S6 Physics Practice Paper I Photoelectric effect, radioactive half-life, RC circuits, satellite orbits, Doppler effect, hydrogen energy levels

S6 Physics I Time allowed: 75 minutes I Total: 100 marks I 24 questions

Question 1: Photoelectric effect (18 marks)

Photoelectric effect

1. (a) Light of wavelength 400 nm falls on a metal surface of work function 2.20 eV. Taking $h = 6.63 \times 10^{-34}$ J s, $c = 3.00 \times 10^{8}$ m s^{-1} and $1\ \text{eV} = 1.60 \times 10^{-19}$ J, find the frequency of the light, the photon energy in J and in eV, and the maximum kinetic energy of the emitted photoelectrons. (6 marks)

2. (b) Find the threshold (cut-off) wavelength of this metal and explain why light of longer wavelength cannot eject photoelectrons. (5 marks)

3. (c) Find the stopping potential. If the intensity is doubled while the wavelength is unchanged, how does the stopping potential change? (4 marks)

4. (d) If light of wavelength 300 nm is used instead, find the maximum kinetic energy in eV and state the increase. (3 marks)

Question 2: Radioactive decay and half-life (17 marks)

Radioactivity

5. (a) A sample has an initial activity of 8000 Bq and a half-life of 6.0 hours. How long does the activity take to fall to 1000 Bq? Show the formula and the steps. (6 marks)

6. (b) After 4 half-lives, what percentage of the original nuclei has decayed? (4 marks)

7. (c) Find the decay constant λ in s^{-1}, correct to 3 significant figures. (4 marks)

8. (d) What is the activity 24 hours after the start? (3 marks)

Question 3: Capacitors and RC circuits (17 marks)

Electricity

9. (a) A 470 μF capacitor is connected across a 12 V d.c. supply. Find the charge stored. (5 marks)

10. (b) Find the energy stored in the capacitor at 12 V. (4 marks)

11. (c) The capacitor discharges through a 22 kΩ resistor. Find the time constant and explain its meaning. (4 marks)

12. (d) How long after discharge begins does the voltage fall to 10% of its initial value? (4 marks)

Question 4: Satellite orbits and gravitation (17 marks)

Mechanics

13. (a) A satellite orbits at 400 km above the Earth. With Earth radius 6.37×10^{6} m, Earth mass 5.97×10^{24} kg and $G = 6.67 \times 10^{-11}$ N m² kg⁻², find its orbital speed. (6 marks)

14. (b) Find the orbital period in seconds and in minutes. (5 marks)

15. (c) Find the gravitational field strength at that altitude and compare it with the value at the surface. (3 marks)

16. (d) For the satellite to be geostationary (period 24 hours), must its orbital radius be larger or smaller, and what happens to its speed? Explain briefly. (3 marks)

Question 5: Doppler effect (16 marks)

Waves

17. (a) A car sounding a 500 Hz horn approaches a stationary observer at 30 m s^{-1}. With sound speed 340 m s^{-1}, find the observed frequency. (5 marks)

18. (b) After the car has passed and is moving away, what frequency is heard? (4 marks)

19. (c) Find the difference between the approaching and receding frequencies. (3 marks)

20. (d) A hydrogen line of rest wavelength 656.3 nm from a distant galaxy is measured at 669.4 nm on Earth. Find the redshift in nm and the recession speed as a fraction of c. (4 marks)

Question 6: Atomic energy levels and spectra (15 marks)

Atomic physics

21. (a) A spectral line of hydrogen has wavelength 486 nm. Find the photon energy in J and in eV. (5 marks)

22. (b) For hydrogen, $E_2 = -3.40$ eV and $E_4 = -0.85$ eV. Show that the photon emitted in the n = 4 to n = 2 transition matches the line in (a). (4 marks)

23. (c) A group of hydrogen atoms is excited to n = 4. What is the maximum number of spectral lines possible? (3 marks)

24. (d) Find the wavelength of the photon emitted in the n = 4 to n = 1 transition and state its region. (3 marks)