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Where Minds Pollinate

Class 12
Physics

Chapter 21

Printed Notes

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FBISE CLASS 12 PHYSICS

Domain F: Modern Physics — Important MCQs & Short Questions

Based on NCP SLOs (P-12-F-01 to P-12-F-21)

SECTION A — MULTIPLE CHOICE QUESTIONS (MCQs)

Q1. Electromagnetic radiation has a particulate nature. The name of these particles is:

A) Electrons
B) Protons
C) Photons
D) Neutrons
✓ Answer: (C) Photons

Q2. The energy of a photon of frequency f is given by:

A) $E = mc^2$
B) $E = hf$
C) $E = \frac{1}{2}mv^2$
D) $E = eV$
✓ Answer: (B) $E = hf$

Q3. The unit of electron volt (eV) is used to express:

A) Charge of electron
B) Mass of electron
C) Energy of a photon or particle
D) Frequency of light
✓ Answer: (C) Energy of a photon or particle

Q4. The momentum of a photon is given by:

A) $p = hf$
B) $p = E/c$
C) $p = mc$
D) $p = h\lambda$
✓ Answer: (B) $p = E/c$

Q5. Photoelectrons are emitted from a metal surface when illuminated with:

A) Any radiation
B) Only infrared light
C) Electromagnetic radiation above threshold frequency
D) Sound waves
✓ Answer: (C) Electromagnetic radiation above threshold frequency

Q6. The minimum frequency of radiation required to eject photoelectrons is called:

A) Resonant frequency
B) Threshold frequency
C) Natural frequency
D) Cut-off frequency
✓ Answer: (B) Threshold frequency

Q7. The threshold wavelength is the:

A) Minimum wavelength that causes emission

B) Maximum wavelength that can cause photoelectric emission
C) Wavelength of emitted electrons
D) Wavelength of X-rays
✓ **Answer: (B) Maximum wavelength that can cause photoelectric emission**

Q8. Photoelectric emission is explained using the equation:
A) $E = mc^2$
B) $hf = \Phi + KE_{max}$
C) $E = \frac{1}{2}mv^2$
D) $p = mv$
✓ **Answer: (B) $hf = \Phi + KE_{max}$**

Q9. The work function of a metal is the:
A) Kinetic energy of emitted electrons
B) Minimum energy needed to eject an electron from its surface
C) Energy of incident photon
D) Frequency of incident light
✓ **Answer: (B) Minimum energy needed to eject an electron from its surface**

Q10. The maximum kinetic energy of photoelectrons depends on:
A) Intensity of light
B) Frequency of incident light
C) Area of metal surface
D) Temperature of metal
✓ **Answer: (B) Frequency of incident light**

Q11. The photoelectric current is proportional to the __________ of the incident radiation.
A) Frequency
B) Wavelength
C) Intensity
D) Energy
✓ **Answer: (C) Intensity**

Q12. The maximum kinetic energy of photoelectrons is independent of:
A) Frequency of light
B) Work function
C) Intensity of light
D) Nature of metal
✓ **Answer: (C) Intensity of light**

Q13. Which phenomenon best supports the wave nature of light?
A) Photoelectric effect
B) Compton effect
C) Interference and diffraction
D) Pair production
✓ **Answer: (C) Interference and diffraction**

Q14. Which phenomenon best supports the particle nature of light?
A) Diffraction
B) Interference
C) Polarisation
D) Photoelectric effect
✓ **Answer: (D) Photoelectric effect**

Q15. Electron diffraction provides evidence for the:

A) Wave nature of particles
B) Particle nature of waves
C) Charge of electron
D) Mass of electron
✓ **Answer: (A) Wave nature of particles**

Q16. The de Broglie wavelength of a particle is given by:

A) $\lambda = h/p$
B) $\lambda = hp$
C) $\lambda = h/mv^2$
D) $\lambda = p/h$
✓ **Answer: (A) $\lambda = h/p$**

Q17. If the momentum of a particle is doubled, its de Broglie wavelength:

A) Doubles
B) Halves
C) Remains same
D) Quadruples
✓ **Answer: (B) Halves**

Q18. Discrete electron energy levels exist in:

A) Free electrons
B) Isolated atoms
C) Metals only
D) Plasma
✓ **Answer: (B) Isolated atoms**

Q19. Emission spectra consist of:

A) Continuous bands of colour
B) Bright coloured lines on dark background
C) Dark lines on bright background
D) Only ultraviolet lines
✓ **Answer: (B) Bright coloured lines on dark background**

Q20. Absorption spectra consist of:

A) Bright lines on dark background
B) Continuous rainbow spectrum
C) Dark lines on bright/continuous background
D) X-ray lines
✓ **Answer: (C) Dark lines on bright/continuous background**

Q21. The formula used to solve problems involving energy levels is:

A) $E = hf = \Delta E$
B) $E = mc^2$
C) $E = qV$
D) $E = \frac{1}{2}mv^2$
✓ **Answer: (A) $E = hf = \Delta E$**

Q22. The Compton effect demonstrates that photons:

A) Have no mass
B) Travel at the speed of sound

C) Carry momentum
D) Can be split
✓ **Answer: (C) Carry momentum**

Q23. In Compton scattering, after the photon collides with an electron, the wavelength of the scattered photon:

A) Decreases
B) Remains same
C) Increases
D) Becomes zero
✓ **Answer: (C) Increases**

Q24. Pair production is the process in which a photon:

A) Ejects an electron from a metal
B) Creates an electron–positron pair
C) Splits into two photons
D) Is absorbed by a nucleus
✓ **Answer: (B) Creates an electron–positron pair**

Q25. Pair annihilation is the reverse of:

A) Photoelectric effect
B) Pair production
C) Compton effect
D) Diffraction
✓ **Answer: (B) Pair production**

Q26. In pair production, the minimum energy of the photon must be:

A) Equal to hf of visible light
B) At least 1.02 MeV (equivalent to $2m_ec^2$)
C) Equal to work function
D) Greater than threshold wavelength
✓ **Answer: (B) At least 1.02 MeV (equivalent to 2m_e c²)**

Q27. Electron microscopes achieve very high resolution because electrons have:

A) Large mass
B) Very short de Broglie wavelength
C) Negative charge
D) High speed only
✓ **Answer: (B) Very short de Broglie wavelength**

Q28. Heisenberg's uncertainty principle states that it is impossible to simultaneously determine with precision the __________ and __________ of a particle.

A) Mass and charge
B) Speed and acceleration
C) Position and momentum
D) Energy and mass
✓ **Answer: (C) Position and momentum**

Q29. Heisenberg's uncertainty principle is expressed as:

A) $\Delta x \cdot \Delta p \geq h/4\pi$
B) $\Delta x \cdot \Delta p = mc^2$
C) $\Delta x \cdot \Delta p = hf$
D) $\Delta x \cdot \Delta p = 0$

✓ **Answer: (A) $\Delta x \cdot \Delta p \geq h/4\pi$**

Q30. The uncertainty principle implies that empirical measurements must always have:

A) Zero error
B) Systematic error only
C) Some inherent uncertainty
D) Instrumental error only
✓ **Answer: (C) Some inherent uncertainty**

Q31. The photon model of light was introduced by:

A) Newton
B) Einstein
C) Bohr
D) de Broglie
✓ **Answer: (B) Einstein**

Q32. Planck's constant h has the value:

A) $6.63 \times 10^{■3■}$ J·s
B) $6.63 \times 10^{■2■}$ J·s
C) $9.11 \times 10^{■31}$ J·s
D) $1.6 \times 10^{■1■}$ J·s
✓ **Answer: (A) $6.63 \times 10^{■3■}$ J·s**

Q33. 1 eV is equal to:

A) $1.6 \times 10^{■1■}$ J
B) $1.6 \times 10^{■2■}$ J
C) $9.1 \times 10^{■31}$ J
D) $6.6 \times 10^{■3■}$ J
✓ **Answer: (A) $1.6 \times 10^{■1■}$ J**

Q34. Which of the following has the shortest de Broglie wavelength at the same speed?

A) Electron
B) Proton
C) Alpha particle
D) Neutron
✓ **Answer: (C) Alpha particle (most massive among the options)**

Q35. The stopping potential in the photoelectric effect is used to determine:

A) Work function only
B) Maximum kinetic energy of photoelectrons
C) Threshold frequency only
D) Intensity of light
✓ **Answer: (B) Maximum kinetic energy of photoelectrons**

Q36. The photoelectric effect cannot be explained by:

A) Quantum theory
B) Photon model
C) Wave theory of light
D) Einstein's equation
✓ **Answer: (C) Wave theory of light**

Q37. Light can exert a force on objects because photons have:

A) Mass

B) Momentum
C) Charge
D) Energy only
✓ **Answer: (B) Momentum**

Q38. Which phenomenon is explained by the wave–particle duality of light?
A) Diffraction — wave; photoelectric effect — particle
B) Reflection — particle; refraction — wave
C) Emission — particle; absorption — wave
D) All — only wave
✓ **Answer: (A) Diffraction — wave; photoelectric effect — particle**

Q39. The hydrogen atom's emission spectrum has discrete lines because:
A) Electrons have continuous energies
B) Electrons occupy only specific quantised energy levels
C) Photons travel at different speeds
D) Hydrogen has only one electron
✓ **Answer: (B) Electrons occupy only specific quantised energy levels**

Q40. In pair annihilation, when an electron meets a positron, the product(s) are:
A) Two protons
B) Two photons (gamma rays)
C) A neutron
D) An alpha particle
✓ **Answer: (B) Two photons (gamma rays)**

Q41. Electron diffraction was first demonstrated using a crystal, confirming:
A) Particle nature of light
B) Wave nature of electrons
C) Charge of electron
D) Mass of proton
✓ **Answer: (B) Wave nature of electrons**

Q42. The de Broglie hypothesis states that all matter has:
A) Wave-like properties
B) Only particle properties
C) No momentum
D) Infinite energy
✓ **Answer: (A) Wave-like properties**

Q43. Which of the following cannot emit photoelectrons from a typical metal surface?
A) Ultraviolet light
B) X-rays
C) Infrared light (below threshold frequency)
D) Gamma rays
✓ **Answer: (C) Infrared light (below threshold frequency)**

Q44. In the photoelectric effect, increasing the intensity of incident light increases:
A) Maximum kinetic energy of electrons
B) Threshold frequency
C) Number of emitted electrons (photoelectric current)
D) Work function
✓ **Answer: (C) Number of emitted electrons (photoelectric current)**

Q45. The Compton effect confirms that photons behave like:

A) Waves only
B) Particles with momentum
C) Stationary objects
D) Magnetic fields
✓ **Answer: (B) Particles with momentum**

Q46. According to the uncertainty principle, if $\Delta x \to 0$ (very precise position), then Δp:

A) $\to 0$
B) $\to \infty$
C) Remains constant
D) Equals h
✓ **Answer: (B) $\to \infty$ (becomes very large)**

Q47. The energy of the ground state of hydrogen atom is approximately:

A) –13.6 eV
B) +13.6 eV
C) –3.4 eV
D) 0 eV
✓ **Answer: (A) –13.6 eV**

Q48. An electron transitions from a higher to a lower energy level. The emitted photon has energy equal to:

A) Sum of both energy levels
B) Difference of the two energy levels ($\Delta E = hf$)
C) The lower energy level
D) Planck's constant
✓ **Answer: (B) Difference of the two energy levels ($\Delta E = hf$)**

Q49. Compton scattering involves collision between a photon and a:

A) Proton
B) Nucleus
C) Free electron
D) Positron
✓ **Answer: (C) Free electron**

Q50. The wave nature of particles is most significant for:

A) Large macroscopic objects
B) Very small particles like electrons
C) Planets
D) Cars
✓ **Answer: (B) Very small particles like electrons**

SECTION B — SHORT QUESTIONS WITH ANSWERS

Q1. State that electromagnetic radiation has a particulate nature. What are these particles called?

Answer: Electromagnetic radiation exhibits a particulate (quantum) nature. The individual packets (quanta) of electromagnetic energy are called photons. Each photon carries a discrete amount of energy $E = hf$, where h is Planck's constant and f is the frequency.

Q2. What is a photon? State its energy and momentum.

Answer: A photon is a massless quantum (particle) of electromagnetic radiation travelling at the speed of light c. Its energy is $E = hf$ (or $E = hc/\lambda$) and its momentum is $p = E/c = h/\lambda$. The electron volt (eV) is often used as its energy unit ($1\ eV = 1.6 \times 10^{■1■}$ J).

Q3. Define the photoelectric effect.

Answer: The photoelectric effect is the emission of electrons from a metal surface when electromagnetic radiation of frequency equal to or greater than the threshold frequency f■ is incident on it. The emitted electrons are called photoelectrons.

Q4. Define threshold frequency and threshold wavelength.

Answer: Threshold frequency (f■): The minimum frequency of incident radiation required to eject photoelectrons from a metal surface. Threshold wavelength (λ■): The maximum wavelength of radiation that can cause photoelectric emission; λ■ = c/f■.

Q5. Explain why the maximum kinetic energy of photoelectrons is independent of intensity but depends on frequency.

Answer: In the photon model, each photoelectron absorbs exactly one photon. The photon's energy (hf) provides the work function (Φ) and the remaining is kinetic energy: $KE_{max} = hf - \Phi$. Since KE_{max} depends only on frequency (f), not intensity (number of photons), increasing intensity only increases the number of emitted electrons, not their energy.

Q6. Explain why the photoelectric current is proportional to intensity.

Answer: Higher intensity means a greater number of photons striking the surface per second. Since each photon (above threshold frequency) ejects one photoelectron, more photons produce more photoelectrons, thus a larger photoelectric current. KE_{max} remains unchanged.

Q7. Juxtapose the evidence for light as a wave and as a particle.

Answer: Wave evidence: Interference (Young's double-slit), diffraction, polarisation — phenomena that require superposition of waves. Particle evidence: Photoelectric effect, Compton scattering, pair production — phenomena where light interacts as discrete packets (photons) with definite momentum. This dual behaviour is called wave–particle duality.

Q8. Explain how electron diffraction provides evidence for the wave nature of particles.

Answer: When electrons are directed at a crystal or thin film, they produce diffraction patterns similar to X-rays. This can only be explained if electrons behave as waves with wavelength $\lambda = h/p$ (de Broglie). The observation of diffraction rings confirms that matter (electrons) possesses wave properties.

Q9. State and apply the de Broglie wavelength formula.

Answer: The de Broglie wavelength of a particle is $\lambda = h/p = h/(mv)$, where h is Planck's constant, p is momentum, m is mass, and v is speed. Example: An electron ($m = 9.11 \times 10^{■31}$ kg) moving at 10■ m/s has $\lambda = (6.63 \times 10^{■3■})/(9.11 \times 10^{■31} \times 10^{■}) \approx 7.3 \times 10^{■1■}$ m — similar to atomic spacings.

Q10. Why do isolated atoms have discrete electron energy levels?

Answer: In an atom, electrons can only occupy specific allowed energy states due to the quantum nature of matter (wave–particle duality). Electrons behave as standing waves around the nucleus; only specific wavelengths (and therefore energies) form stable standing wave patterns. This results in discrete, quantised energy levels (e.g., in hydrogen: $E\_n = -13.6/n^2$ eV).

Q11. Explain the appearance and formation of emission line spectra.

Answer: Emission spectra appear as bright coloured lines on a dark background. They are formed when electrons in excited atoms fall from higher to lower energy levels, releasing photons of specific frequencies ($hf = \Delta E$). Since energy levels are discrete, only certain photon frequencies are emitted, producing characteristic line spectra unique to each element.

Q12. Explain the appearance and formation of absorption line spectra.

Answer: Absorption spectra appear as dark lines on a continuous (rainbow) background. When white light passes through a cool gas, atoms absorb photons of exactly the same frequencies they would emit. Electrons jump to higher energy levels, removing those frequencies from the continuous spectrum and leaving dark lines at the same positions as the emission lines.

Q13. Use $hf = \Delta E$ to solve an energy level problem. (Example)

Answer: Example: An electron drops from n=3 (E = −1.51 eV) to n=2 (E = −3.4 eV) in hydrogen. ΔE = −1.51 − (−3.4) = 1.89 eV = 1.89 × 1.6 × 10■¹■ = 3.02 × 10■¹■ J. Frequency: f = ΔE/h = 3.02 × 10■¹■ / 6.63 × 10■³■ ≈ 4.56 × 10¹■ Hz (visible red — Balmer series).

Q14. Describe the Compton effect qualitatively.

Answer: The Compton effect is the increase in wavelength (Compton shift) of X-rays or gamma rays after scattering off a free electron. It cannot be explained by wave theory. Treating the photon as a particle with momentum $p = h/\lambda$ and applying conservation of energy and momentum to the photon–electron collision explains the observed wavelength increase, confirming the particle nature of photons.

Q15. Explain pair production and pair annihilation.

Answer: Pair production: A high-energy photon (≥ 1.02 MeV) passing near a nucleus spontaneously converts into an electron–positron pair: γ → e■ + e■. Energy is conserved (photon energy = rest mass energy + kinetic energies). Pair annihilation: The reverse process — an electron and positron collide and annihilate, producing two gamma-ray photons (each ≥ 0.51 MeV) to conserve momentum.

Q16. How do electron microscopes achieve very high resolution?

Answer: Resolution depends on the wavelength used — shorter wavelength gives finer detail. Electrons accelerated through high voltages acquire very short de Broglie wavelengths ($\lambda = h/p$), far smaller than the wavelength of visible light. This allows electron microscopes to resolve details at the nanometre scale, far beyond the capability of optical microscopes.

Q17. State and explain Heisenberg's uncertainty principle qualitatively.

Answer: Heisenberg's uncertainty principle states that it is fundamentally impossible to simultaneously know both the exact position (Δx) and exact momentum (Δp) of a particle: $\Delta x \cdot \Delta p \geq h/4\pi$. The more precisely position is known, the less precisely momentum can be known, and vice versa. This is not a measurement limitation — it is an inherent property of nature arising from wave–particle duality.

Q18. Use the uncertainty principle to explain why empirical measurements must have uncertainty.

Answer: Any measurement disturbs the system being measured. For example, measuring an electron's position with a photon imparts momentum to the electron (Compton recoil), altering its momentum unpredictably. Since $\Delta x \cdot \Delta p \geq h/4\pi$, reducing position uncertainty increases momentum uncertainty. Thus, all empirical measurements at the quantum level carry inherent, irreducible uncertainty.

Q19. State Einstein's photoelectric equation and identify each term.

Answer: Einstein's photoelectric equation: $hf = \Phi + KE_{max}$. Here, hf = energy of incident photon; Φ = work function (minimum energy to remove electron from surface); $KE_{max} = \frac{1}{2}mv^2_{max}$ = maximum kinetic energy of emitted photoelectron. This equation shows energy conservation during the photoelectric process.

Q20. State the photon model of light and explain how light can exert a force.

Answer: In the photon model, light consists of discrete packets (photons) each with energy $E = hf$ and momentum $p = E/c = h/\lambda$. When photons are absorbed or reflected by a surface, they transfer momentum to it. By Newton's second law ($F = \Delta p/\Delta t$), this momentum transfer constitutes a radiation pressure/force. This is used in applications like solar sails.

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