S6 Physics Practice Paper: Circular Motion and Gravitation, Simple Harmonic Motion, Double-Slit Interference, Photoelectric Effect and Atomic Model, Electric Field and Capacitance, Transformers and Power Transmission

S6 Physics | 100 marks | 75 minutes

Question 1 Circular Motion and Gravitation

Take $g = 9.8\ m/s^2$ and the radius of the Earth as 6.4×10^6 m. Show the formula used.

A ball of mass 0.20 kg moves in a horizontal circle of radius 0.50 m with a period of 0.40 s. Find its angular velocity and linear speed. *(4 marks)*

Answer: $\omega = 2\pi/T = 2\pi \div 0.40 = 15.71$ rad/s; $v = \omega r = 15.71 \times 0.50 = 7.85$ m/s

Find the centripetal acceleration of the ball and the tension in the string. *(4 marks)*

Answer: $a = v^2/r = 7.85^2 \div 0.50 = 123.4\ m/s^2$; $T = ma = 0.20 \times 123.4 = 24.7$ N

If the string suddenly breaks, in what direction does the ball move afterwards? Explain. *(3 marks)*

Answer: It moves along the tangent at that instant in a straight line at constant speed, because once the centripetal force disappears no net force acts on the ball.

A satellite orbits in a circle at twice the Earth radius from the Earth centre. Find the gravitational field strength there, its speed and its period. *(5 marks)*

Answer: $r = 2R$; $g' = GM/r^2 = g/4 = 2.45$ N/kg; $v = \sqrt{(g'r)} = 5600$ m/s; $T = 2\pi r/v = 1.44e{+}04$ s ≈ 3.99 hours

Question 2 Simple Harmonic Motion

A spring-mass oscillator has mass 0.50 kg, spring constant 50 N/m and amplitude 0.10 m.

Find the angular frequency, period and frequency of the oscillation. *(4 marks)*

Answer: $\omega = \sqrt{(k/m)} = \sqrt{(50 \div 0.50)} = 10$ rad/s; $T = 2\pi/\omega = 0.628$ s; $f = 1/T = 1.59$ Hz

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

Answer: $v(max) = \omega A = 1.0$ m/s; $a(max) = \omega^2 A = 10\ m/s^2$

At a displacement of 0.06 m, find the magnitude of the velocity and of the acceleration. *(4 marks)*

Answer: $v = \omega\sqrt{(A^2 - x^2)} = 0.80$ m/s; $a = \omega^2 x = 6.0\ m/s^2$, directed towards the equilibrium position

Find the total mechanical energy, and the potential and kinetic energy at a displacement of 0.06 m. *(4 marks)*

Answer: $E = \tfrac{1}{2}kA^2 = 0.25$ J; $PE = \tfrac{1}{2}kx^2 = 0.09$ J; $KE = E - PE = 0.16$ J

Question 3 Double-Slit Interference

Slit separation 0.50 mm, screen distance 2.0 m, monochromatic light of wavelength 600 nm.

Find the spacing between adjacent bright fringes on the screen. *(4 marks)*

Answer: $\Delta y = \lambda D/d = 2.4e{-}03$ m $= 2.4$ mm

Find the distance between the third-order bright fringe and the central bright fringe. *(4 marks)*

Answer: $y_3 = 3\Delta y = 7.2$ mm

What is the path difference at the third-order bright fringe? How would the fringe spacing change if light of longer wavelength were used? *(4 marks)*

Answer: Path difference = $3\lambda = 1.8 \times 10^{-6}$ m; since $\Delta y = \lambda D/d$, a longer wavelength gives a larger fringe spacing.

If light of wavelength 500 nm is used instead, find the new fringe spacing and the percentage change in spacing. *(4 marks)*

Answer: $\Delta y' = 2.0$ mm; change = -16.7%

Question 4 Photoelectric Effect and Atomic Model

Take hc = 1240 eV·nm, the work function of the metal as 2.30 eV and the incident wavelength as 400 nm.

Find the energy of an incident photon. *(5 marks)*

Answer: $E = hc/\lambda = 1240 \div 400 = 3.10$ eV

Find the maximum kinetic energy of the photoelectrons and the stopping potential. *(5 marks)*

Answer: KE(max) = $E - \phi = 0.80$ eV; stopping potential = 0.80 V

Find the threshold wavelength of the metal and the maximum speed of the photoelectrons. *(4 marks)*

Answer: $\lambda_0 = hc/\phi = 539$ nm; $v = \sqrt{(2KE/m)} = 5.30e{+}05$ m/s

For hydrogen, find the photon energy and wavelength for the n = 3 to n = 2 and the n = 4 to n = 2 transitions ($E_n = -13.6/n^2$ eV). *(4 marks)*

Answer: 3→2: $\Delta E = 1.89$ eV, $\lambda = 656$ nm; 4→2: $\Delta E = 2.55$ eV, $\lambda = 486$ nm

Question 5 Uniform Electric Field and Capacitance

Two parallel metal plates are 0.050 m apart with a potential difference of 250 V.

Find the electric field strength between the plates. Find the magnitude of the force on a charge of −4.0 μC placed between them. *(5 marks)*

Answer: $E = V/d = 5000$ V/m; $F = qE = 0.020$ N

The charge moves 0.020 m along the field from the positive to the negative plate. Find the work done by the field and the potential difference between the two points. *(5 marks)*

Answer: $W = Fs = 4.0e{-}04$ J; $\Delta V = Ed = 100$ V

A 20 μF capacitor is connected to a 250 V supply. Find the charge and the energy stored. *(4 marks)*

Answer: $Q = CV = 0.005$ C; $U = \frac{1}{2}CV^2 = 0.625$ J

What is the potential at a distance of 0.30 m from a point charge of +2.0 μC? (Take $k = 9.0 \times 10^9$ N m^2 C^{-2}) *(4 marks)*

Answer: $V = kQ/r = 6.0e{+}04$ V = 60 kV

Question 6 Transformers and Power Transmission

Assume ideal transformers throughout.

A transformer has 1 000 turns in the primary and 50 turns in the secondary, with 220 V across the primary. Find the secondary voltage. *(4 marks)*

Answer: $V_s = V_p \times N_s/N_p = 11$ V

If the secondary delivers 44 W, find the secondary current and the primary current. *(4 marks)*

Answer: $I_s = P/V_s = 4.0$ A; $I_p = P/V_p = 0.20$ A

A power station delivers 100 kW at 10 kV. The total resistance of the transmission cables is 5.0 Ω. Find the current, the power loss and the percentage loss. *(5 marks)*

Answer: $I = 10$ A; loss $= I^2R = 500$ W; percentage loss = 0.5%

If the same power were delivered at 1 kV, find the percentage loss and explain why high-voltage transmission is used. *(3 marks)*

Answer: $I = 100$ A; loss = 50 000 W; percentage loss = 50%. High voltage reduces the current and the loss varies as I^2, so the loss, and hence the wasted power, is greatly reduced.
