AQA A-Level Physics: Electromagnetic Radiation & Quantum Phenomena – Calculation Questions

Praneel Physics

1. Calculate the energy of a photon with frequency 5.0×10^{14} Hz. **(P)**

Working and Answer:

Use $E = hf$.
$E = 6.63 \times 10^{-34} \times 5.0 \times 10^{14} = 3.32 \times 10^{-19}$ J.

2. Calculate the frequency of electromagnetic radiation with wavelength 600 nm. **(P)**

Working and Answer:

Use $f = \frac{c}{\lambda}$.
$f = \frac{3.0\times10^8}{600\times10^{-9}} = 5.0 \times 10^{14}\,\mathrm{Hz}$.

3. Calculate the wavelength of light with frequency 4.0×10^{14} Hz. **(P)**

Working and Answer:

Use $\lambda = \frac{c}{f}$.
$\lambda = \frac{3.0\times10^8}{4.0\times10^{14}} = 7.5 \times 10^{-7}\,\mathrm{m} = 750\,\mathrm{nm}$.

4. Calculate the energy of a photon with wavelength 400 nm. **(P)**

Working and Answer:

Use $E = \frac{hc}{\lambda}$.
$E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{400\times10^{-9}} = 4.97 \times 10^{-19}$ J.

5. Calculate the frequency of UV light with wavelength 300 nm. **(P)**

Working and Answer:

Use $f = \frac{c}{\lambda}$.
$f = \frac{3.0\times10^{8}}{300\times10^{-9}} = 1.0 \times 10^{15}$ Hz.

6. Calculate the energy and frequency of a photon with wavelength 500 nm. **(PP)**

Working and Answer:

Step 1: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^8}{500\times10^{-9}} = 6.0 \times 10^{14}$ Hz.
Step 2: Calculate energy $E = hf = 6.63 \times 10^{-34} \times 6.0 \times 10^{14} = 3.98 \times 10^{-19}$ J.

7. Calculate the wavelength and energy of a photon with frequency 7.0×10^{14} Hz. **(PP)**

Working and Answer:

Step 1: Calculate wavelength $\lambda = \frac{c}{f} = \frac{3.0\times10^8}{7.0\times10^{14}} = 4.29 \times 10^{-7}$ m = 429 nm.
Step 2: Calculate energy $E = hf = 6.63 \times 10^{-34} \times 7.0 \times 10^{14} = 4.64 \times 10^{-19}$ J.

8. Calculate the stopping potential for photoelectrons emitted from a metal with work function 2.0 eV when illuminated by light of wavelength 400 nm. **(PP)**

Working and Answer:

Step 1: Calculate photon energy $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{400\times10^{-9}} = 4.97\times10^{-19}$ J.
Step 2: Convert work function $\phi = 2.0\times1.60\times10^{-19} = 3.20\times10^{-19}$ J.
Stopping potential $V = \frac{E-\phi}{e} = \frac{4.97\times10^{-19}-3.20\times10^{-19}}{1.60\times10^{-19}} = 1.06$ V.

9. Calculate the frequency and stopping potential for light with wavelength 350 nm incident on a metal with work function 2.5 eV. **(PP)**

Working and Answer:

Step 1: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{350\times10^{-9}} = 8.57 \times 10^{14}$ Hz.
Step 2: Photon energy $E = hf = 6.63 \times 10^{-34} \times 8.57 \times 10^{14} = 5.68 \times 10^{-19}$ J.
Work function $\phi = 2.5 \times 1.60 \times 10^{-19} = 4.00 \times 10^{-19}$ J. Stopping potential $V = \frac{E-\phi}{e} = \frac{5.68\times10^{-19}-4.00\times10^{-19}}{1.60\times10^{-19}} = 1.05$ V.

10. Calculate the wavelength and energy of a photon required to eject electrons with kinetic energy 1.0×10^{-19} J from a metal with work function 2.2 eV. **(PP)**

Working and Answer:

Step 1: Convert work function $\phi = 2.2 \times 1.60 \times 10^{-19} = 3.52 \times 10^{-19}$ J.
Step 2: Total photon energy
$E = KE + \phi = 1.0 \times 10^{-19} + 3.52 \times 10^{-19} = 4.52 \times 10^{-19}$ J. Calculate wavelength $\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{4.52\times10^{-19}} = 4.40 \times 10^{-7}$ m $= 440$ nm.

11. Calculate the maximum kinetic energy of photoelectrons emitted when light of wavelength 450 nm strikes a metal with work function 2.1 eV. Also find the stopping potential and frequency of the light. **(PPP)**

Working and Answer:

Step 1: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{450\times10^{-9}} = 6.67 \times 10^{14}$ Hz.
Step 2: Photon energy $E = hf = 6.63 \times 10^{-34} \times 6.67 \times 10^{14} = 4.42 \times 10^{-19}$ J.
Step 3: Convert work function $\phi = 2.1 \times 1.60 \times 10^{-19} = 3.36 \times 10^{-19}$ J. Kinetic energy $KE = E - \phi = 4.42 \times 10^{-19} - 3.36 \times 10^{-19} = 1.06 \times 10^{-19}$ J. Stopping potential $V = \frac{KE}{e} = \frac{1.06\times10^{-19}}{1.60\times10^{-19}} = 0.66$ V.

12. Calculate the energy, wavelength, and frequency of photons emitted when electrons fall from the second to the first energy level in a hydrogen atom. (Energy levels: $E_n = -\frac{13.6}{n^2}$ eV) **(PPP)**

Working and Answer:

Step 1: Calculate energy difference $\Delta E = E_2 - E_1 = \left(-\frac{13.6}{2^2}\right) - (-13.6) = -3.4 + 13.6 = 10.2\,\text{eV} = 10.2 \times 1.60 \times 10^{-19} = 1.63 \times 10^{-18}$ J.
Step 2: Calculate frequency $f = \frac{\Delta E}{h} = \frac{1.63\times10^{-18}}{6.63\times10^{-34}} = 2.46 \times 10^{15}$ Hz.
Step 3: Calculate wavelength $\lambda = \frac{c}{f} = \frac{3.0\times10^{8}}{2.46\times10^{15}} = 1.22 \times 10^{-7}\,\text{m} = 122\,\text{nm}$.

13. Calculate the threshold frequency, stopping potential, and kinetic energy of photoelectrons when light of wavelength 250 nm hits a metal with work function 2.5 eV. **(PPP)**

Working and Answer:

Step 1: Calculate threshold frequency $f_0 = \frac{\phi}{h} = \frac{2.5 \times 1.60 \times 10^{-19}}{6.63 \times 10^{-34}} = 6.03 \times 10^{14}$ Hz.
Step 2: Calculate frequency of incident light $f = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}}{250 \times 10^{-9}} = 1.20 \times 10^{15}$ Hz.
Step 3: Calculate kinetic energy
$KE = hf - \phi = 6.63 \times 10^{-34} \times 1.20 \times 10^{15} - 2.5 \times 1.60 \times 10^{-19} =$
$7.96 \times 10^{-19} - 4.00 \times 10^{-19} = 3.96 \times 10^{-19}$ J. Stopping potential
$V = \frac{KE}{e} = \frac{3.96 \times 10^{-19}}{1.60 \times 10^{-19}} = 2.48$ V.

14. Calculate the energy, momentum, and speed of an electron accelerated through a potential difference of 200 V. **(PPP)**

Working and Answer:

Step 1: Calculate kinetic energy
$KE = eV = 1.60 \times 10^{-19} \times 200 = 3.20 \times 10^{-17}$ J.
Step 2: Calculate momentum
$p = \sqrt{2mKE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 3.20 \times 10^{-17}} = 7.64 \times 10^{-24}$ kg m/s.
Step 3: Calculate speed $v = \frac{p}{m} = \frac{7.64 \times 10^{-24}}{9.11 \times 10^{-31}} = 8.39 \times 10^{6}$ m/s.

15. Calculate the de Broglie wavelength, frequency, and energy of an electron moving at 2.5×10^6 m/s. **(PPP)**

Working and Answer:

Step 1: Calculate momentum
$p = mv = 9.11 \times 10^{-31} \times 2.5 \times 10^6 = 2.28 \times 10^{-24}\,\text{kg m/s}$.
Step 2: Calculate wavelength $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{2.28\times10^{-24}} = 2.91 \times 10^{-10}\,\text{m}$.
Step 3: Calculate kinetic energy $KE = \frac{p^2}{2m} = \frac{(2.28\times10^{-24})^2}{2\times9.11\times10^{-31}} = 2.86 \times 10^{-18}\,\text{J}$.
Calculate frequency $f = \frac{KE}{h} = \frac{2.86\times10^{-18}}{6.63\times10^{-34}} = 4.31 \times 10^{15}\,\text{Hz}$.

16. Calculate the energy levels for $n = 1$, 2 and 3 in a hydrogen atom and the wavelength of the photon emitted during the transition from $n = 3$ to $n = 2$. **(PPPP)**

Working and Answer:

Step 1: Calculate energy at $n = 1$: $E_1 = -\frac{13.6}{1^2} = -13.6\,\text{eV}$.
Step 2: Calculate energy at $n = 2$: $E_2 = -\frac{13.6}{2^2} = -3.4\,\text{eV}$.
Step 3: Calculate energy at $n = 3$: $E_3 = -\frac{13.6}{3^2} = -1.51\,\text{eV}$.
Step 4: Calculate energy difference
$E_{32} = E_3 - E_2 = -1.51 - (-3.4) = 1.89\,\text{eV} = 3.02 \times 10^{-19}\,\text{J}$. Calculate wavelength $\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{3.02\times10^{-19}} = 6.58 \times 10^{-7}\,\text{m} = 658\,\text{nm}$.

17. Calculate the maximum kinetic energy, stopping potential, frequency, and wavelength of electrons emitted when light of wavelength 350 nm hits a metal with work function 2.0 eV. **(PPPP)**

Working and Answer:

Step 1: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{350\times10^{-9}} = 8.57 \times 10^{14}$ Hz.
Step 2: Calculate photon energy
$E = hf = 6.63 \times 10^{-34} \times 8.57 \times 10^{14} = 5.68 \times 10^{-19}$ J.
Step 3: Convert work function $\phi = 2.0 \times 1.60 \times 10^{-19} = 3.20 \times 10^{-19}$ J.
Calculate kinetic energy
$KE = E - \phi = 5.68 \times 10^{-19} - 3.20 \times 10^{-19} = 2.48 \times 10^{-19}$ J.
Step 4: Calculate stopping potential $V = \frac{KE}{e} = \frac{2.48\times10^{-19}}{1.60\times10^{-19}} = 1.55$ V. Calculate wavelength $\lambda = \frac{c}{f} = 350$ nm.

18. Calculate the de Broglie wavelength, kinetic energy, momentum, and speed of an electron accelerated through a potential difference of 400 V. **(PPPP)**

Working and Answer:

Step 1: Calculate kinetic energy
$KE = eV = 1.60 \times 10^{-19} \times 400 = 6.40 \times 10^{-17}$ J.
Step 2: Calculate momentum
$p = \sqrt{2mKE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 6.40 \times 10^{-17}} = 1.08 \times 10^{-23}$ kg m/s.
Step 3: Calculate speed $v = \frac{p}{m} = \frac{1.08 \times 10^{-23}}{9.11 \times 10^{-31}} = 1.19 \times 10^{7}$ m/s.
Step 4: Calculate wavelength $\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{1.08 \times 10^{-23}} = 6.14 \times 10^{-11}$ m.

19. Calculate the threshold frequency, maximum kinetic energy, stopping potential, and wavelength of photons for a metal with work function 3.0 eV illuminated by light of wavelength 400 nm. **(PPPP)**

Working and Answer:

Step 1: Calculate threshold frequency $f_0 = \frac{\phi}{h} = \frac{3.0 \times 1.60 \times 10^{-19}}{6.63 \times 10^{-34}} = 7.24 \times 10^{14}$ Hz.
Step 2: Calculate frequency of incident light $f = \frac{c}{\lambda} = \frac{3.0 \times 10^{8}}{400 \times 10^{-9}} = 7.50 \times 10^{14}$ Hz.
Step 3: Calculate kinetic energy
$KE = hf - \phi = 6.63 \times 10^{-34} \times 7.50 \times 10^{14} - 3.0 \times 1.60 \times 10^{-19} =$
$4.97 \times 10^{-19} - 4.80 \times 10^{-19} = 0.17 \times 10^{-19}$ J.
Step 4: Calculate stopping potential $V = \frac{KE}{e} = \frac{0.17 \times 10^{-19}}{1.60 \times 10^{-19}} = 0.11$ V.

20. Calculate the photon energy, momentum, wavelength, and frequency for X-rays of wavelength 0.05 nm. **(PPPP)**

Working and Answer:

Step 1: Calculate photon energy $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{0.05\times10^{-9}} = 3.98 \times 10^{-15}$ J.
Step 2: Calculate momentum $p = \frac{E}{c} = \frac{3.98\times10^{-15}}{3.0\times10^{8}} = 1.33 \times 10^{-23}$ kg m/s.
Step 3: Wavelength is given 0.05 nm = 0.05×10^{-9} m.
Step 4: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{0.05\times10^{-9}} = 6.0 \times 10^{18}$ Hz.

21. Calculate the wavelength, frequency, energy, maximum kinetic energy, and stopping potential for photoelectrons emitted from a metal with work function 2.8 eV when illuminated with light of wavelength 320 nm. **(PPPPP)**

Working and Answer:

Step 1: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^{8}}{320\times10^{-9}} = 9.38 \times 10^{14}$ Hz.
Step 2: Calculate photon energy
$E = hf = 6.63 \times 10^{-34} \times 9.38 \times 10^{14} = 6.22 \times 10^{-19}$ J.
Step 3: Convert work function $\phi = 2.8 \times 1.60 \times 10^{-19} = 4.48 \times 10^{-19}$ J.
Step 4: Calculate maximum kinetic energy
$KE = E - \phi = 6.22 \times 10^{-19} - 4.48 \times 10^{-19} = 1.74 \times 10^{-19}$ J.
Step 5: Calculate stopping potential $V = \frac{KE}{e} = \frac{1.74\times10^{-19}}{1.60\times10^{-19}} = 1.09$ V.

22. Calculate the first four energy levels in the hydrogen atom, the energy difference between $n = 4$ and $n = 2$, and the wavelength and frequency of the emitted photon during this transition. **(PPPPP)**

Working and Answer:

Step 1: $E_1 = -\frac{13.6}{1^2} = -13.6\,\text{eV}$.
Step 2: $E_2 = -\frac{13.6}{2^2} = -3.4\,\text{eV}$.
Step 3: $E_3 = -\frac{13.6}{3^2} = -1.51\,\text{eV}$.
Step 4: $E_4 = -\frac{13.6}{4^2} = -0.85\,\text{eV}$.
Step 5: Calculate energy difference
$\Delta E = E_4 - E_2 = -0.85 - (-3.4) = 2.55\,\text{eV} = 4.08 \times 10^{-19}\,\text{J}$. Calculate frequency $f = \frac{\Delta E}{h} = \frac{4.08\times10^{-19}}{6.63\times10^{-34}} = 6.16 \times 10^{14}\,\text{Hz}$. Calculate wavelength $\lambda = \frac{c}{f} = \frac{3.0\times10^{8}}{6.16\times10^{14}} = 4.87 \times 10^{-7}\,\text{m} = 487\,\text{nm}$.

23. Calculate the de Broglie wavelength, kinetic energy, momentum, speed, and frequency of an electron accelerated through a potential difference of 600 V. **(PPPPP)**

Working and Answer:

Step 1: Calculate kinetic energy
$KE = eV = 1.60 \times 10^{-19} \times 600 = 9.60 \times 10^{-17}$ J.
Step 2: Calculate momentum
$p = \sqrt{2mKE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 9.60 \times 10^{-17}} = 1.32 \times 10^{-23}$ kg m/s.
Step 3: Calculate speed $v = \frac{p}{m} = \frac{1.32\times10^{-23}}{9.11\times10^{-31}} = 1.45 \times 10^{7}$ m/s.
Step 4: Calculate wavelength $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{1.32\times10^{-23}} = 5.02 \times 10^{-11}$ m.
Step 5: Calculate frequency $f = \frac{KE}{h} = \frac{9.60\times10^{-17}}{6.63\times10^{-34}} = 1.45 \times 10^{17}$ Hz.

24. Calculate the photon energy, momentum, wavelength, frequency, and stopping potential for photons of wavelength 600 nm hitting a metal surface with work function 2.2 eV. **(PPPPP)**

Working and Answer:

Step 1: Calculate frequency $f = \frac{c}{\lambda} = \frac{3.0\times10^8}{600\times10^{-9}} = 5.0 \times 10^{14}$ Hz.
Step 2: Calculate photon energy
$E = hf = 6.63 \times 10^{-34} \times 5.0 \times 10^{14} = 3.32 \times 10^{-19}$ J.
Step 3: Convert work function $\phi = 2.2 \times 1.60 \times 10^{-19} = 3.52 \times 10^{-19}$ J.
Step 4: Calculate kinetic energy
$KE = E - \phi = 3.32 \times 10^{-19} - 3.52 \times 10^{-19} = -0.20 \times 10^{-19}$ J (No emission, so $KE = 0$).
Step 5: Since no electrons emitted, stopping potential $V = 0$ V.

25. Calculate the energy levels for $n = 1$, 2, 3, and 4 in hydrogen and the wavelength of photons emitted during transitions $n = 4 \rightarrow n = 3$ and $n = 3 \rightarrow n = 2$. **(PPPPP)**

Working and Answer:

Step 1: $E_1 = -\frac{13.6}{1^2} = -13.6\,\text{eV}$.
Step 2: $E_2 = -\frac{13.6}{2^2} = -3.4\,\text{eV}$.
Step 3: $E_3 = -\frac{13.6}{3^2} = -1.51\,\text{eV}$.
Step 4: $E_4 = -\frac{13.6}{4^2} = -0.85\,\text{eV}$.
Step 5: Calculate wavelength for $n = 4 \rightarrow n = 3$:
$\Delta E_{43} = E_4 - E_3 = -0.85 - (-1.51) = 0.66\,\text{eV} = 1.06 \times 10^{-19}\,\text{J}$.
$\lambda = \frac{hc}{\Delta E} = \frac{6.63\times10^{-34}\times3.0\times10^8}{1.06\times10^{-19}} = 1.88 \times 10^{-6}\,\text{m} = 1880\,\text{nm}$.
Calculate wavelength for $n = 3 \rightarrow n = 2$:
$\Delta E_{32} = E_3 - E_2 = -1.51 - (-3.4) = 1.89\,\text{eV} = 3.02 \times 10^{-19}\,\text{J}$.
$\lambda = \frac{hc}{\Delta E} = \frac{6.63\times10^{-34}\times3.0\times10^8}{3.02\times10^{-19}} = 6.58 \times 10^{-7}\,\text{m} = 658\,\text{nm}$.

26. Calculate the energy, frequency, wavelength, and speed of electrons accelerated through a potential difference of 800 V. **(PPPPP)**

Working and Answer:

Step 1: Calculate kinetic energy
$KE = eV = 1.60 \times 10^{-19} \times 800 = 1.28 \times 10^{-16}$ J.
Step 2: Calculate momentum
$p = \sqrt{2mKE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 1.28 \times 10^{-16}} = 1.53 \times 10^{-23}\,\text{kg m/s}$.
Step 3: Calculate speed $v = \frac{p}{m} = \frac{1.53\times10^{-23}}{9.11\times10^{-31}} = 1.68 \times 10^{7}$ m/s.
Step 4: Calculate frequency $f = \frac{KE}{h} = \frac{1.28\times10^{-16}}{6.63\times10^{-34}} = 1.93 \times 10^{17}$ Hz.
Step 5: Calculate wavelength $\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{1.53\times10^{-23}} = 4.33 \times 10^{-11}$ m.