicircular path (from one horizontal extreme, through the lowest point, to the other horizontal extreme). The bob's mass is 0.05 kg and its density is 5000 kgm^{-3}. If the bob is fully submerged in water (density 1000 kgm^{-3}) while swinging, find the difference between its maximum and minimum instantaneous speeds.

(A) 3.13 ms^{-1} (B) 6.26 ms^{-1}

(C) 1.4 ms^{-1} (D) 2.8 ms^{-1}

22. Given Earth's radius 6400 km and g = 9.8 ms^{-2}, find the height of a geostationary satellite above the surface. (T = 24 h)

(A) 42,340 km (B) 35.94 km

(C) 60,830 km (D) 35,940 km

23. The height of a hydroelectric dam is 20 m. To continuously generate 1 MW of electricity, how much water must be released from the reservoir per second? The reservoir is located at 30° latitude on Earth, where g = 9.807 ms^{-2} (assume 100% conversion efficiency).

(A) 0.0051 kgs^{-1} (B) 5098.4 kgs^{-1}

(C) 50,000 kgs^{-1} (D) 5000 kgs^{-1}

24. In a hydraulic lift, the small piston has area 8 cm^2 and the large piston has area 400 cm^2. To raise a 1200 kg car by 1.5 m on the large piston, the small piston must be pushed down 30 cm per stroke, for a total of 40 strokes. If 20% of the input work is lost to friction, find the average force applied on the small piston in each stroke.

(A) 1470 N (B) 2205 N

(C) 1837.5 N (D) 918.75 N

25. A hammer of mass 7.5 kg starts falling freely from rest. At exactly 1.74 s, it strikes the floor. Due to the impact, the hammer sinks 3 cm into the soil. Find the average resisting force of the soil. (g = 9.8 m/s^2)

(A) 441 N (B) 36,750 N

(C) 36,411 N (D) 73,500 N

26. A 5 kg stone is dropped from a building 15 m high. If breaking an object kept on the ground requires one-fourth of the stone's impact energy, from what height should a 3 kg stone be dropped to break the object?

(A) 3.75 m

(B) 6.25 m

(C) 5.75 m

(D) 8.25 m

27. Water falls 60 m over a waterfall to drive a turbine, at a flow rate of 2500 kgs^{-1}. The turbine's mechanical efficiency is 82% and the connected generator's electrical efficiency is 90%. Find the total electrical output power (in MW).

(A) 1.323 MW (B) 1.470 MW

(C) 1.204 MW (D) 1.086 MW

28. A car engine (car's mass = 1200 kg) has a power of 135 HP and 72% efficiency. Find the minimum time needed to bring the car from rest to a speed of 35 ms^{-1}.

(A) 5.25 s (B) 10.14 s

(C) 0.58 s (D) 7.30 s

29. At the pole of a planet, an object's true weight is 500 N. The planet's angular velocity is $\omega = 7.5 \times 10^{-5}$ $rads^{-1}$, radius $R = 6 \times 10^6$ m, and true surface gravity g = 9.8 ms^{-2}. Find the apparent weight of the same object at latitude 45°.

(A) 498.78 N (B) 498.28 N

(C) 499.98 N (D) 499.14 N

30. An object is projected vertically upward at $8.0\ \text{kms}^{-1}$ from a height of 1500 km above Earth's surface. Ignoring air resistance and accounting for the variation of g with altitude, what maximum height above Earth's surface will it reach? ($R = 6400$ km, $g = 9.8\ \text{ms}^{-2}$)

(A) 6400 km (B) 14939 km
(C) 10439 km (D) 17850 km

31. An object is thrown straight up at $5\ \text{kms}^{-1}$ from a planet's surface. If 15% of its kinetic energy is lost to air resistance, to what height will it rise? Planet's mass = 6.5×10^{23} kg, radius = 5000 km.

(A) 5000 km
(B) 6124 km
(C) It escapes the gravitational field and travels to infinity
(D) 7205 km

32. In an Atwood machine, 5 kg and 3 kg masses are connected by a string over a frictionless, massless pulley. Released from rest, find the speed of the masses after they have moved 2 m (use energy methods).

(A) $3.13\ \text{ms}^{-1}$ (B) $6.26\ \text{ms}^{-1}$
(C) $2.21\ \text{ms}^{-1}$ (D) $4.95\ \text{ms}^{-1}$

33. A 500 kg satellite orbits Earth at a radius of 7000 km. Find the additional energy required to move it to a new circular orbit of radius 14,000 km. ($GM_{earth} = gR^2$, $g = 9.8\ \text{ms}^{-2}$, $R = 6400$ km)

(A) -7.168×10^9 J
(B) 1.4336×10^{10} J
(C) 7.168×10^9 J
(D) 2.867×10^{10} J

34. A sphere has density $\varrho = \varrho_0 r$, where ϱ_0 is a constant and r is the distance from the center. If the sphere's radius is R, find the gravitational field intensity at a distance $\frac{R}{3}$ from the center.

(A) $\frac{\pi G \varrho_0 R^2}{9}$
(B) $\frac{GM}{R^2}$
(C) $\frac{GM}{27R^2}$
(D) $\frac{GM}{3R^2}$

35. Two planets have a density ratio of 5 : 6 and a radius ratio of 3 : 5. Find the ratio of their escape velocities.

(A) 1.826 : 1 (B) 0.913 : 1
(C) 0.5 : 1 (D) 0.548 : 1

36. A satellite of mass m orbits a planet (mass M) in a circular orbit of radius r, and another satellite of mass 3m orbits the same planet at radius 4r. Find the ratio of their total mechanical energies ($E_1 : E_2$).

(A) 3 : 4 (B) 16 : 3
(C) 1 : 12 (D) 4 : 3

37. If a planet's mean density is $\varrho = 5500\ \text{kgm}^{-3}$, find the orbital period of a satellite skimming just above its surface ($h \approx 0$).

(A) 2.567×10^7 s (B) 5851 s
(C) 5067 s (D) 2926 s

38. A planet has an escape velocity of $15\ \text{kms}^{-1}$ and a radius of 8000 km. Find its mean density.

(A) $0.419\ \text{kgm}^{-3}$
(B) $6289.5\ \text{kgm}^{-3}$
(C) $26,342\ \text{kgm}^{-3}$
(D) $12,579\ \text{kgm}^{-3}$

39. A car engine delivers 60 kW of power while moving at a constant $108\ \text{kmh}^{-1}$ on a level road. Find the total resistive force (friction + air resistance) acting on the car.

(A) 154.32 N (B) 555.56 N
(C) 2000 N (D) 2 N

40. A toy car's spring launcher ($k = 150\ \text{Nm}^{-1}$) is compressed 10 cm and launches a 0.2 kg car along a frictionless horizontal track, which then climbs a frictionless 25° ramp. How far along the ramp does the car travel before momentarily stopping?

(A) 0.422 m (B) 0.383 m
(C) 0.906 m (D) 1.811 m

41. A 0.5 kg piece of glass slides down a rough incline (angle 37°, coefficient of friction $\mu = 0.2$). At the bottom, it strikes a spring (spring constant $k = 400\ \text{Nm}^{-1}$) placed along the incline, compressing it by 25 cm before momentarily stopping. Find the speed of the glass at the instant it first touches the spring.

(A) $6.80\ \text{ms}^{-1}$ (B) $6.92\ \text{ms}^{-1}$
(C) $6.86\ \text{ms}^{-1}$ (D) $7.14\ \text{ms}^{-1}$

42. A 10 kg object falls from a height of 5 m onto a spring, compressing it by 15 cm. Find the spring constant.

(A) $44,862\ \text{Nm}^{-1}$ (B) $22,431\ \text{Nm}^{-1}$
(C) $43,556\ \text{Nm}^{-1}$ (D) $4.49\ \text{Nm}^{-1}$

43. A lift capable of carrying a maximum of 1500 kg rises at a constant speed of $6\ \text{ms}^{-1}$. The friction force = $0.2mg$, where m is the lift's maximum (car + load) mass. Find the motor power (in HP) required.

(A) 94.6 HP (B) 141.9 HP
(C) 105840 HP (D) 118.23 HP

44. An astronaut can jump 2 ft high on planet A. How high can he jump on planet B? Given: density $\varrho_A = 5\varrho_B$ and radius $R_A = 4R_B$.

(A) 10 ft (B) 18 ft
(C) 0.1 ft (D) 40 ft

45. A comet orbits the Sun in a highly elliptical orbit with a perihelion distance of 0.4 AU and an aphelion distance of 40 AU. Earth orbits the Sun in an (idealized) circular orbit of radius 1 AU. Find the ratio of the comet's perihelion speed to Earth's orbital speed ($v_p : v_{Earth}$).

(A) 5.00 : 1 (B) 1.58 : 1

(C) 2.23 : 1 (D) 0.45 : 1

46. Earth orbits the Sun at a mean distance of 1.5×10^{11} m with a period of 365.25 days. Find the mass of the Sun.

(A) 1.336×10^{19} kg (B) 2.005×10^{30} kg

(C) 5.078×10^{28} kg (D) 6.325×10^{37} kg

47. The position of a 5 kg object is given by $x = 5t - 2t^3 + 7t^2$ (x in metres, t in seconds). Find the total work done on the object from $t = 2.5$ s to $t = 4.5$ s.

(A) 1428 J (B) 7840 J

(C) 14280 J (D) 7140 J

48. A satellite's orbital radius slowly decreases due to atmospheric drag (orbital decay). As the radius decreases, what happens to its (i) kinetic energy, (ii) potential energy, and (iii) total mechanical energy?

(A) All three increase

(B) All three decrease

(C) KE increases, PE decreases, Total E decreases

(D) KE decreases, PE increases, Total E decreases

49. If the average density of planet X is $\frac{16}{27}$ times that of Earth's average density, and its radius is 1.5 times Earth's radius, what is the ratio of the escape velocity at the surface of X relative to Earth?

(A) 1.155 : 1 (B) 1.333 : 1

(C) 0.866 : 1 (D) 1.732 : 1

50. A pump delivers water from a well to a tank 18 m above at a rate of 200 litres per minute. If the pump's efficiency is 60%, find the required input power in HP. (1 litre of water = 1 kg)

(A) 0.473 HP (B) 1.314 HP

(C) 78.85 HP (D) 0.788 HP