# A2 Physics Question Bank

**Q1. State evidence provided by the photoelectric effect for a particulate nature of electromagnetic radiation.**

A1.

1. Instantaneous emission of electron (no time between illumination and emission)
2. Threshold frequency below which there is no emission
3. Maximum electron energy is dependent on frequency
4. Maximum electron energy is NOT dependent on intensity
5. Rate of emission of electrons depends on intensity

**Q2. Briefly describe the concept of a photon.**

A2. A photon is a quantum of energy of electromagnetic radiation. Its energy can be calculated by multiplying the Planck constant with its frequency.

**Q3. Explain how lines in the emission spectrum of gases at low pressure provide evidence for discrete electron energy levels in atoms.**

A3. Discrete wavelengths (depicted by the lines) mean photons have particular energies. The energy of a photon is determined by the energy change of an orbital electron and therefore proves discrete energy levels.

**Q4. Explain why most electrons are emitted with less than maximum kinetic energy.**

A4. Maximum kinetic energy corresponds to electrons emitted from the surface of the metal. Energy is required to bring other electrons to the surface as photon interaction with electrons might be below the surface. Hence, some energy is used for this process and electrons are emitted with less than maximum kinetic energy.

**Q5. State and explain why the rate of emission of electrons changes as the frequency of the incident light (of constant intensity) is increased.**

A5. Since intensity remains the same, increasing the frequency will increase the energy of each photon. Thus, in order to get the same intensity, there must be fewer photons present; therefore fewer electrons will be emitted and the rate of emission will decrease.

**Q6. Explain what is meant by the work function of the metal surface.**

A6. The minimum energy of a photon to cause emission of electrons from the metal surface with zero kinetic energy.

**Q7. Explain how a line emission spectrum leads to an understanding of the existence of the discrete energy levels in atoms.**

A7. Each line corresponds to a specific photon energy. Photon emitted when electron changes its energy level. Discrete energy changes so discrete energy levels.

**Q8. What is a threshold frequency?**

A8. It is the minimum frequency photons must have to cause emission of electrons from the metal surface.

**Q9. State what is meant by de Broglie wavelength.**

A9. It is the wavelength of the wave associated with a moving particle.

**Q10. Describe an experiment to demonstrate the wave nature of electrons.**

A10. Davisson-Germer experiment

- Electron beam in vacuum
- Incident on thin metal target/carbon film
- Fluorescent screen
- Pattern of concentric rings observed
- Pattern similar to diffraction pattern observed with visible light

**Q11. Suggest why accelerated electrons may assist with an understanding of crystal lattice.**

A11. The wavelength of the electrons is about (roughly equivalent) to the separation of atoms in the lattice and they can be used in electron diffraction.

**Q12. Suggest why observed concentric rings provide evidence for wave nature.**

A12. Concentric circles are evidence of diffraction. Diffraction is a wave property. Similar patterns observed when light passes through suitable films and diffraction occurs.

**Q13. Explain why dark lines occur in an emission spectrum.**

A13. Photon absorbed by electron. Photon has energy equal to difference in energy of two energy levels. Electron de-excites emitting photon of same energy in any direction.

**Q14. Explain why a continuous spectrum of wavelengths is produced in x-ray radiation.**

A14. X-ray radiation is produced when the electrons are decelerated at the metal target. Since the electrons have a distribution of decelerations, there will be a continuous spectrum of wavelengths produced because the wavelength is dependent upon the magnitude of deceleration.

**Q15. Explain why the spectrum has a sharp cut-off at short wavelengths.**

A15. The sharp cut-off at short wavelengths corresponds to an electron that is stopped in one collision in the metal target so that all of its kinetic energy is given up as one x-ray photon. Minimum wavelength= maximum energy= greatest acceleration.

**Q16. Explain what is meant by Linear Absorption Coefficient.**

A16. For a parallel beam in a medium, $I = I_0 \times e^{(-\mu x)}$ where:

$I$ is the emergent intensity of the beam,

$I_0$ is the incident intensity of the beam,

μ is the linear absorption coefficient which determines/indicates the ability of the medium to attenuate the beam's intensity per unit thickness and,

*x* is the thickness of the medium.

**Q17. Explain why it is advantageous to filter out low-energy photons from the x-ray beam.**

A17. The low-energy photons are less penetrating and are absorbed so this could result in tissue damage. Also, they do not make any contribution to the X-ray image so removing them will not affect the image.

**Q18. State, with reference to X-ray images, what is meant by sharpness.**

A18. Sharpness relates to the ease with which the edges of structures can be determined.

**Q19. Describe briefly the factors that affect the sharpness of an X-ray image.**

A19.

1. The area of the target anode: larger the anode, the wider the beam, leading to decreased sharpness.
2. Size of the aperture at the exit window through which the X-ray beam passes: reduced using adjustable plates to increase sharpness.
3. Amount of scattering of X-ray photons: decreased by collimating beam using lead slits to increase sharpness.

**Q20. Suggest why on an X-ray plate, the contrast between bone and muscle is much greater than between fat and muscle.**

A20. Attenuation (coefficients) in muscle and in fat are similar where as attenuation (coefficients) in bone and in muscle are different, thus affecting the contrast as it depends on difference in attenuation. (can quote values)

**Q21. Distinguish between sharpness and contrast in X-ray imaging.**

A21. Sharpness: ease with which edges of structures can be seen

Contrast: difference in degree of blackening between structures

**Q22. State what is meant by hardness of an X-ray beam.**

A22. Hardness measures the penetration of a beam. Greater the hardness, greater the penetration of the beam (the two quantities are directly proportional).

**Q23. State how hardness is controlled.**

A23. It is controlled by changing the anode voltage. Higher the anode voltage, greater the hardness.

**Q24. Why is long wavelength X-ray radiation a greater health hazard compared to short wavelength? How is the hazard minimised?**

A24. Long wavelength radiation is more likely to be absorbed and cause tissue damage. It is minimised by placing an aluminium filter in the X-ray beam.

**Q25. Explain how the hardness of an X-ray beam is controlled by the accelerating voltage in the X-ray tube.**

A25. Changing the voltage changes the kinetic energy of the electrons. Changing electron energy changes the maximum X-ray photon energy and therefore its penetration power.

**Q26. State what is meant by attenuation.**

A26. Attenuation is the loss of power/energy/intensity.

**Q27. Why does the expression $I = I_0 \times e^{(-\mu x)}$ apply only to parallel beams?**

A27. Intensity changes when the beam is not parallel (even when there is no absorption). It decreases when the beam is divergent.

**Q28. Explain why an aluminium filter may be placed in the X-ray beam when producing an X-ray image of the patient.**

A28. An X-ray beam contains many wavelengths. Aluminium filter absorbs long wavelength X-ray radiation that would be absorbed by the body and so not contribute to the image.

**Q29. Outline briefly the main principles of the use of magnetic resonance to obtain information about internal body structures.**

A29.

- Large/strong (constant) magnetic field
- Nuclei [of hydrogen atoms/ions (protons)] rotate about direction of field/precess
- Radio frequency pulse
- Causes resonance in nuclei as they absorb energy
- Pulse is at the Larmour frequency
- On relaxation, nuclei emit pulse of radio frequency
- This is detected and processed
- Non-uniform field superimposed

- Allows for position of nuclei to be determined
- And for location of detection to be changed
- Resonant frequency depends on magnetic field strength

**Q30. Distinguish between images produced by CT scanning and X-ray imaging.**

A30. CT image: (thin) slice through structure, image can be rotated, 3D image built up from many slices at different angles

X-ray image: shadow image of whole structure, 2D image, depth not indicated

**Q31. By reference to the principles of CT scanning, suggest why CT scanning could not be developed before powerful computers were available.**

A31. X-ray image of slice taken from many different angles. These images are combined and processed and repeated for many different slices to build up a 3D image that can be rotated. A powerful computer is required to store and process the huge quantity of data.

**Q32. By reference to formation of the image in each case, suggest why the exposure to radiation differs between CT and X-ray imaging techniques.**

A32. X-ray image involves a single exposure. CT scan: exposure of a slice from many different angles; repeated for different slices and hence, CT scan involves a much greater exposure.

**Q33. Describe the functions of the two superimposed magnetic fields used in MR scanner.**

A33. Strong uniform magnetic field:

- Aligns nuclei; gives rise to Larmour/resonant frequency in radio frequency region
- Frequency of precession depends on the strength of the magnetic field
- Large field strength means frequency in radio frequency range

Non-uniform magnetic field:

- Enables nuclei to be detected; changes the Larmour frequency
- Frequency of precession different in different regions of the subject
- Enables location of precessing nuclei to be determined
- Enables thickness of slice to be varied/location of slice to be changed

**Q34. Explain the main principles behind the generation of ultrasound to obtain diagnostic information about internal body structures.**

A34. A piezo-electric crystal such as quartz has two sides coated with silver to act as electrodes. The centres of (+) and (-) are not coincident. A potential difference across the crystal causes it to change shape. So an alternating voltage (in ultrasound frequency range) applied across the crystal causes it to vibrate. The crystal is cut so that it vibrates at its resonant frequency. The vibrations generate the ultrasound.

**Q35. Explain the use of a gel on the surface of skin during ultrasound diagnosis.**

A35. There is very little transmission at an air-skin boundary and almost complete transmission at a gel-skin boundary when the wave travels in or out of the body.

**Q36. Explain the principle behind the detection of ultrasound waves.**

A36. When the crystal is made to vibrate by an ultrasound wave, alternating potential difference is produced across the crystal.

**Q37. By reference to ultrasound waves, state what is meant by acoustic impedance.**

A37. It is the product of the density of the medium and the speed of the sound wave in that medium.

**Q38. Explain the importance of the difference between $Z_1$ and $Z_2$ for the transmission of ultrasound across a boundary.**

A38. If $(Z_1 - Z_2)$ is small, mostly transmission.

If $(Z_1 - Z_2)$ is large, mostly reflection.

Intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$

**Q39. State and explain one advantage of the use of high-frequency ultrasound compared with lower-frequency ultrasound.**

A39. Smaller structures can be distinguished because better resolution at higher frequency due to shorter wavelength.

**Q40. Explain the main principles behind the use of ultrasound.**

A40. Pulse of ultrasound produced by piezo-electric crystal is reflected from boundaries between media. The reflected pulse is detected by the ultrasound transmitter and the signal is processed and displayed. The intensity of the reflected pulse gives information about the boundary and the time delay between transmission and detection gives information about depth.

**Q41. Suggest why any signal received later at the detector is usually amplified more than that received at an earlier time.**

A41. Later signal has passed through greater thickness of medium so as greater attenuation/greater absorption/smaller intensity.

**Q42. State on application and in each case where information is carried using:**

a) Microwave- satellite communication (linking ground station to a satellite); mobile phones; line-of-sight communication; Wi-Fi and Bluetooth.
b) Co-axial cables- connection of TV to aerial; loudspeaker, microphone.
c) Wire-pairs- linking a landline phone to local exchange, amplifier to loudspeaker, switch to doorbell.

**Q43. Explain what is meant by geostationary satellite.**

A43. It is a satellite in the equatorial orbit around 36,000 km from the Earth's surface, travelling from West to East with a period of revolution of 24 hours.

**Q44. Comment on time delays experienced by two people when communicating either using geostationary satellite or using optic fibre.**

A44. The speed of the signal is of the same order of magnitude in both systems. However, the optic fibre link is much shorter than via satellite in which case the signal has to travel twice the same distance- up and down. Time delay in optic fibre is much lesser due to the lesser attenuation of the signal.

**Q45. State two reasons why frequencies in the Ghz range are used in satellite communication.**

A45.

a) Little ionospheric reflection
b) High frequencies mean higher bandwidth leading to large information-carrying capacity.

**Q46. Explain what is meant by cross-linking.**

A46. Signal in one wire pair is picked up by a neighbouring pair.

**Q47. Suggest why cross-linking in co-axial cables is much less than in wire-pair.**

A47. The outer finely woven thin copper wire braid that acts as the "return" for the signal is earthed; and it shields the inner metal wire conductor core from external noise/interference as electromagnetic waves do not pass easily through metals.

**Q48. Suggest advantages of optic fibres over co-axial cables for the transmission of data.**

A48.

1) Larger bandwidth so carries more information per second
2) Low attenuation of signal so repeater and regenerator amplifiers can be further apart
3) Low cost as compared to same length of copper wire
4) High security as impossible to tap; no cross-talk
5) Smaller diameter, easier handling, easier storage, less weight
6) Low noise, no electromagnetic interference
7) Immune to lightning and the effects of nearby power lines

**Q49. Suggest why infra-red radiation is used rather than visible light in optic fibre.**

A49.

- Optic fibre (made of glass) does not absorb or scatter infra-red radiation
- Lower attenuation than for visible light per unit length (due to lesser frequency)
- Fewer repeaters and amplifiers required
- Longer uninterrupted length of fibre

**Q50. What are the advantages of satellite communication over ionospheric reflection (IR) of radio waves?**

A50.

1. More reliable communication because ion layers vary in height/density thus giving rise to variable quality in signals
2. IR bandwidth is too narrow so cannot carry all info required

3. IR coverage is limited as reception is poor in hilly areas

**Q51. State 2 functions of the copper braid in co-axial cables.**

A51.

1. Acts as "return" for the signal
2. Shields inner core form noise/interference/cross-talk

**Q52. Why is co-axial cable used rather than wire-pair to connect the aerial to the receiver?**

A52.

1. Greater bandwidth so increased information-carrying capacity per second
2. Less attenuation per unit length
3. Less noise/interference

**Q53. Outline the principles of the use of a geostationary satellite for communication on Earth.**

A53. The satellite receives a space-wave from a transmitter on Earth, the uplink, with a carrier frequency in the microwave region. The satellite receives a greatly attenuated signal. The signal is amplified and re-transmitted back to Earth, as the downlink, on another frequency and with more power than it received. Different frequencies prevent swamping of uplink signal (as the signal sent from the satellite could swamp the signal sent from the Earth). Examples of frequencies used: 6/4 GHz, 14/11 GHz, 30/20 GHz.

**Q54. State and explain advantages and disadvantages of polar-orbiting satellite as compared with geo-stationary satellites.**

A54. Advantages: (of polar-orbiting satellites)

- Their orbital heights being less, the time delays in telephone conversations are not noticed.
- Being closer to the Earth, these satellites can see smaller details when used for observations and espionage.
- The entire planet may be viewed in several orbits/with network.

Disadvantages: (of polar-orbiting satellites)

- Continuous communication is only possible with a number of satellites but for that they need to be tracked.
- Limited use in any one orbit.
- Satellites in polar orbit are not always in the same position relative to Earth so dish aerial on Earth must be removed.

**Q55. Suggest and explain two ways in which the reproduction of the original analogue signal may be improved.**

A55.

1. Increase the number of bits in digital numbers at each sampling so that the step height is reduced.
2. Increase sampling frequency/reduce time between samples so that width of step is reduced.

**Q56. Explain how reception of signals to and from the mobile phone is maintained as a person moves through several different cells.**

A56. The computer at the cellular exchange monitors signal strength from the mobile phone and switches the call from one base station to another to maintain maximum signal strength.

**Q57. Describe what is meant by frequency modulation.**

A57. It is when the frequency of the carrier wave varies in synchrony with the displacement of the information signal.

**Q58. State reasons why the cost of FM broadcasting to a particular area is greater than that of AM broadcasting.**

A58.

1. More radio stations required due to shorter range
2. More complex electronics involved
3. Larger bandwidth required

**Q59. Explain what is meant by:**

i. Cross talk- It is the picking up of a signal in one cable from another cable nearby
ii. Noise- It is the random, unwanted signal/power that distorts the transmitted signal

**Q60. Explain the role of the base station and the cellular exchange when a mobile phone is switched on and before a call is made or received.**

A60. When switched on, the phone transmits a signal to identify itself. This signal is received by several base stations and is then transferred to the cellular exchange where a computer selects the

base station with the strongest signal and assigns the phone a carrier frequency so it can make and receive calls.

**Q61. Suggest and explain why a country is divided into a number of cells.**

A61. This is so that carrier frequencies can be re-used simultaneously without interference so that the possible number of handsets is increased. Lower power transmitters used so decreased interference. Ultra-high frequency (UHF) used so must be line-of-sight.

**Q62. Suggest why the base stations in mobile phone networks operate on UHF.**

A62. Limited range so cells do not overlap appreciably. Short wavelength so convenient length aerial on mobile phone.

**Q63. Explain what is meant by:**

Analogue signal- A signal that has the same variation with time as the information signal data/ varies continuously within limits.

Digital signal- A signal that consists of a series of 'highs' and 'lows' with no intermediate values.

**Q64. Describe the function of the analogue-to-digital converter.**

A64. It samples the analogue signal at regular time intervals and the sampled signal is converted into a binary number.

**Q65. Suggest why the transmission cable has a number of channels.**

A65. One channel is required for each bit of the digital number.

**Q66. State the function of:**

i. A.F. Amplifier- To increased power of signal to drive the loudspeaker
ii. Switch- enables transmission and reception to occur in quick succession so one aerial can be used
iii. Tuning circuit- gives large signal for one input carrier frequency and rejects very small signal for all other frequencies OR it selects desired AM wave signal from the different signals picked up by the receiver aerial.
iv. Parallel-to-serial converter- takes all simultaneous digits for one number and sends them one after another along the transmission line.

v. Oscillator- a device that converts energy of a DC source into an alternating voltage of high frequency and provides the carrier wave frequency.

**Q67. State what is meant by amplitude modulation.**

A67. In AM, the carrier wave has a constant frequency. The amplitude if the carrier is made to vary in synchrony with the displacement of the information signal.

**Q68. State what is meant by a modulated carrier wave.**

A68. It is a high frequency wave whose amplitude is varied in synchrony with the displacement of the information signal.

**Q69. State reasons why modulated carrier waves are used rather than direct transmission of electromagnetic waves having audio frequencies.**

A69.

i. Shorter aerial required as carrier wave frequencies are higher
ii. Longer transmission range/lower transmission power
iii. Less attenuation, less distortion
iv. Allows more than one station in a region

**Q70. Explain why regenerator amplifiers do not amplify the noise that has been picked up on digital signals.**

A70. For a digital signal, only the highs and lows are necessary so the variation between highs and lows caused by the noise are not recognised by the electronic circuit.

**Q71. State the advantages of digital over analogue.**

A71.

1. Signal can be regenerated so noise is filtered.
2. Extra data can be added to transmissions so that signals can be checked for errors.
3. Digital circuits are more reliable/cheaper.
4. Data can be encrypted for security.
5. Multiplexing possible.
6. Greater rate of transfer of data.
7. Can be transmitted over long distances with regular regenerations without the signal becoming degraded.

**Q72. Explain what is meant by damping.**

A72. It is the continuous loss of energy which leads to a reduction in the amplitude of the oscillating system which is caused by a force acting in an opposite direction to the motion.

**Q73. State what is meant by resonance.**

A73. It is the phenomenon where the maximum amplitude of vibration is produced when the impressed/driver frequency equals the natural frequency of vibration.

**Q74. State what is meant by oscillations.**

A74. It is the backward and forward motion of an object between two limits.

**Q75. State what is meant by free oscillations.**

A75. Oscillations where there is no external force acting so amplitude is constant.

**Q76. State 3 situations where resonance is useful and 3 where it is not.**

A76. Useful:

1. Quartz crystal for time-keeping
2. Production of ultrasound
3. Magnetic resonance imaging

Not useful:

1. Car suspension system oscillated- resonance when going over bump- maximum amplitude of vibration can cause damage
2. Metal panels on machinery vibrate- motor in machine impresses frequency on panel
3. Bridges during earthquakes

**Q77. State 2 ways in which resonance peak can be decreased without changing original frequency.**

A77.

1. Attach sheet of card/feathers to object. This will increase damping.
2. Reduce oscillator amplitude. This reduces the energy input to the system.

**Q78. Explain what is meant by simple harmonic motion.**

A78. It is defined as the motion of an object about a fixed point such that its acceleration is proportional to its displacement from the fixed point and directed towards the point.

**Q79. Define the decay constant of a radioactive isotope.**

A79. It is the probability of decay of an individual nucleus per unit time interval.

**Q80. Explain what is meant by the binding energy of a nucleus.**

A80. It is the minimum energy required to completely separate a nucleus into its individual constituent nucleons.

**Q81. Suggest why the activity of $U_{234}$ appears to be constant.**

A81. The half-life is very long compared with the time of counting.

**Q82. Suggest why a measurement of the mass and the activity of a radioactive isotope is NOT an accurate means of determining its half-life if the half-life is approximately one hour.**

A82. There would be a appreciable decay of source during the taking of measurements.

**Q83. State what is meant by nuclear fission.**

A83. It is the splitting of a heavy nucleus into two lighter nuclei of approximately the same mass.

**Q84. Suggest why, when neutrons are absorbed into the Boron rods, the rods become hot as a result of their nuclear reaction.**

A84. The emitted particles have kinetic energy and when they are stopped in the rods, they lose their kinetic energy which gets converted to thermal energy.

**Q85. Explain how nuclear fission is energetically possible/feasible.**

A85. Binding energy of nucleus= A (nucleon number) x $E_B$ (binding energy per nucleus)

Binding energy of parent nucleus is less than sum of binding energies of fragments. Therefore, fragments are more stable so fission is favoured.

**Q86. Define radioactive half-life.**

A86. It is the time taken for the initial number of nuclei in a sample to reduce to one half of its initial value.

**Q87. Explain the meaning of the symbol $<c^2>$.**

A87. It is the mean value of the square of the speed of the atoms. [ ½ x m x $<c^2>$ = mean kinetic energy]

**Q88. State what is meant by an ideal gas.**

A88. An ideal gas is one which obeys the law $\frac{PV}{T} = constant$ at all pressures, volumes and temperatures. P is the pressure, T is the temperature and V is the volume of the gas.

**Q89. Explain qualitatively how molecular movement causes the pressure exerted by a gas.**

A89. Gas molecules hit and rebound from the walls of the vessel. The change in momentum for this collision gives rise to an impulse. Many impulses are averaged to give constant force on area of the wall to give pressure.

**Q90. State the basic assumptions of the kinetic theory of gases.**

A90.

1. Atoms behave as elastic identical spheres.
2. Volume of atoms negligible compared to volume of containing vessel.
3. Time of collision negligible compared to time between collisions.
4. No forces of attraction/repulsion between atoms.
5. Atoms are in continuous random motion.

**Q91. State what is meant by the Avogadro constant, $N_A$.**

A91. It is the number of atoms of carbon-12 in exactly 12g of the isotope carbon-12 and has a value of $6.02 \times 10^{23}$ $mol^{-1}$.

**Q92. State what is meant by a mole.**

A92. It is the amount of substance containing same number of particles as 0.012 kg of the isotope carbon-12.

**Q93. State what is meant by internal energy of a substance.**

A93. It is the sum of the random distribution of kinetic and potential energies of its molecules.

**Q94. Explain why, for an ideal gas, internal energy is equal to kinetic energy.**

A94. No intermolecular forces so potential energy is not there therefore, internal energy is equal kinetic energy which is proportional to temperature.

**Q95. Define specific latent heat.**

A95. It is the energy required per unit mass of the substance to change its state without any change in temperature.