S6 Physics Practice Paper (Set 1): Circular Motion and Centripetal Force, Gravitation and Satellite Orbits, Momentum and Collisions, Electric Field and Potential, Capacitor Charging and Discharging, Radioactive Decay and Half-life

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

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Section A: Circular Motion and Centripetal Force (16 marks)

Show all working with units; give answers to 3 significant figures.

1. A car travels at a constant 20 m/s on a circular track of radius 50 m. Find its centripetal acceleration.

a = v^2 / r = 20^2 / 50 = 8.0 m/s^2.

2. The car has mass 1200 kg. Find the net centripetal force acting on it.

F = m a = 1200 x 8.0 = 9600 N, directed towards the centre.

3. A ball on a string of length 0.80 m moves in a vertical circle with speed 3.0 m/s at the top. Find the centripetal acceleration at the top.

a = v^2 / L = 3.0^2 / 0.80 = 11.25 m/s^2.

4. For the car above, find the time to complete one lap.

T = 2 pi r / v = 2 pi x 50 / 20 = 15.7 s.

Section B: Gravitation and Satellite Orbits (16 marks)

Take G = 6.67 x 10^-11 N m^2 kg^-2, Earth mass 5.97 x 10^24 kg, radius 6.37 x 10^6 m.

5. Find the gravitational field strength g at the Earth surface.

g = GM / R^2 = 6.67e-11 x 5.97e+24 / (6.37e+06)^2 = 9.81 m/s^2.

6. A satellite orbits at an altitude of 400 km. Find its orbital radius and speed.

r = 6.37e+06 + 4.00e+05 = 6.770e+06 m; v = sqrt(GM/r) = 7.669e+03 m/s = 7.67 km/s.

7. Find the orbital period of this satellite in minutes.

T = 2 pi r / v = 2 pi x 6.770e+06 / 7.669e+03 = 5546 s = 92.4 min.

8. A geostationary satellite has period 86164 s. Find its orbital radius and altitude.

r = (GMT^2/4pi^2)^(1/3) = 4.215e+07 m; altitude = 3.578e+07 m = 3.58 x 10^7 m.

Section C: Momentum and Collisions (18 marks)

All collisions occur on a smooth horizontal track; take rightward as positive.

9. A 2 kg object moving at 3 m/s hits a stationary 1 kg object and they stick together. Find their common velocity.

Momentum: 2 x 3 = (2 + 1) v, so v = 2.0 m/s.

10. For the collision above, find the kinetic energy before and after, and the percentage of kinetic energy lost.

KE before = 9.0 J, after = 6.0 J, loss = 3.0 J = 33.3%.

11. Two balls of mass 2 kg each collide elastically; A moves at 4 m/s and strikes stationary B. Find their velocities after collision.

Equal masses exchange velocities: A = 0 m/s (at rest), B = 4 m/s.

12. A 0.15 kg ball hits a wall at 8 m/s and rebounds at 6 m/s; contact time is 0.02 s. Find the impulse and average force.

Impulse = m(v - u) = 0.15 x (6 + 8) = 2.1 N s; F = 2.1 / 0.02 = 105 N.

Section D: Electric Field and Potential (18 marks)

Take k = 8.99 x 10^9 N m^2 C^-2 and elementary charge 1.6 x 10^-19 C.

13. A point charge Q = 2.0 x 10^-6 C. Find the electric field strength at 0.30 m from it.

E = kQ / r^2 = 8.99 x 10^9 x 2.0e-06 / 0.30^2 = 2.00e+05 N/C = 2.0 x 10^5 N/C.

14. Find the electric potential at the same point (0.30 m from Q).

V = kQ / r = 8.99 x 10^9 x 2.0e-06 / 0.30 = 5.99e+04 V = 6.0 x 10^4 V.

15. A charge of 3.0 x 10^-6 C is moved through a potential rise of 200 V. Find the work done by the electric field on this positive charge.

W = q dV = 3.0e-06 x 200 = -6.0e-04 J (the field does -W; 6.0e-04 J of external work is needed).

16. Two parallel plates 2.0 cm apart have a potential difference of 500 V. Find the uniform field between them and the force on an electron.

E = V / d = 500 / 0.020 = 2.5e+04 V/m; F = eE = 1.6e-19 x 2.5e+04 = 4.0e-15 N.

Section E: Capacitor Charging and Discharging (16 marks)

A 470 uF capacitor is charged through a 10 k ohm resistor from a 12 V supply.

17. Find the charge stored when fully charged.

Q = C V = 470 x 10^-6 x 12 = 5.64e-03 C = 5.64 mC.

18. Find the energy stored when fully charged.

E = 0.5 C V^2 = 0.5 x 470 x 10^-6 x 12^2 = 3.38e-02 J = 33.8 mJ.

19. Find the time constant of the charging circuit.

tau = R C = 10 x 10^3 x 470 x 10^-6 = 4.7 s.

20. Find the voltage across the capacitor after charging for 2 tau.

V = V0 (1 - e^(-t/tau)) = 12.0 (1 - e^-2) = 10.4 V.

Section F: Radioactive Decay and Half-life (16 marks)

Assume constant half-lives; give answers to 3 significant figures.

21. A nuclide has half-life 8.0 days. Find the fraction of nuclei remaining after 24 days.

24 days = 3 half-lives, fraction = (1/2)^3 = 0.125 = 12.5%.

22. A sample contains 80 g of a radioisotope with half-life 5.0 days. Find the mass remaining after 20 days.

20 days = 4 half-lives, remaining = 80 / 2^4 = 5.0 g.

23. Carbon-14 has a half-life of 5730 years. Find its decay constant in s^-1.

lambda = ln2 / t(1/2) = 0.693 / (5730 x 3.156 x 10^7 s) = 3.83e-12 s^-1.

24. A sample has an initial count rate of 640 Bq. Find the count rate after 3 half-lives.

A = A0 (1/2)^3 = 640 / 8 = 80 Bq.

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