Exam Papers Practice

Quantum Physics

Mark Schemes

Course	HL IB Physics
Section	Nuclear & Quantum Physics
Topic	Quantum Physics
Difficulty	Medium

To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

1

The correct answer is **D** because:

- Red light has a longer wavelength than violet light
- The energy of each photon is:
  - $E = \frac{hc}{\lambda}$
  - Where c is the speed of light and λ is the wavelength
- E is inversely proportional to λ ($E \propto \frac{1}{\lambda}$)
- Therefore, the photons of red light carry **less** energy than photons of violet light
- The stopping potential V_S is the potential difference at which there is **no photocurrent** detected
  - This occurs when the potential of the collecting plate V is connected to the negative terminal
  - Since photons of red light transfer less maximum kinetic energy to each photoelectron, then the stopping potential must become less negative (closer to zero)
- This eliminates option C
- The intensity of incident light is kept constant
  - Therefore, the number of incident photons per second stays constant for both violet and red light
- Hence, the maximum photocurrent remains constant
  - This eliminates option B
- If the maximum photocurrent remains constant, then the potential difference at this maximum photocurrent will remain constant
  - This eliminates option A
- Therefore, the correct answer is option D

2

The correct answer is **B** because:

- The first minimum is identified as the angle at which the first dip in intensity of scattered electrons occurs
  - This is at 42° on the graph
- Therefore the correct answer is **B**

It is important to be able to identify maxima and minima on graphs involving diffraction. In structured questions you will also be expected to perform calculations involving readings from the graphs, therefore you should ensure you are comfortable interpreting them.

The graph has increasing and decreasing intensity due to the diffraction pattern when electrons scatter being concentric bright (high intensity) and dark (low intensity) rings.

3

The correct answer is **D** because:

- Electrons are diffracted when they are scattered by a nucleus
- A circular diffraction pattern forms with a central bright spot (maxima) with dimmer concentric circles (minima) around it
- However, the first diffraction minima isn't found at zero intensity
    - The subsequent minima reduce in intensity until reaching zero
- This is graph **D**

A is incorrect as the maxima in the diffraction become dimmer as angle θ increases. The maxima in this graph are all at the same intensity.

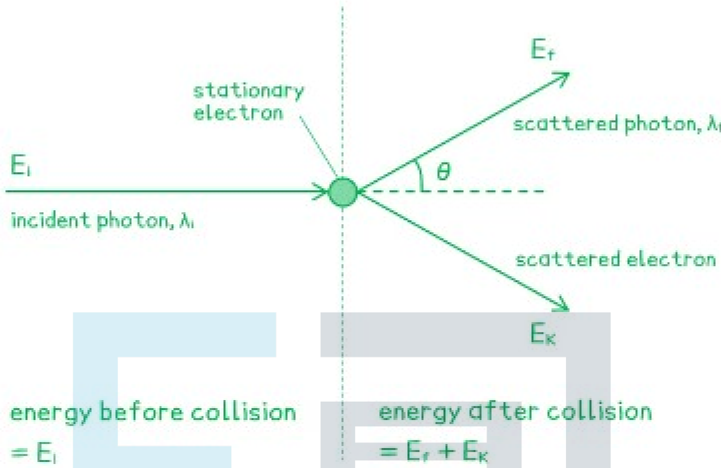
B & **C** are incorrect as the first few minima shouldn't go to zero intensity.

4

The correct answer is **D** because:

- Compton scattering: $\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$
- The energy of the X-ray photon is given by: $E = \frac{hc}{\lambda}$
- To understand how to maximise the energy transferred by the photon, we need to understand how the energy changes before and after the collision

- From conservation of energy: $E_K = E_i - E_f = \frac{hc}{\lambda_i} - \frac{hc}{\lambda_f}$
    - Where E_K is the kinetic energy of the electron, E_i is the energy of the incident photon and E_f is the energy of the scattered photon



- The ratio of the kinetic energy of the electron to the initial photon energy is
    - $E_K = E_i - E_f \quad \Rightarrow \quad \frac{E_K}{E_i} = 1 - \frac{E_f}{E_i}$
- This tells us the proportion of the energy transferred to the electron:
    - $\frac{E_K}{E_i} = 1 - \left(\frac{hc}{\lambda_f} \times \frac{\lambda_i}{hc}\right) = 1 - \frac{\lambda_i}{\lambda_f}$
    - $\frac{E_K}{E_i} = \frac{\lambda_f - \lambda_i}{\lambda_f} = \frac{\Delta\lambda}{\lambda_f}$
- Therefore, for maximum energy transfer, the Compton shift in wavelength must be maximised as $E_K \propto \Delta\lambda$
- This can be achieved if the photon rebounds in the opposite direction, i.e. if it scatters by 180°
    - $\Delta\lambda = \frac{h}{m_e c}(1 - \cos 180°) = \frac{2h}{m_e c}$

A is incorrect because $\Delta\lambda = \frac{h}{m_e c}(1 - \cos 0°) = 0$

B is incorrect because $\Delta\lambda = \frac{h}{m_e c}(1 - \cos 45°) = 0.293 \times \frac{h}{m_e c}$

C is incorrect because $\Delta\lambda = \frac{h}{m_e c}(1 - \cos 90°) = \frac{h}{m_e c}$

5

The correct answer is **C** because:

- From the principle of conservation of energy: $E = E' + E_K$
  - Where E_K is the kinetic energy of the recoiled electron and E' is the energy of the scattered photon
- Therefore: $E_K = E - E' = \frac{hc}{\lambda} - \frac{hc}{\lambda'}$
- The ratio of the kinetic energy of the electron to the initial photon energy is
  - $E_K = E - E' \quad \Rightarrow \quad \frac{E_K}{E} = \frac{E - E'}{E} = 1 - \frac{E'}{E}$
- This tells us the fraction of the energy transferred to the electron:
  - $\frac{E_K}{E} = 1 - \left(\frac{hc}{\lambda'} \times \frac{\lambda}{hc}\right) = 1 - \frac{\lambda}{\lambda'}$
- Since the electron is initially at rest, when it recoils its kinetic energy will be $E_K = \frac{1}{2}m_e v^2$
  - $\frac{1}{2}m_e v^2 = E\left(1 - \frac{\lambda}{\lambda'}\right)$
  - $v^2 = \frac{2E}{m_e}\left(\frac{\lambda' - \lambda}{\lambda'}\right) \quad \Rightarrow \quad v = \sqrt{\frac{2E}{m_e}\left(\frac{\lambda' - \lambda}{\lambda'}\right)}$