S6 Physics Practice Paper (Set 2)

S6 | Physics | Time: 75 minutes | Total: 100 marks | 24 questions

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Part A Circular Motion and Centripetal Force (12 marks)

A ball of mass 0.20 kg tied to a 0.50 m string moves in a horizontal circle on a smooth table with a period of 0.80 s.

1. Find the angular velocity of the ball. (3 marks)

Answer: $\omega = 2\pi / T = 2\pi / 0.80 = 7.85$ rad/s.

2. Find the linear speed of the ball. (3 marks)

Answer: $v = \omega r = 7.85 \times 0.50 = 3.93$ m/s.

3. Find the centripetal acceleration. (3 marks)

Answer: $a = \omega^2 r = 7.85^2 \times 0.50 = 30.84$ m/s^2.

4. Find the tension in the string. (3 marks)

Answer: Tension provides the centripetal force: $F = ma = 0.20 \times 30.84 = 6.17$ N, directed towards the centre.

Part B Gravity and Satellite Orbits (18 marks)

The mass of the Earth is 5.97 x 10^24 kg and its radius is 6.37 x 10^6 m; G = 6.67 x 10^-11 N m² kg^-2. A satellite moves in a circular orbit of radius 7.00 x 10^6 m.

5. Find the acceleration due to gravity at the Earth surface. (4 marks)

Answer: $g = GM / R^2 = (6.67\text{x}10^{-11} \times 5.97\text{x}10^{24}) / (6.37\text{x}10^6)^2 = 9.81$ m/s^2.

6. Find the orbital speed of the satellite. (5 marks)

Answer: $v = \sqrt{GM / r} = \sqrt{3.98\text{x}10^{14} / 7.00\text{x}10^6} = 7542$ m/s, about 7.54 km/s.

7. Find the period of the satellite in minutes. (5 marks)

Answer: $T = 2\pi r / v = 2\pi \times 7.00\text{x}10^6 / 7542 = 5831$ s = 97.19 minutes.

8. If the orbital radius is doubled, find the new orbital speed. (4 marks)

Answer: v is proportional to 1/sqrt(r), so the new speed is 7542 / sqrt(2) = 5333 m/s (about 5.33 km/s).

Part C Simple Harmonic Motion (16 marks)

A 0.50 kg mass on a smooth horizontal surface is attached to a spring of force constant 20 N/m and oscillates with amplitude 0.080 m.

9. Find the angular frequency and the period. (4 marks)

Answer: $\omega = \sqrt{k / m} = \sqrt{20 / 0.50} = 6.32$ rad/s; $T = 2\pi / \omega = 0.99$ s.

10. Find the frequency of oscillation. (4 marks)

Answer: f = 1 / T = 1.01 Hz.

11. Find the maximum speed and the maximum acceleration. (4 marks)

Answer: maximum speed = $\omega A = 6.32 \times 0.080 = 0.51$ m/s; maximum acceleration = $\omega^2 A = 3.2$ m/s^2.

12. Find the total mechanical energy of the oscillation. (4 marks)

Answer: $E = \frac{1}{2}kA^2 = 0.5 \times 20 \times 0.080^2 = 0.06$ J.

Part D Gas Laws and Kinetic Theory (18 marks)

An ideal gas at 300 K occupies 2.0 x 10^-3 m^3 at a pressure of 1.0 x 10^5 Pa. Its molar mass is 0.032 kg/mol; R = 8.31 J mol^-1 K^-1 and k = 1.38 x 10^-23 J K^-1.

13. Find the number of moles of the gas. (4 marks)

Answer: n = pV / RT = (1.0x10^5 x 2.0x10^-3) / (8.31 x 300) = 0.08 mol.

14. Heated at constant pressure to 450 K, find the new volume. (4 marks)

Answer: V2 = V1 x T2 / T1 = 2.0x10^-3 x 450 / 300 = 0 m^3 (volume is proportional to absolute temperature).

15. Find the root-mean-square speed of the molecules at 300 K. (5 marks)

Answer: v(rms) = sqrt(3RT / M) = sqrt(3 x 8.31 x 300 / 0.032) = 483.44 m/s.

16. Find the mean translational kinetic energy of one molecule. (5 marks)

Answer: mean kinetic energy = 3/2 kT = 1.5 x 1.38x10^-23 x 300 = 6.2x10^-21 J.

Part E Photoelectric Effect (18 marks)

The work function of sodium is 2.28 eV. Light of wavelength 400 nm is incident on a sodium surface; h = 6.63 x 10^-34 J s, c = 3.0 x 10^8 m/s and e = 1.602 x 10^-19 C.

17. Find the energy of one incident photon in eV. (5 marks)

Answer: E = hc / λ = (6.63x10^-34 x 3.0x10^8) / 400x10^-9 = 4.97x10^-19 J = 3.1 eV.

18. Find the maximum kinetic energy of the photoelectrons. (4 marks)

Answer: maximum kinetic energy = E - W = 3.1 - 2.28 = 0.82 eV, about 1.32x10^-19 J.

19. Find the stopping potential. (4 marks)

Answer: stopping potential = 0.82 V, at which the field does work equal to the maximum kinetic energy.

20. Find the threshold wavelength. (5 marks)

Answer: λ0 = hc / W = (6.63x10^-34 x 3.0x10^8) / (2.28 x 1.602x10^-19) = 545 nm; no photoelectrons are emitted for longer wavelengths.

Part F Radioactive Decay and Half-life (18 marks)

A radioactive source has a half-life of 8.0 days and an initial activity of 6400 Bq.

21. Find the decay constant in day^-1 and in s^-1. (4 marks)

Answer: λ = ln2 / T½ = 0.693 / 8.0 = 0.09 day^-1 = 1.0x10^-6 s^-1.

22. Find the activity after 24 days. (4 marks)

Answer: 24 days is 3 half-lives, so activity = 6400 / 2^3 = 800 Bq.

23. How long does the activity take to fall to 640 Bq? (5 marks)

Answer: A factor of 10 decrease needs t = ln10 / λ = 26.58 days.

24. Find the number of nuclei present initially. (5 marks)

Answer: N0 = A0 / λ = 6400 / 1.0x10^-6 = 6.4x10^9 nuclei.
