Dual Nature of Radiation and Matter

Standard difficulty · 20 questions · 40 marks · Time: 40 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer — 8 × 1 = 8 marks

1. The energy of a photon of wavelength 125 nm is: (hc = 1240 eV nm)

(a) 0.10 eV **(b)** 9.92 eV **(c)** 4.96 eV **(d)** 99.2 eV

2. Light of wavelength 160 nm falls on nickel (work function 5.15 eV). The stopping potential is: (hc = 1240 eV nm)

(a) 12.9 V **(b)** 5.15 V **(c)** 7.75 V **(d)** 2.6 V

3. The threshold wavelength for potassium (work function 2.3 eV) is: (hc = 1240 eV nm)

(a) 269.57 nm **(b)** 1,078.26 nm **(c)** 2,852 nm **(d)** 539.13 nm

4. The de Broglie wavelength of an electron accelerated from rest through 6,400 V is: ($\lambda = 1.227/\sqrt{V}$ nm)

(a) 0.00153 nm **(b)** 0.000192 nm **(c)** 0.0153 nm **(d)** 0.15 nm

5. The minimum energy needed to free an electron from a metal surface is its:

(a) work function **(b)** binding energy
(c) stopping potential **(d)** threshold wavelength

6. Photons of energy 9.92 eV strike a metal of work function 4.25 eV. The largest kinetic energy of the emitted electrons is:

(a) 5.67 eV **(b)** 2.835 eV **(c)** 14.17 eV **(d)** 9.92 eV

7. The de Broglie wavelength of a body of mass 3×10^{-3} kg moving at 4 m/s is: ($h = 6.6 \times 10^{-34}$ J s)

(a) 5.5×10^{-32} m **(b)** 5.5×10^{-29} m **(c)** 5.5×10^{-38} m **(d)** 7.92×10^{-30} m

8. Assertion (A): Light of wavelength 775 nm ejects electrons from copper (work function 4.65 eV). (hc = 1240 eV nm)
Reason (R): Electrons are emitted only when the photon energy is at least the work function.

(a) Both A and R are true, and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

Section B — Short answer — 8 × 2 = 16 marks

9. A 4 mW laser emits light of wavelength 310 nm. How many photons does it emit each second? (hc = 1240 eV nm) ($e = 1.6 \times 10^{-19}$ C)

10. Light of wavelength 500 nm falls on caesium (φ = 2.14 eV). Find the largest kinetic energy of the photoelectrons and the stopping potential. (hc = 1240 eV nm)

11. Below what frequency, and above what wavelength, does light fail to eject electrons from calcium (φ = 3.2 eV)? ($h = 6.6 \times 10^{-34}$ J s, $e = 1.6 \times 10^{-19}$ C, hc = 1240 eV nm)

12. An electron is accelerated from rest through 100 V. Find its de Broglie wavelength. ($\lambda = 1.227/\sqrt{V}$ nm)

13. Find the de Broglie wavelength of a 170 g ball moving at 43 m/s, and say why its wave nature cannot be noticed. ($h = 6.6 \times 10^{-34}$ J s)

14. A proton and a deuteron have been accelerated through the same potential difference. Find the ratio of their de Broglie wavelengths, λ(proton) : λ(deuteron).

15. In a photoelectric experiment with sodium and light of wavelength 320 nm, the intensity of the light is doubled. What happens to the stopping potential and to the photocurrent? Find the stopping potential. (hc = 1240 eV nm) (φ = 2.75 eV)

16. Will light of wavelength 800 nm eject electrons from calcium (φ = 3.2 eV)? If so, with what largest kinetic energy? (hc = 1240 eV nm)

Section C — Word problems — 4 × 4 = 16 marks

17. Ultraviolet or visible light of wavelength 200 nm falls on calcium, whose work function is 3.2 eV. Find the photon energy, the largest kinetic energy of the electrons, the stopping potential and the threshold wavelength. (hc = 1240 eV nm)

18. In a photoelectric experiment, light of frequency 9×10^{14} Hz gives a stopping potential of 0.9625 V and light of frequency 15×10^{14} Hz gives 3.4375 V. Find Planck's constant and the work function of the metal. ($e = 1.6 \times 10^{-19}$ C)

19. A 100 W lamp gives out light of wavelength 155 nm. Find the energy of one photon and the number of photons emitted each second. Which of these metals would give photoelectrons: caesium (2.14 eV), potassium (2.3 eV), sodium (2.75 eV), calcium (3.2 eV), molybdenum (4.17 eV), lead (4.25 eV), copper (4.65 eV), nickel (5.15 eV)? ($hc = 1240$ eV nm) ($e = 1.6 \times 10^{-19}$ C)

20. (a) Find the de Broglie wavelength of an electron accelerated through 6,400 V. (b) A α-particle and a deuteron are accelerated through the same potential difference. Find the ratio of their de Broglie wavelengths. ($\lambda_e = 1.227/\sqrt{V}$ nm)

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Answer key

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Q	Answer	Working
1	**(b) 9.92 eV**	$E = hc/\lambda$
2	**(d) 2.6 V**	$eV_0 = hc/\lambda - \varphi = 7.75 - 5.15$
3	**(d) 539.13 nm**	$\lambda_0 = hc/\varphi$
4	**(c) 0.0153 nm**	$1.227/\sqrt{6400} = 1.227/80$
5	**(a) work function**	—
6	**(a) 5.67 eV**	K_max = hv − φ
7	**(a) 5.5×10^{-32} m**	$\lambda = h/(mv)$
8	**(d) A is false, but R is true.**	A is false: the photon energy is 1.6 eV, less than 4.65 eV. R is true.
9	**6.25×10^{15}**	$E = 4$ eV $= 4 \times 1.6 \times 10^{-19}$ J; n = P/E
10	**0.34 eV; 0.34 V**	E = 2.48 eV; K = E − φ
11	**7.76×10^{14} Hz; 387.5 nm**	$v_0 = \varphi/h$; $\lambda_0 = hc/\varphi$
12	**0.1227 nm**	$\sqrt{100} = 10$
13	**9.03×10^{-35} m; it is far smaller than any object or gap, so no diffraction can be seen**	$\lambda = h/(mv) = 6.6 \times 10^{-34} \div (170 \times 10^{-3} \times 43)$
14	**$\sqrt{2}$: 1**	$\lambda = h/\sqrt{(2mqV)} \propto 1/\sqrt{(mq)}$
15	**the stopping potential stays 1.125 V; the photocurrent doubles**	V_0 depends on frequency only; the current depends on the number of photons
16	**No: each photon carries only 1.55 eV**	photon energy 1.55 eV
17	**6.2 eV; 3 eV; 3 V; 387.5 nm**	$E = hc/\lambda$; K = E − φ; $V_0 = K/e$; $\lambda_0 = hc/\varphi$
18	**h = 6.6×10^{-34} J s; φ = 2.75 eV (it is sodium)**	$h/e = (V_2 - V_1)/(v_2 - v_1) = 4.125 \times 10^{-15}$ V s; $\varphi = hv_1 - eV_1 = 3.7125 - 0.9625$ eV
19	**8 eV; 7.8125×10^{19} photons/s; caesium, potassium, sodium, calcium, molybdenum, lead, copper, nickel**	n = P/E with E in joules; emission needs E > φ
20	**(a) 0.0153 nm; (b) 1 : 2**	$\lambda = h/\sqrt{(2mqV)} \propto 1/\sqrt{(mq)}$

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