S5 Physics Practice Paper

S5 | Physics | Time: 75 minutes | Total: 100 marks | 24 questions

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Part 1: Circular Motion (17 marks)

Take g = 9.81 m s^-2; give answers to 3 significant figures.

1. A car of mass 1200 kg travels at 20 m s^-1 round a bend of radius 50 m. Find its centripetal acceleration and the centripetal force required.

Answer: a = v^2 / r = 20^2 / 50 = 8.0 m s^-2; F = ma = 1200 x 8.0 = 9600 N, directed towards the centre of the bend.

2. A stone of mass 0.20 kg on a string of length 1.0 m is whirled at 2.0 revolutions per second in a horizontal circle. Find the angular speed, the linear speed and the tension.

Answer: omega = 2(pi)f = 2(pi) x 2.0 = 12.57 rad s^-1; v = (omega)r = 12.57 x 1.0 = 12.6 m s^-1; the tension supplies the centripetal force: T = m(omega)^2 r = 0.20 x 157.91 = 31.6 N.

3. A small ball moves inside a vertical circular track of radius 1.6 m. (a) Find the minimum speed at the top for the ball to stay in contact. (b) If the ball (mass 0.1 kg) has speed 6.0 m s^-1 at the bottom, find the force exerted by the track on the ball.

Answer: (a) At the top the normal force is zero at minimum speed: mg = mv^2 / r, v = sqrt(gr) = sqrt(9.81 x 1.6) = 3.96 m s^-1. (b) At the bottom: N - mg = mv^2 / r, N = 0.98 + 2.25 = 3.23 N.

4. A banked track has radius 80 m and is inclined at 15.000 degrees, with no friction. Find the design speed for a car on this bend.

Answer: The design speed satisfies v^2 = rg tan(theta) = 80 x 9.81 x tan 15.0 deg = 210.3, so v = 14.50 m s^-1.

Part 2: Gravitation and Satellites (17 marks)

Take the Earth radius as 6.37 x 10^6 m and GM = 3.986 x 10^14 m^3 s^-2.

5. A satellite orbits at a height of 1000 km above the Earth. Find the gravitational field strength there and its ratio to g at the surface.

Answer: r = R + h = 7370000.00 x 10^6 m; g = GM / r^2 = 3.986 x 10^14 / (7370000.00 x 10^6)^2 = 7.34 m s^-2; ratio = 7.34 / 9.81 = 0.748.

6. A satellite moves in a circular orbit of radius 7.0 x 10^6 m around the Earth. Find its speed and period in minutes.

Answer: v = sqrt(GM / r) = sqrt(3.986 x 10^14 / 7.0e+06) = 7546 m s^-1, about 7.55 km s^-1; T = 2(pi)r / v = 43982297 / 7546 = 5829 s, about 97.1 minutes.

7. A geostationary satellite has a period of 24 hours. Find its orbital radius and its height above the Earth.

Answer: GMm / r^2 = m(4(pi)^2 r / T^2) gives r = (GM T^2 / 4(pi)^2)^(1/3) = 4.224 x 10^7 m; height h = r - R = 3.587 x 10^7 m, about 35871 km.

8. Find the escape speed from the Earth surface in km s^-1 and explain why the escape speed from the Moon is smaller.

Answer: v = sqrt(2GM / R) = 11187 m s^-1, about 11.2 km s^-1. The Moon has smaller mass and radius, so 2GM / R is smaller and the escape speed is lower.

Part 3: Simple Harmonic Motion (17 marks)

Give all answers to 3 significant figures.

9. A particle performs simple harmonic motion with amplitude 0.050 m and frequency 2.0 Hz. Find the angular frequency, maximum speed and maximum acceleration.

Answer: omega = 2(pi)f = 12.57 rad s^-1; v_max = A(omega) = 0.050 x 12.57 = 0.628 m s^-1; a_max = A(omega)^2 = 0.050 x 157.91 = 7.90 m s^-2.

10. A simple pendulum is 0.80 m long. Find its period and frequency for small oscillations.

Answer: T = 2(pi)sqrt(l / g) = 2(pi)sqrt(0.80 / 9.81) = 1.794 s; f = 1 / T = 0.557 Hz. It depends on length and g, not on mass.

11. A spring oscillator has mass 0.50 kg, spring constant 50 N m^-1 and amplitude 0.10 m. (a) Find the period. (b) Find the total energy. (c) Find the speed at displacement 0.060 m.

Answer: (a) omega = sqrt(k / m) = 10.0 rad s^-1, T = 2(pi) / omega = 0.628 s. (b) E = 0.5kA^2 = 0.5 x 50 x 0.100^2 = 0.25 J. (c) v = (omega)sqrt(A^2 - x^2) = 10.0 x sqrt(0.010 - 0.0036) = 0.80 m s^-1 (KE 0.16 J, PE 0.09 J, total 0.25 J).

12. The amplitude of the same oscillator falls from 0.10 m to 0.05 m with everything else unchanged. Find (a) the ratio of total energies, (b) the ratio of maximum speeds, and explain.

Answer: (a) E is proportional to A^2, so the energy ratio is (1/2)^2 = 0.25, i.e. one quarter of the original. (b) v_max is proportional to A, so the speed ratio is 0.5; energy depends on the square of speed, consistent with (a).

Part 4: Electric Fields and Potential (17 marks)

Take k = 8.99 x 10^9 N m^2 C^-2, e = 1.60 x 10^-19 C and m_e = 9.11 x 10^-31 kg.

13. Two parallel plates 0.020 m apart have a potential difference of 200 V. (a) Find the field strength between them. (b) Find the force on an electron and its acceleration.

Answer: (a) E = V / d = 200 / 0.020 = 1.0e+04 V m^-1. (b) F = eE = 1.60 x 10^-19 x 1.0e+04 = 1.6e-15 N; a = F / m_e = 1.76e+15 m s^-2.

14. A point charge Q = 2.0 x 10^-9 C is in air. Find the field strength and the potential at a distance of 0.30 m.

Answer: E = kQ / r^2 = 199.8 V m^-1; V = kQ / r = 59.9 V.

15. (a) A positive charge of 5.0 x 10^-6 C is moved from 0 V to 300 V. Find the work done by the field. (b) An electron is accelerated through 500 V. Find its kinetic energy in eV and J, and its speed.

Answer: (a) W = QV = 5.0e-06 x 300 = 1.5e-03 J. (b) KE = 500 eV = 8.0e-17 J; v = sqrt(2E / m_e) = 1.325e+07 m s^-1.

16. A capacitor stores 24 uC when the potential difference across it is 12.0 V. (a) Find its capacitance. (b) Find the stored energy. (c) What is the stored energy if the potential difference rises to 24.0 V?

Answer: (a) C = Q / V = 24.0 x 10^-6 / 12.0 = 2.0e-06 F (2.0 uF). (b) E = 0.5CV^2 = 1.44e-04 J. (c) Doubling V quadruples E: 5.76e-04 J.

Part 5: Electromagnetic Induction (16 marks)

Coil resistance and other losses are negligible unless stated.

17. A coil of area 0.020 m^2 lies perpendicular to a uniform field of 0.50 T. The field falls to zero in 0.050 s. Find (a) the initial flux, (b) the average induced emf.

Answer: (a) flux = BA = 0.50 x 0.020 = 0.010 Wb. (b) emf = d(flux) / dt = 0.010 / 0.050 = 0.20 V.

18. A rod of length 0.25 m moves at 4.0 m s^-1 perpendicular to a 0.80 T field. The circuit resistance is 2.0 ohm. Find the induced emf, current and power.

Answer: emf = Blv = 0.80 x 0.25 x 4.0 = 0.80 V; I = 0.40 A; P = 0.32 W.

19. An ideal transformer has 1000 primary turns and 50 secondary turns, with 220 V across the primary and 4.0 A in the secondary. Find the secondary voltage, output power and primary current.

Answer: Vs = Vp x Ns / Np = 11.0 V; P = 44 W; Ip = P / Vp = 0.20 A.

20. An AC supply is connected to a 60 ohm resistor and has a peak voltage of 340 V. Find (a) the rms voltage, (b) the mean power, (c) the peak power, and state the relation between them.

Answer: (a) V_rms = 340 / sqrt(2) = 240.4 V. (b) P = 963 W. (c) P_peak = 1927 W = 2 x mean power, because power is proportional to the square of voltage.

Part 6: Nuclear Decay and Binding Energy (16 marks)

Take 1 u = 931.5 MeV c^-2 and 1 eV = 1.60 x 10^-19 J.

21. A radionuclide has 8.0 x 10^20 nuclei and a half-life of 5.0 days. Find the number of nuclei left after 20 days and the percentage decayed.

Answer: 20 days is 4 half-lives; N = 5.0 x 10^19; percentage decayed = 93.75%.

22. A sample has an initial activity of 800 Bq and a half-life of 10.0 hours. Find (a) the decay constant in s^-1, (b) the activity after 30 hours.

Answer: (a) lambda = ln2 / t_half = 0.0693 per hour = 1.925e-05 s^-1. (b) 30 h is 3 half-lives, A = 100 Bq.

23. A nuclear reaction has a mass defect of 0.030 u. Find the energy released in MeV and in J.

Answer: E = 0.030 x 931.5 = 27.95 MeV = 4.48e-12 J.

24. Uranium-238 (mass number 238, atomic number 92) undergoes alpha decay. (a) Write the nuclear equation. (b) After 2 more alpha decays and 2 beta-minus decays, find the mass number and atomic number of the final nucleus.

Answer: (a) 238/92 U -> 234/90 Th + 4/2 He. (b) Mass number = 238 - 3 x 4 = 226; atomic number = 92 - 3 x 2 + 2 x 1 = 88, so the final nucleus is 226/88 Ra.