AQA (GCSE Notes)

Chapter 6: Waves

Q1. Define the terms transverse wave and longitudinal wave with examples.
Answer: A transverse wave is a wave in which the particles of the medium vibrate at right angles to the direction in which the energy of the wave is moving; the crest and trough pattern on a stretched string or the ripples you see spreading out across the surface of a pond after a stone is dropped are good everyday examples. A longitudinal wave is one in which the particles vibrate parallel to the direction the energy travels; sound travelling through air or compression pulses moving down a stretched slinky spring are common illustrations. Both types move energy from place to place while the medium only oscillates about a fixed position, demonstrating that motion of matter and transport of energy need not be the same.

Q2. Describe how the particles move in a transverse wave compared to the direction of wave travel.
Answer: In a transverse wave the oscillations of the particles are perpendicular to the overall direction of energy transfer. If the wave is moving horizontally from left to right, each particle of the medium moves up and down around its rest position but never actually follows the wave along the horizontal direction. This perpendicular vibration makes crests where particles reach maximum positive displacement and troughs where they reach maximum negative displacement. Despite the dramatic-looking profile that seems to travel, every individual particle simply cycles through its motion and returns to its undisturbed level, so matter does not drift along with the wavefront.

Q3. Describe how the particles move in a longitudinal wave compared to the direction of wave travel.
Answer: In a longitudinal wave the particles vibrate back and forth in the same line—parallel—to the direction in which the wave energy travels. Imagine a slinky stretched out on a table; when you push and release one end, coils bunch together then spread out along the length of the spring, creating regions of compression and rarefaction that shift forward. Each coil, however, only shuttles a small distance either side of its equilibrium position and then reverses. The forward-moving pattern of high-pressure compressions and low-pressure rarefactions carries the energy, while every coil of the slinky remains close to where it started.

Q4. Give one example of a transverse wave and one example of a longitudinal wave.
Answer: Light waves, which are electromagnetic, are transverse because the electric and magnetic fields oscillate at right angles to the direction of propagation. Sound waves travelling through air are longitudinal because the air molecules oscillate back and forth along the same line that the sound energy is moving. Both examples illustrate the two broad families of wave behaviour found in nature and make it easier to see that the classification is based on particle motion relative to energy flow rather than on what material, if any, carries the wave.

Q5. Explain how sound travels through air as a longitudinal wave.
Answer: A vibrating source, such as a loudspeaker cone, alternately pushes and pulls on the adjacent air layers. During the push phase air molecules are forced closer together, producing a compression where local pressure and density are higher than average. As the cone moves back, it creates a region of low pressure and density called a rarefaction. These compressions and rarefactions propagate outward because each compression pushes on the next layer of air, which then pushes on the next, and so on. Individual air molecules only oscillate a minuscule distance about their normal positions, but the pressure pattern advances at the speed of sound, carrying the acoustic energy to a listener.

Q6. Describe the difference between compressions and rarefactions in a sound wave.
Answer: Compressions are regions in a longitudinal sound wave where particles of the medium are close together, pressure is above the equilibrium value, and density is higher. Rarefactions are the opposite: regions where particles are spread further apart, pressure dips below ambient, and density is lower. As the wave propagates, compressions and rarefactions alternate at a rate set by the frequency. The cyclical pattern of high-pressure and low-pressure zones transmits the energy, while each individual particle oscillates between being squeezed in a compression and stretching out in a rarefaction without travelling with the wavefront.

Q7. What does it mean when we say that waves transfer energy but not matter?
Answer: Saying a wave transfers energy but not matter means that the disturbance carrying the energy progresses through space, yet the particles of the medium do not move along with that disturbance over appreciable distances. Instead, each particle vibrates around a fixed rest position, passing on its kinetic energy to neighbouring particles through restoring forces like tension or pressure. The visible or measurable pattern—the crest-trough sequence in water or the compression-rarefaction train in air—travels, but when the wave is gone the medium's particles are almost exactly where they began, showing that energy propagation and mass transport are distinct.

Q8. How can we show that water does not move with the wave in a ripple tank experiment?
Answer: Place a small, neutrally buoyant marker such as a piece of light plastic or a speck of cork on the water surface of the ripple tank before generating circular ripples with a vibrating dipper. As the concentric wavefronts radiate outward, the marker bobs up and down and traces a tiny circular or slightly elliptical path, but it does not drift sideways with the advancing ripples. When the waves pass, the marker is found very close to its starting spot, demonstrating visually that while the wave pattern spreads across the tank, the water molecules—and the floating marker representing them—mainly oscillate rather than travel with the disturbance.

Q9. What evidence shows that air particles do not move with sound waves?
Answer: One clear piece of evidence comes from observation of dust motes or smoke in still air when a loudspeaker emits steady tones. The particles vibrate slightly back and forth in place but do not migrate away from the source as the sound propagates. Another supporting fact is that music played in one room can be heard in another without a continuous wind carrying the air from speaker to listener; if the air itself travelled with the sound, we would feel a strong draught equal to the speed

of sound. Precision experiments using microphones also show pressure variations arriving without bulk air flow, confirming that only energy, not mass, is transported.

Q10. Explain what amplitude of a wave represents and how it is measured.
Answer: The amplitude of a wave is the maximum displacement of any point on the medium from its undisturbed rest position. For a transverse wave on a string it is the height of the crest above the equilibrium line or, equivalently, the depth of the trough below it. For a sound wave it corresponds to the maximum variation in air pressure from the ambient level. Amplitude is measured by taking the distance between the peak and the rest position using a ruler or calibrated graph for water waves, or by measuring the peak pressure difference with a microphone and oscilloscope for sound. Greater amplitude signifies more energy carried by the wave.

Q11. Explain what wavelength of a wave is and how it can be measured from a diagram.
Answer: Wavelength is the spatial period of a wave: the distance between any point on one wave and the identical point on the next wavefront along the direction of propagation. On a diagram of a transverse wave, measure the distance from crest to the next crest or trough to the next trough. On a longitudinal representation, measure from the centre of one compression to the centre of the next. Using a scale on the diagram or direct measurement in a ripple tank with a ruler parallel to the wave travel allows you to quantify wavelength in metres or centimetres depending on the setup.

Q12. Define frequency and give its unit.
Answer: Frequency is the number of complete waves—or cycles—that pass a fixed point in one second. It quantifies how often the repeating pattern occurs in time. The SI unit of frequency is the hertz (Hz), where 1 Hz equals one cycle per second. High-frequency waves have many cycles per second and therefore shorter periods, while low-frequency waves have fewer cycles per second and longer periods. Frequency is determined by the source of the wave and remains constant as the wave moves between media unless the source changes or the wave is absorbed.

Q13. What does the period of a wave mean and how is it calculated from frequency?
Answer: The period, symbol T, is the time taken for one complete cycle of a wave to pass a given point or for one particle to go through its entire oscillation and return to the same stage of motion. It is the reciprocal of frequency: $T = 1 \div f$. If a wave has a high frequency, many cycles occur each second and the period is small; if the frequency is low, each cycle takes longer and the period is larger. Period is measured in seconds and provides a convenient time-based way to describe the same repetitive motion that frequency describes in the rate domain.

Q14. Write the formula linking period and frequency and define all the terms.
Answer: The relationship is $T = 1/f$, where T is the period measured in seconds (s) and f is the frequency measured in hertz (Hz). This formula states that the time for one cycle equals one divided by how many cycles occur per second. It can be rearranged to $f = 1/T$ when you know the period and wish to find the frequency. These two parameters are inversely related, so doubling the frequency halves the period and vice versa, reflecting the repetitive timing of wave cycles.

Q15. If the frequency of a wave is doubled, what happens to its period? Explain.
Answer: Since period and frequency are inverses (T = 1/f), doubling the frequency means each cycle occurs twice as often, so the time for one cycle is halved. For example, a 5 Hz wave has a period of 0.2 s; if the frequency increases to 10 Hz, the period becomes 0.1 s. Physically, the medium's particles complete their back-and-forth oscillations in half the time, which is consistent with the higher rate of wavefronts passing each second. No other wave property must change for this inverse relationship to hold.

Q16. State the wave equation and explain what each symbol means.
Answer: The wave equation is v = f λ. Here v is the wave speed measured in metres per second (m/s), showing how fast the energy or disturbance moves through the medium. The symbol f stands for frequency measured in hertz (Hz), indicating how many cycles occur per second. The Greek letter λ (lambda) represents wavelength measured in metres (m), expressing the spatial length of one complete wave cycle. Multiplying frequency by wavelength gives the distance each cycle travels each second, which by definition is the speed of the wave.

Q17. Describe how to calculate the speed of a wave using its frequency and wavelength.
Answer: Measure or determine the wave's frequency f, usually with a timer or frequency generator, and its wavelength λ, by measuring the spatial distance between repeating points along the wave. Insert these values into the wave equation v = f λ. Multiply the frequency (cycles per second) by the wavelength (metres per cycle). The product has units of metres per second and represents how quickly the wavefront moves through the medium. This calculation assumes the wave is travelling steadily in a uniform medium so v remains constant along its path.

Q18. A wave has a frequency of 5 Hz and a wavelength of 2 m. Calculate its speed.
Answer: The speed is 10 m/s.
Solution: Use v = f λ. Substitute f = 5 Hz and λ = 2 m: v = 5 × 2 = 10 m/s. Thus the wave energy travels through the medium at ten metres per second.

Q19. Describe how the amplitude of a wave affects the energy it carries.
Answer: The energy transported by a wave is proportional to the square of its amplitude. Doubling the amplitude multiplies the energy by four, and halving amplitude reduces energy to one-quarter. In a water ripple, higher crests mean more potential and kinetic energy as the water moves farther from equilibrium. In sound waves, greater pressure variations correspond to louder sounds because more energy per unit area strikes your eardrum. Therefore amplitude is a key control knob for the power conveyed by a wave without altering its speed or frequency.

Q20. What would happen to the wave speed if the wavelength increases but frequency stays the same?
Answer: According to v = f λ, if frequency remains constant and wavelength increases, the product—and therefore the wave speed—must increase proportionally. In practice this situation usually means the wave has entered a region where its propagation conditions allow faster travel, such as deeper water for surface waves. If the medium does not change, wavelength normally cannot

vary independently of speed, so an altered wavelength with constant frequency signals a new medium or altered tension.

Q21. How would the wave speed change if a wave moves from air into water?
Answer: Sound waves typically travel faster in water than in air because water's greater stiffness (bulk modulus) outweighs its higher density in the v = √(elasticity/density) relationship. As the wavefront crosses the boundary, its frequency stays fixed (set by the source), but the higher speed in water means the wavelength increases to keep v = f λ balanced. Thus observers measuring in water would find both higher speed and longer wavelength for the same tone compared with measurements in air.

Q22. Describe a method to measure the speed of ripples using a ripple tank.
Answer: Place a ruler or graph paper beneath the transparent ripple tank and darken the room while illuminating the tank from above so ripples cast shadows on the scale. Generate straight parallel waves with a vibrating bar at a known, adjustable frequency controlled by a signal generator. Use a strobe light set near the wave frequency to "freeze" the pattern, allowing you to measure the distance across several wavelengths with the ruler; divide by the number of waves to find λ accurately. Simultaneously read the frequency from the generator, then compute speed using v = f λ.

Q23. Describe how to use a strobe light and a ruler to measure wavelength in a ripple tank.
Answer: Adjust the strobe frequency until the ripples in the tank appear stationary or move very slowly; this means the strobe flashes once each wave passes the same point. With the pattern effectively frozen, place a transparent ruler along the direction of travel. Count the number of adjacent wave crests spanning a measurable length—say ten crests—then divide that length by the number of wavelengths between the first and last crest (which is one fewer than the number counted) to obtain λ. The strobe's synchronisation makes the crests clear and reduces error due to wave motion.

Q24. Explain how to measure the frequency of ripples using a timer and video recording.
Answer: Record the ripple tank using a camera placed above. Start the vibration generator and film for a known duration, ensuring a steady lighting setup. Later, playback the video in slow motion and count how many wave crests pass a fixed reference point on the screen during a chosen time interval—for example, 50 crests in 10 s. Frequency f is then number of crests divided by time: f = 50/10 = 5 Hz. Using video lets you pause, rewind, and tally accurately, reducing human reaction timing errors.

Q25. Describe a method to measure the speed of sound in air using two microphones and a timer.
Answer: Position two microphones a measured distance apart—say 1.00 m—along a straight line and connect each to the input channels of an oscilloscope or data logger. Produce a sharp sound near the first microphone using a clap or electronic pulse. The oscilloscope traces show the sound arriving at microphone 1, then after a short delay at microphone 2. Measure the time difference Δt between the two peaks. The speed of sound v equals the known separation distance divided by Δt. Repeating the test several times and averaging improves accuracy and cancels random error.

Q26. What are the risks involved in measuring ripple speed in a tank and how can they be reduced?

Answer: Working with a ripple tank involves shallow water, mains-powered lamps, and glass. Water on the bench can create slip hazards or short an electrical supply if it splashes onto wires. The lamp housing becomes hot and may cause burns, and the glass tank can crack or tip, leading to cuts. Reduce these risks by placing the tank on a level, non-slip mat, keeping all leads looped away from the water, using a low-voltage light source or an LED strobe, wearing eye protection to guard against shards if the glass breaks, mopping spills immediately, and switching off electrics before adjusting the equipment. Clear instructions and teacher supervision further cut the chance of accidents because students handle water and electrics more cautiously when they understand the hazards.

Q27. In a wave diagram, how can you identify one full wavelength?

Answer: A full wavelength is the shortest distance over which the wave pattern repeats itself. On a transverse diagram draw a ruler parallel to the direction of travel and pick any crest; the next crest directly in line is one wavelength away. The same works from trough to trough or from any point where the oscillation starts to rise through the equilibrium to the next identical rising point. In a longitudinal sketch showing compressions and rarefactions, measure from the centre of one compression to the centre of the next. Choosing clearly corresponding positions ensures you do not over- or underestimate the true spatial repeat distance, giving an accurate value for λ for later use in speed or energy calculations.

Q28. How can you identify amplitude from a transverse wave diagram?

Answer: Amplitude is the maximum displacement of any point on the wave from its undisturbed level. On a diagram first draw a straight line representing the equilibrium position through the middle of the oscillations. Measure perpendicularly from this line up to the top of a crest or down to the bottom of a trough. The positive or negative sign shows direction, but the magnitude is the same. Only measure to the first peak or valley, not peak-to-peak, because that would give twice the amplitude. Careful perpendicular measurement avoids errors caused by slanted rulers or perspective, and using a graph scale lets you convert centimetres on paper to metres in the actual medium if the diagram is scaled.

Q29. Explain how to calculate wave speed from a diagram if you know wavelength and frequency.

Answer: First use the diagram's scale to convert the drawn distance between identical points—crest to crest or compression to compression—into the real-world wavelength λ in metres. Next, find the frequency f either from an accompanying label or by counting how many waves the source generates each second in an experiment. Insert both values into the wave equation $v = f\lambda$. For example, if the diagram shows $\lambda = 0.12$ m and the frequency is 50 Hz, then $v = 50\text{ Hz} \times 0.12\text{ m} = 6$ m/s. The calculation assumes the medium is uniform so the speed is constant along the path of travel.

Q30. A wave has a period of 0.25 seconds. Calculate its frequency.

Answer: The frequency is 4 Hz.

Solution: Use the relationship $T = 1/f$, rearranged to $f = 1/T$. Substitute $T = 0.25$ s: $f = 1 \div 0.25 =$

4 Hz. Four complete cycles pass a point every second, so listeners or sensors detect four oscillations per second.

Q31. A sound wave travels at 330 m/s and has a frequency of 440 Hz. Find its wavelength.
Answer: The wavelength is 0.75 m.
Solution: Apply v = f λ and rearrange to λ = v ÷ f. Substitute v = 330 m/s and f = 440 Hz: λ = 330 ÷ 440 = 0.75 m. Each successive compression is three-quarters of a metre behind the previous one in the air.

Q32. Why do sound waves travel faster in water than in air?
Answer: Wave speed depends on the medium's stiffness divided by its density. Water molecules are packed closer and bonded more strongly, giving water a much higher bulk modulus (stiffness) than air, so pressure disturbances push neighbouring molecules more effectively. Although water is denser, the stiffness increase outweighs the mass increase, raising the ratio and thus √(stiffness/density). Consequently compressions propagate quicker, about 1500 m/s, compared with 330 m/s in air. The greater cohesion within the liquid lets kinetic energy transfer swiftly between molecules, shortening the response time and boosting speed.

Q33. How do changes in wavelength and frequency affect wave speed when a wave enters a new medium?
Answer: The source continues to vibrate at the same rate, so the frequency f remains constant across a boundary. If the new medium allows the wave to travel faster, the speed v increases and, with v = f λ unchanged f, the wavelength λ must stretch so the product matches the new speed. Conversely, if the wave slows down, its wavelength shortens. Therefore variations in speed manifest as proportional changes in wavelength while frequency stays fixed, maintaining energy continuity and temporal coherence as the wave crosses interfaces.

Q34. When a wave travels into a denser medium, what usually happens to its speed and wavelength?
Answer: For mechanical waves like water ripples or sound, entering a denser medium typically increases inertia more than stiffness, so the speed decreases. Since the frequency is set by the original source and does not change, the wavelength must shorten in proportion to the speed reduction to satisfy v = f λ. The wavefronts bunch up, producing a smaller spatial period even though the temporal period—the time between arriving crests—stays the same. Electromagnetic waves behave similarly in optical materials where higher optical density also reduces speed and hence wavelength.

Q35. If a wave's frequency remains the same but it moves to a new medium, what must change?
Answer: With frequency fixed by the source, any change in wave speed upon entering a new medium must be matched by a corresponding change in wavelength so that v = f λ still holds. If the speed rises, wavelength lengthens; if speed drops, wavelength contracts. This shift explains refraction angles in light and altered spacing of wavefronts in ripple tanks while keeping the timing between successive peaks steady for an observer straddling the boundary.

Q36. A wave with wavelength 3 m has a frequency of 10 Hz. What is its speed?
Answer: The speed is 30 m/s.
Solution: Using v = f λ, substitute f = 10 Hz and λ = 3 m: v = 10 × 3 = 30 m/s. The disturbance covers thirty metres each second along the medium.

Q37. How can you show the difference between transverse and longitudinal waves using a slinky spring?
Answer: Stretch a slinky on a smooth floor. For a transverse demonstration flick one coil sideways; a sideways pulse travels along while coils move perpendicular to the spring's length. For a longitudinal demonstration push then pull one end; compressions travel down the length as coils bunch and spread parallel to the spring's axis. Observers see that energy moves along the spring in both cases, but coil motion is perpendicular in the first setup and parallel in the second, illustrating the fundamental geometric distinction.

Q38. Describe what is meant by the wavefronts in ripple experiments.
Answer: Wavefronts are imaginary lines or curves that connect points on neighbouring waves which are all in the same phase of motion, such as all crests or all troughs. In a ripple tank viewed from above, a straight vibrating bar creates parallel wavefronts that look like successive bright or dark stripes, whereas a point dipper produces circular wavefronts expanding outward. Tracking these fronts lets you see how the disturbance advances, measure wavelength by the spacing between fronts, and observe refraction or diffraction when the pattern bends around obstacles or changes depth.

Q39. How does increasing the frequency of a wave affect the number of waves observed per second?
Answer: Frequency is, by definition, the number of complete cycles passing a fixed point per second, so increasing frequency directly raises that count. Doubling the frequency means double the crests will sweep past each second, halving the period between arrivals. For water waves the surface will rise and fall more rapidly; for sound the pitch rises; for electromagnetic waves the energy grows with the higher oscillation rate, demonstrating the tight link between frequency and temporal wave density.

Q40. Describe the motion of particles in water as a wave passes across the surface.
Answer: Surface water particles follow small roughly circular or slightly elliptical paths. As a crest approaches, a particle moves upward and forward, then downward as the crest passes, and finally backward beneath a trough before returning to its start level. The forward drift averages to almost zero over a full cycle, confirming that energy moves while water remains near its place. The diameter of the circles decreases with depth, so deep particles hardly move, illustrating why surface waves fade with depth and why only the upper layer shows visible oscillations.

Q41. Explain why sound cannot travel through space.
Answer: Sound is a mechanical longitudinal vibration requiring a material medium—solid, liquid, or gas—to sustain alternating compressions and rarefactions. Outer space is a near-perfect vacuum with almost no particles to compress or rarefy, so there is nothing to propagate the pressure

variations. Without adjacent molecules to push on, the kinetic energy of any vibration dissipates locally instead of forming a travelling wave. Consequently astronauts need radios using electromagnetic waves, which do not need a medium, to communicate outside spacecraft.

Q42. What property of a sound wave changes when you increase the pitch?
Answer: Increasing the pitch of a sound raises its frequency: more oscillations occur per second, and the wavelength in a given medium shortens to keep v = f λ constant. The amplitude (loudness) and speed remain the same unless the medium or conditions change. Our ears interpret higher frequency as a higher musical note, so tuning a string tighter raises frequency and pitch while not necessarily making it louder.

Q43. What property of a sound wave changes when you increase the volume?
Answer: Louder sounds have greater amplitude, meaning larger pressure variations above and below the ambient level. Frequency (pitch) and speed are unchanged by turning up the volume: the waves still arrive at the same rate and move through the air at the same speed, but the peaks of pressure are higher and the troughs are deeper, carrying more energy per second through each square metre perpendicular to the direction of travel.

Q44. Why do waves slow down when entering a denser material, even though their frequency stays the same?
Answer: A denser material has more inertia because its particles are more massive, so for a given restoring force it takes longer for the disturbance to accelerate each particle, lengthening the reaction time and therefore reducing speed. The wave source keeps vibrating at the same rate, so frequency is fixed, but because speed v drops the wavelength λ must shrink proportionally, leading to closer-spaced wavefronts in the denser region while the timing of cycles remains unchanged.

Q45. In an experiment with ripples, how can you ensure your measurement of wavelength is accurate?
Answer: Use a strobe to freeze the pattern, choose a region where ripples are even, and lay a transparent ruler parallel to the wave travel. Measure across a span containing at least ten clear crests, then divide that total by the number of wavelengths to average out small errors in crest identification. Record the reading at eye level to avoid parallax and repeat with the ruler shifted to check consistency. Taking several averages and comparing reduces random error and yields a reliable λ.

Q46. How does the use of a strobe light help when measuring wavelength in a ripple tank?
Answer: A strobe flashing at or near the wave frequency makes successive crests appear stationary because each flash illuminates the crests at the same phase. This freezing effect stops the blurring caused by continuous illumination, letting you see crisp wavefronts and place measurement tools without the pattern shifting. Consequently you can mark crest positions accurately, improving precision in determining wavelength, amplitude, or any spatial parameter derived from the frozen snapshot.

Q47. Why is it better to use multiple wavelengths and divide by number of waves in ripple experiments?
Answer: Measuring over many wavelengths averages out small systematic errors such as uneven crest spacing from reflections or slight ruler misalignment. If you misplace one crest by a millimetre on a single-cycle measurement, the fractional error is large, but spread over ten wavelengths the same absolute error is only one-tenth as significant. Dividing the total distance by the number of waves yields a mean wavelength with lower percentage uncertainty, improving the robustness of later calculations like wave speed.

Q48. Explain how frequency is measured when using two microphones and a sound source.
Answer: Connect both microphones to a dual-trace oscilloscope or data logger and place them side by side near the sound source. The oscilloscope shows the pressure-time graph from each mic. Using cursors, measure the time between identical points on successive cycles—say peak to peak—on either trace. Alternatively count how many cycles occur during a known time span displayed on the horizontal axis. The reciprocal of the period gives frequency. Averaging several cycles improves accuracy because it reduces the influence of random timing jitter.

Q49. Describe what happens to wavelength and wave speed when a sound wave moves from air to a solid.
Answer: In solids the greater stiffness causes sound speed to increase significantly—from 330 m/s in air to about 5000 m/s in steel. The source frequency is unchanged, so wavelength stretches proportionally: λ = v/f becomes much larger in the solid. For example, a 1000 Hz tone has λ ≈ 0.33 m in air but ≈ 5 m in steel. The energy therefore travels faster and with longer spatial separation between compressions, illustrating how the medium's properties dictate both speed and wavelength while frequency stays the same.

Q50. Why is understanding wave properties important in communication technology?
Answer: Modern communications rely on precisely manipulating wave parameters. Frequency determines channel allocation and bandwidth; wavelength sets antenna sizes and propagation behaviours; amplitude and phase carry data via modulation schemes; speed affects latency and determines cable or optical fibre specifications. Knowing how waves refract, reflect, and attenuate across media informs the design of fibre-optic links, satellite dishes, and underwater acoustics. Accurate control of these properties enables high-speed, high-capacity, and reliable transfer of information that underpins global networks.

Q51. State the law of reflection and identify the two angles involved.
Answer: The law of reflection says that when a wave or light ray strikes a smooth boundary, the angle of incidence equals the angle of reflection, both angles being measured between the ray and the normal line drawn at right angles to the surface at the point of contact. The two angles are therefore the angle of incidence, symbol i, and the angle of reflection, symbol r. This rule holds for all reflecting surfaces, from mirrors to smooth water, regardless of the wave type, provided the boundary is smooth compared with the wavelength.

Q52. Describe how you would draw a ray diagram to show the reflection of light from a plane mirror.

Answer: Begin by drawing a straight horizontal line to represent the mirror surface and add a vertical dashed normal at the point where the incident ray meets the mirror. Using a protractor, mark the desired angle of incidence on one side of the normal and draw the incident ray coming from the top or bottom edge of the page toward the normal. Measure an equal angle on the opposite side of the normal and draw the reflected ray away from the surface. Label both angles with small arcs and the letters i and r, and indicate the normal with a right-angle marker where it meets the mirror, making clear that $i = r$.

Q53. Explain the difference between specular reflection and diffuse reflection with examples.

Answer: Specular reflection occurs on smooth, polished surfaces such as a bathroom mirror or calm lake, where incident parallel rays remain parallel after reflection, producing a clear image because the angle of incidence equals the angle of reflection for every ray. Diffuse reflection happens on rough, irregular surfaces like paper, fabric, or a painted wall; micro-facets reflect each incident ray at a slightly different orientation so outgoing rays scatter in many directions. Although energy is still reflected, the scattering scrambles image information, so you see colour or brightness but no distinct image, making it ideal for even illumination.

Q54. Why does a matte white wall appear bright even though it does not reflect rays specularly like a mirror?

Answer: A matte white wall contains microscopic bumps and pigment particles that scatter incoming light in all directions (diffuse reflection), ensuring light from a lamp or window is redistributed evenly into the room. White pigments reflect most visible wavelengths with minimal absorption, so very little light energy is lost as heat; instead, almost the full spectrum is returned, though now scattered. Our eyes receive reflected light from every part of the wall irrespective of viewing angle, making the surface look bright, but because the scattering scrambles directional information no mirror-like image appears.

Q55. Describe what happens to a ray of light when it meets a transparent material at an angle other than 90°.

Answer: On hitting a transparent boundary such as air-to-glass at an oblique angle, part of the light energy is reflected, obeying the law of reflection, while the remainder enters the new medium and bends toward or away from the normal in accordance with Snell's law $n_1 \sin i = n_2 \sin r$. The change in speed from one medium to the next causes this refraction. If the second medium has a higher refractive index (slower speed) the ray bends toward the normal; if lower, it bends away. The transmitted beam continues in the new direction unless absorbed or reflected at another boundary.

Q56. What is meant by transmission of a wave at a boundary, and how is it shown on a ray diagram?

Answer: Transmission occurs when a portion of the wave passes through the interface into the second medium rather than being reflected or absorbed. In a ray diagram, this is depicted by drawing an incident ray up to the boundary, then continuing the ray beyond the boundary at the refracted angle predicted by Snell's law. The transmitted ray is typically drawn lighter or with a different colour to distinguish it from the reflected ray, and arrows indicate the direction of energy flow. Labels such as incident, reflected, and refracted help identify each ray.

Q57. Give one everyday example where absorption of light is desirable and explain why.
Answer: Black solar-thermal panels deliberately absorb as much sunlight as possible to convert light energy into heat for water-heating systems. Their dark matt coatings contain pigments or micro-textures that minimise reflection and maximise absorption across the solar spectrum, trapping radiant energy and raising the panel's temperature. Efficient absorption improves performance by ensuring more solar power is captured rather than wasted as reflected glare, making the household heating system more effective and reducing reliance on conventional fuel sources.

Q58. Explain how the colour of an object relates to the absorption and reflection of different wavelengths of visible light.
Answer: An object's colour arises from selective absorption and reflection by its surface pigments or structure. When white light strikes it, certain wavelengths corresponding to particular colours are absorbed and converted to internal energy, while others are reflected or transmitted. A red apple absorbs most green and blue wavelengths but reflects red wavelengths into the observer's eye, so it appears red. A black shirt absorbs nearly all visible wavelengths, reflecting very little, hence looks dark and warms up in sunlight, whereas a white shirt reflects most wavelengths, remaining cooler and appearing bright.

Q59. Describe how total internal reflection occurs in an optical fibre and state the condition for it to happen.
Answer: In a fibre, light travels along a dense glass or plastic core surrounded by a lower-index cladding. When the internal incident angle at the core-cladding boundary exceeds the material's critical angle, calculated by $\sin c = n_2/n_1$, refraction cannot occur and all light is reflected back into the core. This total internal reflection traps the beam, allowing it to zig-zag down the fibre with minimal loss. For total internal reflection, the wave must travel from a higher to a lower refractive index medium, and the incident angle must be greater than the critical angle determined by their indices.

Q60. Explain why diamonds sparkle by referring to their high refractive index and multiple internal reflections.
Answer: Diamond has a refractive index around 2.4, meaning light entering slows sharply and bends strongly toward the normal, so internal rays strike the facets at angles well above the critical angle, creating total internal reflection. Careful cutting produces facet angles that maximise repeated internal reflections, keeping light trapped until it exits through the crown. Each exit undergoes dispersion, splitting white light into coloured flashes. The combination of strong refraction, dispersion, and multiple reflections causes intense brilliance and characteristic "fire," making diamonds sparkle dramatically.

Q61. A light ray enters glass from air at 40° to the normal. Describe how to find its angle in the glass using a protractor and graphite outline.
Answer: Place a rectangular glass block on plain paper, trace its outline, and draw the incident normal line. Using a protractor, mark a 40° incident ray toward the block. Shine a narrow light beam

along the ray and mark the emerging path inside the glass. Remove the block and use a pencil to connect entry and internal points. Draw the normal at the entry point, then measure with the protractor the angle between this normal and the internal ray; this value is the angle of refraction, letting you compare with values predicted by Snell's law for glass.

Q62. Explain why a red laser beam is still visible when shone through smoke but a green laser is more strongly absorbed.
Answer: Smoke particles contain organic carbon compounds and water droplets that scatter and absorb shorter wavelengths more efficiently due to Rayleigh and Mie scattering. Green light has a shorter wavelength than red, so it is scattered and absorbed more, losing intensity. Red laser light, with longer wavelength and lower scattering, travels farther through the smoke with less attenuation, remaining visible. Additionally, human eyes are more sensitive to green but if it is heavily attenuated the red beam's surviving intensity can appear brighter in smoky conditions.

Q63. Explain what is meant by the term "angle of refraction" and how it differs from the angle of incidence.
Answer: The angle of refraction is the angle between the refracted (transmitted) ray and the normal when a wave passes from one medium into another with different speed. The angle of incidence is the angle between the incident ray and the normal before the boundary. They differ because the change in speed causes bending according to Snell's law; if the second medium has higher index the refracted angle is smaller than the incident angle, and vice versa. The two angles are measured on opposite sides of the boundary along the same normal.

Q64. Describe how to set up the required practical to measure the critical angle of glass using a semicircular block.
Answer: Place a semicircular glass block flat-face down on graph paper and draw its outline. Use a ray box to send a narrow beam toward the curved face so refraction happens only at the flat face. Rotate the block or beam, measuring the incident angle at the flat face while observing the refracted ray's path through the block. Gradually increase the angle until the refracted ray disappears and is replaced by a faint, intense ray along the inside surface; at this point measure the incident angle—this is the critical angle. Repeat several times and average to improve accuracy.

Q65. How can you tell whether a surface is good at reflecting ultrasound in a medical scanner?
Answer: A highly reflective interface returns a strong echo producing a bright spot on the ultrasound image. In practice, bone surfaces and air pockets yield strong reflections because of the large acoustic impedance mismatch with surrounding tissue, whereas soft tissue boundaries reflect less. Technicians watch for intense, well-defined echo patterns and compare signal strength; high amplitude and sharp timing indicate efficient reflection, helping outline organ boundaries, while weak echoes suggest poorer reflecting surfaces.

Q66. State the normal range of human hearing and explain why very young children may hear slightly higher frequencies.
Answer: Typical human hearing spans from 20 Hz to about 20 kHz. Very young children and babies

can sometimes detect frequencies a little above 20 kHz because their ear structures, such as the flexible basilar membrane and sensitive hair cells, have not yet suffered age-related or noise-induced damage. Over time, repeated exposure to loud sounds and natural stiffening of ear components reduce the upper limit, meaning adults often hear only up to 16 kHz or lower.

Q67. Describe how sound waves make the ear drum vibrate and how these vibrations are converted into electrical signals in the auditory nerve.
Answer: Incoming longitudinal sound waves funnel through the ear canal, producing alternating compressions and rarefactions that apply varying pressure on the tympanic membrane (ear drum), causing it to vibrate at the same frequency. The malleus, incus, and stapes bones amplify and transmit these vibrations to the oval window of the cochlea, where pressure waves in cochlear fluid move the basilar membrane. Hair cells on this membrane shearing against the tectorial membrane open ion channels, generating electrical impulses that travel along the auditory nerve to the brain for interpretation as sound.

Q68. Explain why a tuning fork held against a metal rod can be heard on the far side even if the rod is long.
Answer: The vibrating prongs of the tuning fork set the rod into longitudinal vibration by compression waves travelling through the metal lattice at roughly 5000 m/s. Metal's low damping and high stiffness allow these waves to propagate with little energy loss over significant lengths. The far end then transfers the vibrations into the surrounding air, creating audible sound at the fork's frequency. Because metals conduct mechanical energy efficiently, the original tone is heard clearly despite distance.

Q69. Describe why the ability of the middle ear bones to vibrate decreases at very high frequencies.
Answer: At high frequencies the inertia of the ossicles and stiffness of the ligaments and muscles limit their ability to follow rapid oscillations; mass and rigidity act as a low-pass mechanical filter, attenuating vibration amplitude. Furthermore, the cochlear fluid's inertia resists rapid pressure changes through the oval window. These mechanical constraints reduce transmission efficiency of very high frequency sounds, contributing to the natural upper limit of human hearing.

Q70. Explain how a pregnant mother's scan uses ultrasound reflections to create an image of the fetus.
Answer: A transducer emits short ultrasound pulses into the mother's abdomen. Whenever pulses hit boundaries between tissues of different acoustic impedances—such as amniotic fluid and fetal skin—some energy reflects back while the rest transmits. The transducer, now acting as a receiver, detects returning echoes. A computer measures the time delay for each echo and, knowing the speed of sound in tissue, calculates distance to each interface, assembling a two-dimensional map of echo strengths that forms a grayscale image of the fetus and placenta in real time.

Q71. A pulse of ultrasound takes 0.00012 s to return from a kidney boundary and the speed of sound in tissue is 1540 m/s. Calculate the depth of the kidney.
Answer:

Solution: The pulse travels to the kidney and back, so time to the boundary is half the total: t = 0.00012 s ÷ 2 = 0.00006 s. Depth d = speed × time = 1540 m/s × 0.00006 s = 0.0924 m ≈ 9.24 cm. The kidney boundary is therefore about nine centimetres beneath the skin surface, consistent with typical anatomical positioning in an adult.

Q72. Explain why ultrasound is preferred to X-rays for scanning soft tissues.
Answer: Ultrasound is non-ionising, avoiding DNA damage associated with X-ray ionisation, making it safe for repeated prenatal and soft-tissue imaging. Soft tissues of similar density show little contrast in X-rays because absorption differences are small, whereas ultrasound exploits acoustic impedance differences, offering clear boundaries. Real-time imaging allows dynamic observation of movement such as blood flow or fetal activity. Equipment is portable and less expensive than X-ray CT, providing quick, versatile bedside diagnostics without radiation risks.

Q73. Describe two industrial uses of ultrasound that rely on partial reflection at material boundaries.
Answer: First, weld inspection in pipelines uses high frequency ultrasound pulses to detect flaws; internal cracks reflect echoes that reveal defect size and location. Second, thickness monitoring of metal tanks employs ultrasound through-transmission; partial reflections from the inner surface give a time delay proportional to wall thickness, allowing detection of corrosion without cutting the vessel. Both depend on the contrast in acoustic impedance between intact metal and void or corroded regions, producing measurable echoes.

Q74. Explain why very high frequency sound is chosen for echo sounding in deep oceans.
Answer: High frequency ultrasound yields shorter wavelengths, improving resolution so small objects like fish shoals or submarine contours are distinguishable. Although high frequencies attenuate faster, the ocean's relatively low absorption at chosen sonar frequencies (tens of kilohertz) balances range and clarity. Shorter pulses reduce overlap between successive echoes, essential for distinguishing features at great depths, while beam focusing is easier with high frequencies, producing narrow, well-defined search cones that pinpoint targets precisely.

Q75. Describe how a ship's sonar can measure the depth of water beneath its keel.
Answer: The vessel's sonar transducer emits a brief sound pulse downward. The pulse travels through water, reflects off the seabed, and returns to the transducer, which records the echo arrival time. The onboard computer multiplies half the round-trip time by the known speed of sound in seawater (about 1500 m/s) to calculate depth: depth = (v × time)/2. Continuous pulsing while the ship moves maps depth variations, aiding navigation and charting the seafloor beneath the vessel's path.

Q76. A sonar pulse returns 1.6 s after emission. If the speed of sound in seawater is 1500 m/s, calculate the water depth.
Answer: The depth is 1200 m.
Solution: The pulse travels from the ship to the seabed and back, so the one-way travel time is half the measured round-trip time. Time down = 1.6 s ÷ 2 = 0.8 s. Using distance = speed × time with speed v = 1500 m/s gives depth d = 1500 m/s × 0.8 s = 1200 m. Thus the seabed is 1.2 km beneath the sonar transducer.

Q77. State what P‑waves are and describe their main properties, including direction of particle vibration.

Answer: P‑waves, or primary waves, are longitudinal seismic waves generated by earthquakes. They cause particles in rocks to vibrate back and forth in the same direction that the wave energy travels, producing successive compressions and rarefactions. These waves can move through solids, liquids, and gases because their motion only requires particles to push and pull on neighbours. P‑waves are the fastest seismic waves, typically 6–8 km/s in the crust and faster in denser layers, so they are the first to reach distant seismometers. Their speed and travel path depend on the medium's density and elasticity, which is why changes in velocity provide clues to Earth's interior. P‑waves also refract gradually in layers of varying composition, bending toward regions where their velocity is slower, a behaviour that helps scientists map interior structures.

Q78. State what S‑waves are and explain why they do not travel through the Earth's outer core.

Answer: S‑waves, or secondary waves, are transverse seismic waves in which rock particles vibrate at right angles to the direction of energy propagation, making the ground move side‑to‑side or up‑and‑down. Because their motion involves shear deformation, S‑waves need a material that can support shear stress. Liquids cannot resist these sideways forces, so S‑waves cannot propagate through them. Seismological records show that beyond about 105° from an earthquake source no S‑waves arrive, indicating they are blocked by a large liquid layer. This S‑wave shadow zone provided one of the earliest proofs that Earth's outer core is liquid iron‑nickel alloy; S‑waves travel freely through the solid mantle but disappear when they reach the liquid outer core and do not reappear on the far side.

Q79. Describe how seismologists use the arrival times of P‑waves and S‑waves to locate earthquake epicentres.

Answer: Each seismic station records the precise arrival times of the faster P‑wave and the slower S‑wave. The time gap between them grows with distance because P‑waves outrun S‑waves at roughly 1.7 times the speed. Using travel‑time graphs calibrated from many earthquakes, seismologists convert the P–S interval at a station into a radial distance from the quake. They draw circles of these radii around at least three stations on a map. The point where the circles intersect is the epicentre. Modern networks fit many readings simultaneously to refine location in three dimensions, factoring in variations in crustal velocities. The method works because the velocity contrast between P‑waves and S‑waves is predictable for most crustal paths, letting the arrival‑time separation act as a distance "ruler."

Q80. Explain how the absence of S‑waves beyond a certain angle from an earthquake source led to the discovery of the liquid outer core.

Answer: Early global seismic networks showed that seismometers more than about 105° from large earthquakes never detect S‑waves, even though nearer stations do. If Earth were entirely solid, S‑waves should appear everywhere, albeit refracted. The simplest explanation is that S‑waves encounter a layer through which they cannot propagate—namely, a liquid outer core. P‑waves entering this layer slow and refract, producing a separate P‑wave shadow zone, but some convert to

S‑waves when they re‑enter solid mantle, partially filling higher‑angle gaps. This pattern of complete S‑wave loss and partial P‑wave bending could only be explained by a liquid shell around a solid inner region, a conclusion confirmed by later waveform modelling and laboratory studies of iron's melting curve under core pressures.

Q81. Describe how differences in P‑wave velocities helped scientists estimate the size of the Earth's core.
Answer: Precise measurements of P‑wave travel times reveal two distinct shadow zones and marked velocity jumps at certain depths. P‑waves traveling only through mantle layers arrive earlier than expected, while those that pass through a deeper region arrive later and follow curved paths. By modelling these travel‑time curves with spherical layering, scientists inferred a boundary where P‑wave velocity drops sharply—the core‑mantle boundary—about 2900 km below the surface. Further, a smaller velocity jump inside the core reveals a solid inner core radius of roughly 1220 km. Fitting thousands of observed seismograms with different hypothetical core sizes until predicted arrival times match real data allowed geophysicists to constrain the outer core thickness and inner core dimensions long before direct sampling was imaginable.

Q82. Explain why seismic waves bend as they travel through the mantle and core.
Answer: As seismic waves descend, temperature, pressure, mineral phase, and composition change, altering density and elasticity. Because wave speed generally increases with depth in the mantle but drops at the core‑mantle boundary, Snell's‑law‑like refraction bends waves gradually toward regions of lower speed. In the mantle, increasing speed with depth curves waves back upward, allowing them to return to the surface great distances away. At layer boundaries with abrupt velocity contrasts, waves refract sharply or reflect. This continuous and discontinuous bending makes seismic ray paths arc rather than go straight, producing shadow zones and complex arrival patterns that encode information about Earth's interior structure.

Q83. Describe how ground penetrating radar differs from seismic reflection when exploring subsurface features.
Answer: Ground penetrating radar (GPR) transmits high‑frequency electromagnetic pulses into the ground and records echoes from changes in electrical permittivity, useful for detecting buried pipes, voids, or archaeological artefacts to depths of a few metres. Seismic reflection sends mechanical vibrations into the earth and records echoes from density and elasticity contrasts, imaging deeper structures like sedimentary layers or oil traps up to several kilometres down. GPR offers centimetre‑scale resolution but limited depth in conductive soils, whereas seismic methods achieve greater depth penetration but coarser resolution and require heavy vibration sources. Because GPR waves move at lightlike speeds, time scales are nanoseconds; seismic waves travel thousands of times slower, needing millisecond timing.

Q84. Explain what is meant by absorption of seismic energy and why it makes deeper reflections weaker.
Answer: Absorption, or attenuation, is the conversion of a wave's mechanical energy into heat as it travels through imperfectly elastic rock. Friction at grain boundaries, fluid movement, and mineral anelasticity dissipate energy, reducing amplitude with distance. High‑frequency components are

absorbed more strongly, so deep reflections returning to the surface are weaker and lower-frequency, making them harder to detect. Energy loss is cumulative, so each additional kilometre travelled diminishes reflected signal amplitude, requiring more sensitive equipment or larger vibration sources to image deep layers.

Q85. Describe one safety precaution needed when performing the light reflection practical with a ray box.
Answer: Position the ray box so the bulb housing is stable on a heat-resistant mat and ensure students do not touch the hot lamp casing. Instruct them to switch off the power before moving lenses or mirrors, preventing burns and avoiding electric shock. Using low-voltage power supplies and insulating leads reduces hazard further. Properly controlling heat and electrical exposure is essential because the filament and metal case can reach high temperatures during extended use.

Q86. Explain why using black paper around a glass block improves the visibility of light rays in a refraction experiment.
Answer: Black paper absorbs stray ambient light and reflections from the workbench, enhancing contrast so the narrow white ray stands out. It also prevents bright backgrounds from washing out the faint internal rays visible through the glass. By reducing glare and scattered light, the pencil-thin beam path inside the block can be traced accurately, allowing precise angle measurements, especially when ambient classroom lighting would otherwise overwhelm low-intensity rays from the ray box.

Q87. A ray of light strikes a boundary at 60° to the normal in air and enters a medium with refractive index 1.5. Calculate the angle of refraction.
Answer: The angle of refraction is about 35.3°.
Solution: Snell's law: $n_1 \sin i = n_2 \sin r$. Let $n_1 = 1.00$ (air), $i = 60°$, $n_2 = 1.5$. So $\sin r = \sin 60° / 1.5 = 0.866 / 1.5 \approx 0.577$. Taking arcsin(0.577) gives $r \approx 35.3°$. The transmitted ray therefore bends toward the normal because the medium is optically denser.

Q88. Explain why sunglasses with polarising lenses reduce glare from reflecting surfaces like water.
Answer: Glare from horizontal surfaces is largely horizontally polarised because reflection favours vibrations parallel to the surface. Polarising lenses incorporate a chemical filter whose long-chain molecules absorb electric-field components in one orientation—set vertically—while transmitting those oriented perpendicular. When worn normally, they block horizontally polarised glare but allow vertically polarised light carrying scene information to pass, reducing brightness and eye strain without dimming all light equally. This selective absorption improves contrast and comfort for drivers, anglers, and skiers.

Q89. Describe how a periscope uses plane mirrors to allow viewing over an obstacle.
Answer: A simple periscope contains two parallel plane mirrors fixed at 45° to the tube's axis, one at the top facing forward and the other at the bottom facing the viewer. Light from the distant scene strikes the upper mirror, reflecting downward along the tube. It then strikes the lower mirror, reflecting forward into the viewer's eye. Because mirrors reflect rays without changing their relative orientation,

the image appears upright and laterally correct. Increasing mirror separation raises eye level, letting a user see above obstacles such as trenches or crowds.

Q90. Explain why a pencil appears bent when partly submerged in water.
Answer: Light rays from the submerged portion refract at the air–water boundary, bending away from the normal as they enter less dense air. The eye traces these refracted rays back in straight lines, so the submerged image appears offset from the real position, making the pencil seem discontinuous at the surface. The difference between apparent and actual depth depends on viewing angle and the refractive index difference; shallower angles cause greater lateral displacement, exaggerating the bend illusion.

Q91. State Snell's Law and describe how it is used to find the refractive index of a transparent material.
Answer: Snell's law is $n_1 \sin \theta_1 = n_2 \sin \theta_2$, where n is refractive index and θ is the angle to the normal. To measure an unknown index, shine a ray from a medium of known index (usually air, $n \approx 1.0$) into the material. Measure incidence angle θ_1 and refraction angle θ_2 with a protractor. Rearranging gives $n_2 = (n_1 \sin \theta_1)/\sin \theta_2$. Repeating for several angles and averaging reduces experimental error, yielding the material's refractive index, a key optical property for lens design and identification.

Q92. Explain how brushed metal surfaces reduce unwanted specular reflections in optical equipment.
Answer: Brushing creates microscopic grooves and irregularities that disrupt the continuity of the metal surface, converting formerly specular reflection into diffuse scattering. Incoming rays reflect off randomly oriented micro-facets, so any bright glint is broken into weak, scattered light that does not form disruptive highlights. Optical instruments use such finishes on internal parts to suppress stray reflections that could degrade image contrast or introduce artefacts, ensuring that only the desired light path reaches the detector or eyepiece.

Q93. Describe how a diffraction grating can separate white light into its component colours without absorption.
Answer: A diffraction grating has thousands of closely spaced parallel lines that act like multiple slits. When white light hits the grating, each wavelength interferes constructively at specific angles given by the grating equation $d \sin \theta = m \lambda$. Shorter wavelengths diffract less than longer ones, so colours spread out into spectra on either side of the central beam. Because the grating relies on interference rather than pigment absorption, little energy is lost; the light is redistributed into angularly separated monochromatic beams, enabling high-resolution spectroscopy.

Q94. Explain why radar waves are suitable for detecting aircraft but visible light is not.
Answer: Radar uses centimetre to metre-long microwaves that penetrate clouds, fog, and darkness with little attenuation, and reflect strongly from metal aircraft surfaces, producing detectable echoes independent of weather or daylight. Visible light is scattered and absorbed by clouds and is useless at night without illumination; its short wavelength also limits beam spread but requires precise pointing and clear line-of-sight. Radar's long range, all-weather capability, and time-of-flight measurement make it the primary tool for air traffic control and surveillance.

Q95. Describe how thermal imaging relies on absorption and emission of infrared waves rather than reflection.
Answer: Objects above absolute zero emit infrared radiation proportional to their temperature. Thermal cameras detect this emitted IR rather than reflected ambient light. Internal sensors convert varying IR intensities into false-colour images, revealing temperature differences even in darkness or smoke. Because emission dominates over reflection at these wavelengths, the image shows an object's own heat signature, making thermal imaging valuable for night-time search-and-rescue, fault detection in electrical equipment, and energy audits of building insulation.

Q96. Explain how bats use ultrasonic echoes to avoid obstacles and hunt prey.
Answer: Bats emit rapid ultrasonic clicks (20–120 kHz) and listen for returning echoes. Echo timing gives distance via t = 2d/v, while intensity and frequency shifts reveal size, texture, and relative velocity of targets such as insects. By sweeping pulse direction and analysing binaural time differences, bats build a 3-D acoustic map, allowing agile navigation in total darkness. Their auditory cortex processes echo patterns faster than visual systems, guiding quick steering and precise prey interceptions.

Q97. Describe one limitation of using ultrasound for detecting cracks in thick metal beams.
Answer: Ultrasound attenuation increases with distance and frequency, so in thick steel beams high-frequency waves needed to resolve small cracks lose energy rapidly, producing weak echoes. Grain structure scattering further degrades signal-to-noise ratio, making small flaws hard to distinguish. Operators must balance depth penetration against resolution, sometimes missing fine cracks deep inside large structural members or needing complex angle-beam probes and signal processing to compensate.

Q98. Explain why medical ultrasound gel is applied between the transducer and skin.
Answer: Air gaps reflect almost all ultrasound due to a huge acoustic impedance mismatch with tissue, preventing energy from entering the body. Gel fills microscopic gaps and matches impedance more closely to skin, providing a continuous coupling medium that allows efficient transmission and reception of ultrasonic pulses. The gel's viscosity keeps a stable layer during scanning, ensuring consistent contact, better image quality, and reduced artefacts.

Q99. Describe how an oscillating crystal in a piezoelectric transducer both generates and detects ultrasound.
Answer: When an alternating voltage is applied to a piezoelectric crystal, it expands and contracts, emitting ultrasonic vibrations at the drive frequency. When returning echoes strike the same crystal, mechanical strain generates charge separation, producing an electric voltage proportional to the echo amplitude. Switching circuitry alternates the crystal between transmit and receive modes, enabling a single element to send pulses and record their reflections for imaging or distance measurement.

Q100. Explain why understanding reflection, absorption, and transmission of waves is essential for designing energy-efficient buildings.
Answer: Efficient designs manage heat (infrared), light (visible), and sound waves to reduce energy use and enhance comfort. Low-emissivity coatings reflect internal IR, cutting heat loss; selective

glazing transmits daylight while absorbing or reflecting unwanted solar IR, lowering cooling loads. Acoustic panels absorb sound, improving indoor quality without adding mass. Wall layers with correct impedance prevent microwave or radio interference. By tailoring material interfaces to control wave behaviour, architects minimise heating, lighting, and acoustical power consumption, creating sustainable, comfortable environments that meet stringent energy standards.

Q101. What type of wave are electromagnetic waves and how do they transfer energy?
Answer: Electromagnetic waves are transverse waves. They transfer energy by oscillating electric and magnetic fields that move at right angles to the direction of the wave. These waves carry energy from the source, like the Sun or a light bulb, to an absorber, like your skin or a solar panel, without needing a medium. This means they can travel through the vacuum of space.

Q102. List the electromagnetic waves in order of increasing frequency.
Answer: The electromagnetic waves in order of increasing frequency are: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. As the frequency increases, the wavelength becomes shorter and the energy of the waves increases as well.

Q103. Which electromagnetic waves have the longest and shortest wavelengths?
Answer: Radio waves have the longest wavelengths in the electromagnetic spectrum, which can be longer than a football field. Gamma rays have the shortest wavelengths, often smaller than the diameter of an atom. The wavelength affects how each wave behaves and interacts with matter.

Q104. What do all electromagnetic waves have in common when travelling through a vacuum?
Answer: All electromagnetic waves travel at the same speed in a vacuum, which is approximately 3×10^8 metres per second (the speed of light). This constant speed allows them to move energy through empty space, such as from the Sun to the Earth, without needing any particles or medium.

Q105. Explain why radio waves can be used for communication over long distances.
Answer: Radio waves can travel long distances because they have low frequency and long wavelengths, which allows them to diffract around hills and buildings and reflect off the ionosphere. This means they can reach far beyond the horizon and be used for broadcasting, communication, and navigation signals.

Q106. Why are gamma rays suitable for sterilising medical equipment?
Answer: Gamma rays are highly energetic and can kill bacteria, viruses, and other microorganisms by damaging their DNA. Because of their strong penetrating power, they can reach all parts of the equipment, even through packaging. This makes them effective for sterilising tools without using heat or chemicals.

Q107. What is the difference between the way visible light and X-rays interact with the human body?
Answer: Visible light cannot pass through the body and is mostly absorbed or reflected by the skin. X-rays, on the other hand, have high energy and can pass through soft tissue but are absorbed by

dense materials like bones. This difference allows X-rays to produce images of the inside of the body, especially bones.

Q108. Explain how electromagnetic waves can transfer energy from a campfire to your skin.
Answer: A campfire emits infrared radiation, which is part of the electromagnetic spectrum. These waves travel through the air and are absorbed by your skin, where the energy is transferred as heat. You feel this as warmth even if you are not directly touching the flames because the energy moves by radiation.

Q109. Describe how infrared waves are used in everyday heating applications.
Answer: Infrared waves are used in heaters, toasters, and remote controls. In heaters, they transfer energy to objects and people directly, warming them without needing to heat the air first. Infrared is also used in thermal imaging to detect heat loss from buildings or to spot warm objects in darkness.

Q110. Give an example of how ultraviolet waves are used and one risk they carry.
Answer: Ultraviolet (UV) waves are used in sunbeds and to disinfect water by killing bacteria. However, they also carry risks because they can damage skin cells. Excessive exposure to UV rays from the Sun or artificial sources can cause sunburn, premature ageing of the skin, and increase the risk of skin cancer.

Q111. What is meant by the term 'ionising radiation'?
Answer: Ionising radiation refers to electromagnetic waves that have enough energy to remove tightly bound electrons from atoms, creating ions. This type of radiation includes ultraviolet, X-rays, and gamma rays. Ionising radiation can damage or kill cells and can cause mutations that lead to cancer.

Q112. Which electromagnetic waves are classified as ionising and why?
Answer: Ultraviolet (in part), X-rays, and gamma rays are classified as ionising radiation. This is because they have high frequencies and short wavelengths, giving them enough energy to ionise atoms and molecules in human tissue, which can lead to cell damage and increase the risk of cancer or genetic changes.

Q113. Why can X-rays be used to image bones inside the human body?
Answer: X-rays have high energy and can pass through soft tissue but are absorbed by dense materials like bone. When X-rays pass through the body, they create shadows or images based on what they are absorbed by. Bones absorb more X-rays than flesh, so they appear white on an X-ray image, allowing doctors to see them.

Q114. Describe how microwaves are used to cook food.
Answer: Microwaves are absorbed by water molecules in food. As the water molecules absorb this energy, they start to vibrate rapidly, generating heat. This heat then spreads through the food, cooking it from the inside out. Microwave ovens are designed to contain and direct these waves to heat food efficiently.

Q115. What is the danger of excessive exposure to ultraviolet radiation?
Answer: Too much exposure to ultraviolet radiation can damage skin cells. It can cause sunburn, speed up skin ageing, and increase the risk of skin cancer. UV radiation can also harm the eyes, leading to cataracts. This is why protective clothing and sunscreen are important when spending time in strong sunlight.

Q116. State one use of infrared radiation in medicine.
Answer: Infrared radiation is used in medicine for physical therapy and to monitor blood flow. Infrared lamps can help relieve muscle pain by increasing blood circulation and relaxing tissues. Thermal imaging cameras are also used to detect inflamed areas or poor blood flow by measuring temperature differences on the skin.

Q117. What is the difference between absorption and reflection of electromagnetic waves?
Answer: Absorption occurs when a material takes in the energy of a wave, often converting it into heat. Reflection happens when a wave bounces off a surface without being absorbed. For example, a black object absorbs most light and gets hot, while a mirror reflects light, allowing you to see your reflection.

Q118. How do electromagnetic waves cause alternating currents in radio receivers?
Answer: When radio waves are absorbed by an antenna, the changing electric and magnetic fields cause electrons in the metal to move. This movement of electrons creates an alternating current in the circuit that matches the frequency of the incoming radio wave. The signal can then be decoded into sound or data.

Q119. Explain how oscillations in electrical circuits produce radio waves.
Answer: In a radio transmitter, electrical circuits are made to oscillate at a certain frequency. These oscillations generate changing electric and magnetic fields, which spread out as radio waves. The frequency of the wave depends on the frequency of the circuit's oscillation, allowing specific signals to be sent.

Q120. What happens when radio waves are absorbed by a conductor?
Answer: When radio waves are absorbed by a conductor, the energy of the wave makes the electrons in the conductor vibrate. This produces an alternating current with the same frequency as the wave. This is how signals are picked up by aerials and antennas in devices like radios and televisions.

Q121. Explain how energy from the Sun reaches the Earth through space.
Answer: The energy from the Sun reaches Earth as electromagnetic radiation, mostly visible light, ultraviolet, and infrared. Since space is a vacuum, there are no particles to carry the heat by conduction or convection. Radiation is the only way energy can travel through space, carried by electromagnetic waves.

Q122. Why can't humans see ultraviolet or infrared light?
Answer: The human eye can only detect electromagnetic waves within the visible light spectrum,

from about 400 to 700 nanometres in wavelength. Ultraviolet has shorter wavelengths and infrared has longer wavelengths than visible light, so they fall outside the sensitivity range of the retina and are invisible to us.

Q123. What determines the amount of energy carried by an electromagnetic wave?
Answer: The energy of an electromagnetic wave depends on its frequency. The higher the frequency, the more energy the wave carries. Gamma rays, which have very high frequencies, carry much more energy than radio waves, which have low frequencies. This is why gamma rays can damage cells while radio waves cannot.

Q124. What visible light colour has the highest frequency and what does this mean for its energy?
Answer: Violet light has the highest frequency of all visible light colours. Because energy is directly proportional to frequency, violet light also has the most energy in the visible spectrum. This means it can affect materials more strongly than red light, which has the lowest frequency and lowest energy.

Q125. Why does light bend when it enters a different medium at an angle?
Answer: Light bends, or refracts, when it enters a new medium at an angle because its speed changes. In a denser medium, light slows down, causing the wave to change direction. This happens because one side of the wavefront enters the new medium first, making the wave turn or bend at the boundary.

Q126. Describe how to draw a ray diagram showing refraction through a glass block.
Answer: To draw a ray diagram for refraction through a glass block, start by drawing a rectangular block and mark the normal lines at both entry and exit surfaces. Draw an incident ray hitting the block at an angle to the normal. Inside the block, draw the refracted ray bending towards the normal. At the far side of the block, draw the ray exiting and bending away from the normal. Label all angles and rays clearly.

Q127. What causes refraction in terms of wavefronts?
Answer: Refraction happens when wavefronts change speed as they enter a different medium. If the wave hits the boundary at an angle, part of the wavefront slows down before the rest, causing the wavefront to bend. This bending is what we see as refraction. The change in direction is due to the change in speed, and it happens because the wave moves faster or slower depending on the medium's density.

Q128. What is the effect of wavelength on the refraction of electromagnetic waves?
Answer: The amount of refraction depends on the wavelength of the electromagnetic wave. Shorter wavelengths (like violet light) bend more than longer wavelengths (like red light) when passing through a medium. This is why white light can spread into a spectrum when it goes through a prism — each colour bends by a different amount due to its wavelength.

Q129. Describe how the velocity of light changes when moving from air to water.
Answer: When light travels from air into water, it slows down because water is denser than air. This

decrease in speed causes the light to bend towards the normal line in a ray diagram. The change in velocity depends on the optical density of the material — the greater the density, the more the light slows down.

Q130. How does the nature of a surface affect how much infrared radiation it emits?
Answer: The amount of infrared radiation emitted by a surface depends on its colour and texture. Dark, matte surfaces emit more infrared radiation than light or shiny surfaces. Shiny surfaces reflect infrared radiation and emit less. This is because good emitters are also good absorbers, and rough, dark surfaces absorb and emit heat more efficiently.

Q131. What practical method could you use to compare the emission of infrared radiation from different surfaces?
Answer: A practical method involves heating identical metal containers painted with different surfaces (black, white, shiny, matte) to the same temperature. Then use an infrared sensor or a thermometer to measure the temperature drop or the infrared radiation emitted. The surface that cools fastest or gives the strongest infrared reading emits the most radiation.

Q132. Explain how surface colour and texture influence the absorption of infrared radiation.
Answer: Dark and rough surfaces absorb more infrared radiation because they trap more heat and reflect less. Light-coloured or shiny surfaces reflect more radiation and absorb less. That's why black surfaces heat up more in sunlight. The texture also matters — rough surfaces increase the surface area, improving absorption.

Q133. Why are shiny surfaces used in thermal blankets?
Answer: Shiny surfaces are used in thermal blankets because they reflect infrared radiation back toward the body. This reduces heat loss by radiation, keeping the person warm. The reflective surface prevents body heat from escaping into the environment, making the blanket effective in conserving warmth in emergencies.

Q134. What is radiation dose and how is it measured?
Answer: Radiation dose is a measure of the potential harm caused by exposure to ionising radiation. It takes into account the type of radiation and the amount absorbed by body tissues. It is measured by how much energy is deposited per kilogram of tissue, giving a sense of risk and potential biological effect.

Q135. Which unit is used to measure radiation dose and what does it represent?
Answer: Radiation dose is measured in sieverts (Sv). One sievert represents the biological effect of a dose of radiation on human tissue. Since a full sievert is a large amount, doses are often given in millisieverts (mSv), which are one-thousandth of a sievert. The unit reflects the risk of long-term health effects, like cancer.

Q136. What health risks are associated with prolonged exposure to X-rays?
Answer: Prolonged exposure to X-rays increases the risk of cell damage, which may lead to cancer. X-rays are ionising radiation, so they can damage or mutate DNA in cells. Over time, repeated

exposure — even at low levels — can accumulate and increase the chance of developing serious health conditions.

Q137. How can exposure to gamma rays affect living cells?
Answer: Gamma rays have high energy and can penetrate deeply into tissues, damaging internal organs and DNA. This can kill cells or cause mutations that may result in cancer. High doses can lead to radiation sickness, while lower doses over time can increase the risk of long-term health issues like tumours or genetic defects.

Q138. Why must workers using ionising radiation wear protective shielding?
Answer: Workers wear protective shielding to reduce their exposure to harmful radiation. Materials like lead or thick concrete can block or absorb ionising radiation, protecting body tissues from damage. Shielding is essential because even small doses over time can build up and cause serious health problems.

Q139. Explain the risk of genetic mutation from high doses of ionising radiation.
Answer: High doses of ionising radiation can damage the DNA in cells, including reproductive cells. This can cause genetic mutations, which may lead to inherited conditions or developmental problems in future generations. It can also increase the risk of cancer if the mutation affects cell growth or repair processes.

Q140. How does the frequency of a wave affect the type of electromagnetic wave?
Answer: The frequency of a wave determines its place on the electromagnetic spectrum. Low-frequency waves like radio and microwaves have low energy, while high-frequency waves like X-rays and gamma rays carry more energy and can be ionising. As frequency increases, wavelength decreases and the wave becomes more penetrating and hazardous.

Q141. Why do ultraviolet rays cause more damage to skin than visible light?
Answer: Ultraviolet rays have higher frequency and more energy than visible light, making them more capable of damaging cells. They can penetrate the outer layers of the skin and damage DNA, leading to sunburn, premature ageing, or skin cancer. Visible light has less energy and generally does not cause such damage.

Q142. Why is lead often used in X-ray rooms?
Answer: Lead is dense and effective at absorbing X-rays, preventing them from passing through and reaching other areas. X-ray rooms are often lined with lead or have lead shields to protect patients and workers from unnecessary exposure, reducing the risk of health effects from ionising radiation.

Q143. What changes in atoms or nuclei can produce electromagnetic waves?
Answer: When electrons change energy levels in atoms, they can emit or absorb electromagnetic waves. Similarly, changes in the nucleus — such as radioactive decay — can produce gamma rays. These processes release energy in the form of electromagnetic radiation, depending on the type and size of the energy change.

Q144. Describe how gamma rays are generated during radioactive decay.
Answer: Gamma rays are produced when an unstable nucleus releases excess energy after radioactive decay. The nucleus does not change its structure, but it emits a high-energy photon (gamma ray) to become more stable. This usually happens after alpha or beta decay as the final step in the process.

Q145. How do the properties of electromagnetic waves make them suitable for satellite communication?
Answer: Electromagnetic waves like microwaves can pass through the Earth's atmosphere with little interference, allowing them to travel between ground stations and satellites. Their high speed, ability to carry large amounts of data, and low energy loss over long distances make them ideal for global communication.

Q146. Why is visible light used in fibre optic cables instead of microwaves?
Answer: Visible light is used in fibre optic cables because it can be totally internally reflected within the cable, allowing data to be transmitted with minimal loss. Microwaves are not easily reflected in the same way and are better for wireless transmission. Visible light also supports higher bandwidth for data.

Q147. What makes gamma rays useful for treating cancer?
Answer: Gamma rays are highly penetrating and can target and destroy cancer cells deep inside the body. They damage the DNA of the cancerous cells, stopping them from dividing. By focusing the radiation precisely, doctors can treat tumours while minimising harm to surrounding healthy tissue.

Q148. Why must exposure time be limited when using ultraviolet lamps for disinfection?
Answer: Ultraviolet lamps can damage skin and eyes if people are exposed for too long. Limiting exposure time helps reduce health risks like burns or long-term cell damage. The UV rays are strong enough to kill microbes, but also harmful to humans, so proper shielding and timing are important for safety.

Q149. How does wavelength affect the penetration ability of electromagnetic waves?
Answer: Generally, shorter wavelengths have more energy and can penetrate materials better. Gamma rays, with short wavelengths, can pass through most substances, including body tissue. Longer wavelengths like radio waves have lower energy and cannot penetrate dense materials easily. Wavelength affects how the wave interacts with matter.

Q150. Describe how X-rays interact differently with soft tissue and bone.
Answer: X-rays pass through soft tissue easily but are absorbed by dense materials like bone. This difference in absorption creates a contrast on X-ray images — bones appear white, while soft tissues show up in varying shades of grey. This allows doctors to examine bones and some organs clearly.

Q151. Why are radio waves used for broadcasting television and radio signals?
Answer:

Radio waves are used for broadcasting because they can travel long distances and are easily reflected by the atmosphere. They have long wavelengths which means they can diffract around obstacles like hills and buildings. This helps them reach radios and televisions even when the signal does not have a direct path.

Q152. Explain why microwaves are suitable for satellite communication.

Answer:

Microwaves are used for satellite communication because they can pass easily through the Earth's atmosphere. They have a short enough wavelength to carry large amounts of data, and they are not easily absorbed by air or water vapour, making them reliable over long distances between satellites and ground stations.

Q153. How do microwaves cook food efficiently?

Answer:

Microwaves cook food by penetrating the outer layers and causing water molecules inside the food to vibrate rapidly. This vibration produces heat, which cooks the food from the inside out. This method is quicker and more efficient than traditional ovens which heat food from the outside.

Q154. Why is infrared radiation useful for cooking and heating?

Answer:

Infrared radiation is useful because it transfers energy as heat. When it is absorbed by objects or food, it increases their temperature. Infrared heaters and grills use this property to warm rooms or cook surfaces quickly without needing to heat the air around them first.

Q155. How do infrared cameras work to detect people or animals?

Answer:

Infrared cameras detect infrared radiation (heat) emitted by objects. People and animals are warmer than their surroundings, so they emit more infrared radiation. The camera senses this and creates an image showing different temperatures, helping detect living beings in darkness or through smoke.

Q156. Why is visible light used in fibre optic communications?

Answer:

Visible light is used in fibre optics because it travels well through the thin glass fibres by total internal reflection. It carries signals quickly over long distances with very little loss. The light bounces along the fibre without escaping, making it ideal for fast internet and phone networks.

Q157. Explain why ultraviolet light is used in energy-efficient lamps.

Answer:

Ultraviolet light in these lamps excites a special coating (phosphor) on the inside of the lamp. This coating then emits visible light. These lamps use less electricity and give off less heat, making them more energy-efficient than traditional bulbs that produce light by heating a wire filament.

Q158. Why can ultraviolet light cause skin tanning?

Answer:

Ultraviolet (UV) light causes skin tanning because it triggers the skin cells to produce more melanin, a pigment that darkens the skin to protect against UV damage. The UV light penetrates the upper layers of skin and starts chemical changes in skin cells, leading to tanning.

Q159. How are X-rays used to produce images of bones?
Answer:
X-rays pass through soft tissues but are absorbed by dense materials like bones. When X-rays pass through the body onto a detector or photographic film, bones appear white because they stop the rays. This contrast creates a clear image of the bones' structure inside the body.

Q160. Why are gamma rays useful in medical treatment such as cancer therapy?
Answer:
Gamma rays can kill living cells and are highly penetrating. In cancer treatment, focused gamma rays are used to target and destroy cancer cells without cutting into the body. Because they are ionising, they damage the DNA of cancer cells, stopping them from dividing and growing.

Q161. What are the advantages of using electromagnetic waves in communication?
Answer:
Electromagnetic waves travel at the speed of light, can carry large amounts of data, and can be transmitted without wires. They can travel long distances, reflect off surfaces, or pass through materials depending on their wavelength, making them suitable for TV, radio, internet, and mobile phones.

Q162. Why are long-wavelength radio waves good for transmitting signals over long distances?
Answer:
Long-wavelength radio waves can diffract around hills and buildings and reflect off the Earth's atmosphere. This allows them to travel great distances, even beyond the horizon. This property makes them ideal for global communication and broadcasting over wide areas.

Q163. How do satellites use microwaves to send signals to Earth?
Answer:
Satellites send signals using microwaves because they can pass through the atmosphere with little interference. The satellite sends the microwave signal to Earth, which is picked up by a dish. These waves carry TV, internet, or phone data quickly and efficiently from space to receivers.

Q164. Why is it important to limit exposure to X-rays during medical imaging?
Answer:
X-rays are ionising radiation, which means they can damage cells and DNA in the body. Repeated or high exposure increases the risk of cancer. Limiting exposure protects patients and medical staff from harm while still allowing useful diagnostic images to be taken when needed.

Q165. What makes infrared radiation safer than ultraviolet radiation for heating?
Answer:
Infrared radiation is non-ionising and only causes heating of the surface it touches. It does not

damage cells or DNA like ultraviolet radiation, which can cause sunburn and increase cancer risk. This makes infrared a safer option for heaters and heat lamps in everyday use.

Q166. Explain how ultraviolet radiation is used to disinfect water.

Answer:

Ultraviolet radiation kills bacteria and viruses in water by damaging their DNA. UV lamps are placed inside water purification systems. When water flows past the UV light, the microorganisms are exposed and destroyed, making the water safer to drink without the need for chemicals.

Q167. Why must gamma radiation be precisely targeted during cancer treatment?

Answer:

Gamma rays are powerful and can kill both cancer and healthy cells. To avoid damaging healthy tissue, doctors aim the radiation carefully at the tumour using imaging scans. This focused approach destroys cancer cells while protecting the rest of the body from unnecessary radiation.

Q168. How does the wavelength of visible light affect its transmission in optical fibres?

Answer:

Shorter wavelengths of visible light can reflect better within the optical fibre, reducing loss of signal. However, different wavelengths may travel at slightly different speeds, causing dispersion. Fibre optic systems use certain wavelengths like red or infrared to balance speed and clarity.

Q169. Describe how microwave ovens heat food from the inside out.

Answer:

Microwaves penetrate food and are absorbed by water molecules. These molecules start to vibrate, producing heat throughout the food. This heats the food more evenly from inside, rather than relying on conduction from the outside as in traditional ovens, which can be slower and less even.

Q170. How does the frequency of infrared radiation relate to the heat it transfers?

Answer:

Higher frequency infrared radiation carries more energy and can transfer more heat to a surface. When it is absorbed by an object, it increases the kinetic energy of the molecules, raising the temperature. So, the higher the frequency, the more heating effect the radiation has.

Q171. What is a convex lens and how does it change light rays?

Answer:

A convex lens is a lens that bulges outward. It causes parallel rays of light to bend inward and meet at a point called the principal focus. This type of lens is used in magnifying glasses and cameras to focus light and create real or virtual images depending on object distance.

Q172. What is meant by the focal length of a convex lens?

Answer:

The focal length of a convex lens is the distance between the centre of the lens and the principal focus, where parallel rays of light meet after passing through the lens. It depends on the shape and material of the lens and determines how strongly the lens converges light.

Q173. Describe how a convex lens forms a real image using a ray diagram.
Answer:
To show a real image with a convex lens, draw three rays: one parallel to the principal axis (refracted through the focus), one through the centre of the lens (passes straight), and one through the focus (refracted parallel). Where these rays meet on the opposite side is the real image.

Q174. When does a convex lens produce a virtual image?
Answer:
A convex lens forms a virtual image when the object is placed closer to the lens than the focal point. The rays appear to diverge, but if extended backward, they seem to come from a point behind the lens. This type of image is upright, magnified, and cannot be projected on a screen.

Q175. What is a concave lens and how does it affect light rays?
Answer:
A concave lens curves inward and causes parallel rays of light to spread out or diverge. The rays appear to come from a point called the principal focus, which is on the same side of the lens as the incoming rays. Concave lenses always produce virtual, smaller, upright images.

Q176. Why does a concave lens always form a virtual image?
Answer: A concave lens diverges incoming parallel light rays so that they spread apart after passing through the lens. Because the outgoing rays never actually meet, they cannot form a real image on a screen. Instead, the human eye or a drawn ray diagram must extend these diverging rays backward on the incident side of the lens. The backward extensions appear to originate from a single point called the principal focus. That point, from which the rays seem to emerge, lies between the lens and the object. Since the rays do not physically converge there, the resulting image is virtual—upright, smaller than the object, and only perceived by looking through the lens rather than captured on a surface. This geometric reality holds for every object position, so concave lenses always create virtual images.

Q177. How can ray diagrams help compare convex and concave lenses?
Answer: Ray diagrams provide a clear, visual way to trace how light behaves with each lens type, revealing differences in image formation. For a convex lens, drawn rays show convergence to a real focus on the far side for distant objects, demonstrating how real or virtual images depend on object distance. For a concave lens, rays diverge, and backward extensions meet at a virtual focus on the object side, proving the image is always virtual and diminished. By using the same object height and lens scale on graph paper, students can compare how the principal rays bend, where images appear, and how magnification varies. This graphical approach clarifies abstract focal-length definitions, distinguishes real versus virtual outcomes, and reinforces that convex lenses can magnify or invert images while concave lenses only minify and keep them upright. Thus ray diagrams are indispensable teaching and design tools for lens comparisons.

Q178. Describe how to draw a ray diagram for a convex lens showing a real image.
Answer: Place a straight horizontal line for the principal axis. Draw a symmetrical double-arrow shape for the convex lens centered on the axis. Mark the focal points F on both sides at one focal

length. Draw an upright object arrow above the axis beyond 2F on the object side. Sketch three principal rays: (1) a ray parallel to the axis from the top of the object, refracted through the far focal point; (2) a ray through the near focal point to the lens, refracted parallel to the axis; (3) a ray through the optical center that continues undeviated. On the far side the refracted rays intersect below the axis at a point between F and 2F. From that intersection, draw a downward image arrow to the axis. Label it inverted and smaller—this represents a real image that could be projected on a screen. Measure object and image heights or distances to determine magnification later.

Q179. Describe how to draw a ray diagram for a concave lens.
Answer: Draw a straight principal axis and the concave lens symbol (two inward curves). Mark focal points on both sides. Sketch an upright object arrow above the axis on the left of the lens. From the top of the object draw: (1) a ray parallel to the axis toward the lens; after refraction it diverges as if coming from the near focal point—draw the backward extension through that focus. (2) A ray heading toward the far focal point; on reaching the lens it emerges parallel to the axis. (3) A central ray through the optical center, which passes straight. The refracted rays diverge on the far side, but their backward extensions intersect above the axis on the object's side. Mark that intersection and draw an upright, reduced arrow from the axis to the intersection: this is the virtual image. Label it virtual, upright, smaller, and on the same side as the object.

Q180. What happens to the size of the image when an object is moved closer to a convex lens?
Answer: As an object approaches a convex lens from beyond twice the focal length toward the lens, the image grows larger because the convergence point where rays meet moves farther from the lens. At exactly twice the focal length the image equals the object's size. Between 2F and F the image becomes magnified and moves further away, becoming real and inverted but larger. If the object is moved inside the focal length, the rays cannot converge to form a real image; instead they diverge, and a virtual, upright magnified image appears on the same side as the object. Thus moving closer first increases real-image size and eventually switches to a virtual magnified image once inside one focal length. This property is exploited in magnifying glasses and cameras to control image scale by adjusting object distance.

Q181. What are the three key rays used to draw a ray diagram for a convex lens?
Answer: The three construction rays are: (1) the parallel ray—starting from the top of the object parallel to the principal axis, refracting through the far focal point after the lens; (2) the focal ray—drawn from the top of the object through the near focal point to the lens, refracting out parallel to the principal axis; (3) the central ray—drawn straight from the top of the object through the optical center, continuing undeviated. These three rays suffice because they intersect at the image position, establishing size and orientation quickly without tracing every light path.

Q182. What is meant by a virtual image?
Answer: A virtual image is an apparent image formed when light rays diverge after interacting with an optical device, so they never physically meet. An observer sees the image by extending the diverging rays backward; the brain interprets them as coming from a point behind or in front of the device. Virtual images cannot be projected onto a screen because no real light converges there. They

are typically upright relative to the object and can be larger (as in magnifying glasses) or smaller (as with concave lens spectacles). Mirrors and lenses both produce virtual images under certain conditions.

Q183. What is meant by a real image?
Answer: A real image forms when refracted or reflected rays of light actually converge at a point. Because the rays meet physically, the image can be captured on a screen or photographic sensor placed at that location. Real images are usually inverted relative to the object. Convex lenses produce real images when the object is beyond one focal length, and concave mirrors do similarly. Projectors, cameras, and the human eye rely on real images to reproduce scenes on film, sensors, or retinas. The ability to project real images distinguishes them fundamentally from virtual images.

Q184. Describe a method for investigating the magnification produced by a convex lens.
Answer: Mount a convex lens on a holder and place a lit object—such as an arrow card—on a metre rule track. Position a white screen on the other side of the lens. Move lens or screen until a sharp inverted real image appears on the screen. Measure object distance u, image distance v, object height h_o, and image height h_i. Repeat for several object distances beyond 2F, near 2F, between F and 2F, and just inside F (where image becomes virtual and measured with a ruler through the lens). Record results and calculate magnification m = h_i/h_o each time. Plot graph of m versus v or u, compare with theoretical lens formula 1/f = 1/u + 1/v, and discuss how magnification changes with distance.

Q185. What equipment is needed to investigate magnification using a convex lens?
Answer: Essential equipment includes a convex lens with known focal length mounted in a holder, a bright object (illuminated arrow or lit filament lamp with scale), a metre rule or optical bench for precise distances, a movable white screen to capture images, a ruler or vernier calipers for measuring object and image heights, and a power supply and lamp to keep illumination constant. Optional items are lens clamps, protractor for alignment, blackout cloth to improve image contrast, and graph paper for recording results.

Q186. How is magnification calculated in a lens experiment?
Answer: Magnification m is the ratio of the image height to the object height, m = h_i / h_o. Both heights must be measured in the same units. Alternatively, when a real image is involved, m can also be determined by the ratio of image distance to object distance, m = v / u, provided the lens formula is satisfied. The height method is direct and works for both real and virtual images, whereas the distance method relies on precise placement but confirms consistency with theory.

Q187. What unit is used for magnification and why?
Answer: Magnification has no unit because it is a ratio of two like quantities—either two lengths or two distances—so the units cancel. Reporting magnification as a pure number (e.g., 2× or 0.5×) conveys how many times larger or smaller the image is compared with the object without introducing unnecessary units.

Q188. If the object height is 3 cm and the image height is 6 cm, what is the magnification?
Answer:
Solution: Using m = h_i / h_o = 6 cm / 3 cm = 2. The magnification is 2, meaning the image is twice as tall as the object. Because the sign is not specified, the image is likely inverted if formed by a convex lens beyond F, but the numerical value of magnification remains 2.

Q189. What does a magnification value greater than 1 mean?
Answer: A magnification greater than 1 indicates the image is larger than the object. In lenses, a convex lens produces such magnification when the object distance is between one and two focal lengths (real inverted image) or less than one focal length (virtual upright image). High magnification is useful for microscopes, magnifiers, and telescope eyepieces where detail enlargement is required.

Q190. What does a magnification value less than 1 mean?
Answer: A magnification less than 1 means the image is smaller than the object. Convex lenses yield reduced real images when the object is beyond twice the focal length. Concave lenses always produce magnifications less than 1 since they minify and diverge rays. This property is used in peephole viewers and correcting short-sightedness where downsized images are needed.

Q191. How does the position of the object affect the magnification in a convex lens?
Answer: As the object moves from far beyond 2F toward the lens, magnification increases steadily. Beyond 2F the image is real, inverted, and smaller (m<1). At 2F it matches object size (m=1). Between 2F and F the image becomes larger and further away (m>1). Inside F the image turns virtual, upright, and greatly magnified (m>>1). Thus object distance controls whether the image is reduced, life-size, magnified real, or magnified virtual.

Q192. How does the shape of the lens affect the focal length?
Answer: Lens curvature and refractive index determine focal length. A lens with more pronounced curvature (steeper surfaces) bends light more strongly, reducing focal length. A flatter lens bends light less and has a longer focal length. Material with higher refractive index also shortens focal length for the same curvature. Designers adjust thickness and curvature to create lenses with required focussing power for cameras, eyeglasses, or projectors.

Q193. What are the uses of convex lenses in everyday life?
Answer: Convex lenses appear in magnifying glasses, camera lenses, spectacles for farsightedness, microscopes, telescopes, projectors, and smartphone cameras. They focus parallel rays to form images on sensors or screens, enlarge tiny objects for study, correct vision by converging rays on the retina, and collect distant starlight. Their ability to create real or magnified virtual images underlies much of modern optics technology.

Q194. What are the uses of concave lenses in real-world applications?
Answer: Concave lenses are used in glasses for nearsightedness to diverge incoming light and extend focal distance onto the retina. They are components in beam expanders and laser cavities, help correct aberrations in multi-lens systems, create upright reduced images for peepholes, and

serve in flashlights to spread light. They are also paired with convex lenses in telescopes to fine-tune magnification and image clarity.

Q195. Why are ray diagrams important in understanding how lenses work?
Answer: Ray diagrams visually trace the path of key rays through lenses, revealing image position, size, and orientation without complex math. They help students predict real versus virtual outcomes, understand focal length significance, and diagnose optical instrument behaviour. Engineers and designers use ray diagrams during preliminary design to ensure lenses meet imaging requirements before detailed modelling.

Q196. Explain how a magnifying glass works using a convex lens.
Answer: When an object is placed within one focal length of a convex lens, outgoing rays diverge so the eye receives them as if they came from a larger upright image on the same side of the lens. The brain traces the rays back, seeing an enlarged virtual image. The lens's curvature concentrates light, increasing apparent angular size, letting the observer examine small details closely without the object touching the eye.

Q197. Why does a concave lens make objects appear smaller?
Answer: A concave lens diverges rays, so the eye sees them spreading as if from a reduced upright image nearer the lens than the object. The brain perceives this virtual image that subtends a smaller angle than the object would without the lens, making it appear smaller. This minification is useful for wide-angle viewers and correcting myopia by moving the focal point backward onto the retina.

Q198. Describe how to measure focal length of a convex lens in a practical.
Answer: Place the lens in sunlight and adjust its distance from a screen until a sharp image of the distant sun appears. Measure the lens-to-screen distance; this equals the focal length because incoming sunlight is effectively parallel. Alternatively, use an illuminated object and measure object distance u and image distance v for several positions, then apply $1/f = 1/u + 1/v$ and average calculated f values for accuracy.

Q199. What precautions should be taken when using a lamp to illuminate objects in a lens experiment?
Answer: Use a low-voltage lamp to reduce burn risk, ensure the housing is stable, and avoid touching hot parts. Keep flammable materials away, secure cables to prevent tripping, and switch off the lamp when adjusting apparatus. Work in a dim room to see images clearly but avoid complete darkness for safety. Provide heat-resistant mats under hot equipment and allow cooling before storage.

Q200. Why must image and object height be measured in the same units when calculating magnification?
Answer: Magnification is a ratio of image height to object height. If heights are measured in different units, the ratio would include a conversion factor, giving an incorrect value. Using consistent units cancels them, yielding a pure number that accurately reflects how many times larger or smaller the image is compared with the object, facilitating comparison across experiments.

Q201. What does each colour in the visible spectrum represent in terms of wavelength and frequency?

Answer: Each colour in the visible spectrum corresponds to a different range of wavelengths and frequencies. Red light has the longest wavelength and lowest frequency, while violet light has the shortest wavelength and highest frequency. This means red light carries less energy compared to violet light. Colours change gradually from red through orange, yellow, green, blue, indigo, to violet.

Q202. Explain how the wavelength of visible light affects its colour.

Answer: The colour we see depends on the wavelength of the light. Longer wavelengths are seen as red and orange, while shorter wavelengths appear as blue or violet. The human eye detects these differences and interprets them as different colours. Light with a single wavelength appears as a pure colour; white light contains all visible wavelengths.

Q203. Describe what happens when white light hits a red apple.

Answer: When white light shines on a red apple, the apple absorbs most of the wavelengths of light except for red. The red wavelengths are reflected off the surface of the apple and into our eyes, which is why we see it as red. The absorbed wavelengths do not contribute to the colour we see.

Q204. Why does a black object appear black under white light?

Answer: A black object appears black because it absorbs all the wavelengths of visible light and reflects none of them back to the eyes. Since no light is reflected, the object looks black to us. This is also why black objects heat up faster under sunlight—they absorb more light energy.

Q205. Why does a white object appear white under white light?

Answer: A white object reflects all the wavelengths of visible light equally. Since no particular wavelength is absorbed more than others, all the colours are reflected, and they mix together to appear white to our eyes. This equal reflection gives the white object its colour.

Q206. How does the surface texture of an object affect the type of reflection that occurs?

Answer: A smooth surface causes specular reflection, where light rays are reflected in a single, clear direction, creating sharp reflections like in a mirror. A rough surface causes diffuse reflection, where light rays scatter in many directions. This means you can still see the object but not a clear image reflected on it.

Q207. What is the difference between specular and diffuse reflection in terms of how light behaves?

Answer: In specular reflection, light rays bounce off a smooth surface in the same direction, allowing you to see a clear reflection or image. In diffuse reflection, light rays bounce off an uneven surface in many different directions, so no clear image is formed. This makes most objects visible to us.

Q208. How does a red filter affect white light passing through it?

Answer: A red filter absorbs all the wavelengths of visible light except red. Only the red wavelengths are transmitted through the filter, so the light that passes through appears red. The rest of the colours are absorbed by the filter and do not pass through.

Q209. What colour does a blue object appear under red light and why?
Answer: A blue object appears black or very dark under red light. This is because the blue object reflects only blue light and absorbs other colours. Since red light does not contain any blue, there is no light for the object to reflect, so it appears black.

Q210. Why do green leaves appear black when viewed through a red filter?
Answer: Green leaves reflect green light and absorb other wavelengths. A red filter only lets red light through and absorbs all others, including green. Since no green light reaches the leaves, and the leaves cannot reflect red, they appear black when viewed through a red filter.

Q211. Explain how colour filters are used in stage lighting to create effects.
Answer: Colour filters in stage lighting absorb all wavelengths except the colour of the filter. For example, a blue filter lets only blue light through. By using different coloured filters on different lights, lighting designers can create moods, highlight costumes, or simulate time of day on stage.

Q212. Describe what happens when red light shines on a white shirt.
Answer: A white shirt reflects all wavelengths of visible light. When red light shines on it, the shirt reflects the red light and appears red. Since no other colours are present in the light, red is the only colour reflected, so the shirt appears the same colour as the light.

Q213. What determines the apparent colour of an opaque object?
Answer: The apparent colour of an opaque object depends on which wavelengths of light it reflects. It appears the colour of the light it reflects most strongly. Wavelengths that are not reflected are absorbed by the object, and do not contribute to the colour we see.

Q214. How do transparent materials affect the transmission of light?
Answer: Transparent materials allow most of the light to pass through them with little scattering. This means you can see clearly through them. However, the light may still slow down or bend slightly as it passes through, which is how lenses and glasses work.

Q215. What is the difference between a translucent and a transparent object?
Answer: A transparent object allows light to pass through clearly, so you can see through it. A translucent object also allows light through but scatters it, so objects on the other side appear blurry or fuzzy. Frosted glass is an example of a translucent object.

Q216. How does a blue filter affect the appearance of a green object?
Answer: A blue filter only allows blue light to pass through and absorbs all other colours. A green object reflects green light. Since the green object receives only blue light, and cannot reflect it, it appears black or very dark when viewed through a blue filter.

Q217. Why does a red object appear dark or black under green light?
Answer: A red object reflects red light and absorbs other colours. Green light contains no red, so when only green light shines on the object, there is no red light to reflect. Therefore, the object absorbs the green light and appears black or very dark.

Q218. How can coloured filters be used in photography?
Answer: Coloured filters in photography change the lighting or highlight certain colours in a scene. They can be used to correct colour balance, add artistic effects, or emphasise certain parts of an image. For example, a red filter can enhance contrast in black and white photography.

Q219. What causes a red shirt to look red in sunlight?
Answer: Sunlight is white light and contains all the colours of the visible spectrum. A red shirt absorbs most wavelengths and reflects red. The reflected red light reaches our eyes, so we see the shirt as red. This only works in white light that includes red wavelengths.

Q220. Explain why some objects look different colours under different lighting conditions.
Answer: The colour of an object depends on the light it reflects. If the lighting lacks certain colours, the object cannot reflect them and may appear a different colour. For example, under red light, a green object appears black because there is no green light to reflect.

Q221. Why does a mirror show clear reflections while a piece of paper does not?
Answer: A mirror has a very smooth surface that causes specular reflection, where light rays reflect in a single direction, forming a clear image. Paper has a rough surface, causing diffuse reflection. The light is scattered in many directions, so no clear image is formed.

Q222. How does diffuse reflection help us see most everyday objects?
Answer: Most everyday objects have rough surfaces that scatter light in all directions through diffuse reflection. This scattering allows the reflected light to reach our eyes from many angles, making the object visible even if we are not directly in line with the light source.

Q223. What happens to light that is not reflected by an opaque object?
Answer: Light that is not reflected by an opaque object is absorbed by it. The absorbed light energy is usually converted into thermal energy, causing the object to warm up. This is why dark objects, which absorb more light, often feel warmer under sunlight.

Q224. Why do we see shadows when objects block light?
Answer: Shadows form when an opaque object blocks light from a source. Since light travels in straight lines and cannot pass through the object, an area behind the object receives no light. This dark area is a shadow, and its shape matches the outline of the object.

Q225. How can you use coloured filters to identify the primary colours present in white light?
Answer: By passing white light through different coloured filters one at a time, you can see which colours are present. A red filter only allows red light to pass, so if light is seen, red is present. If no light passes through a certain filter, that colour is missing from the source light. This helps identify the components of white light.

Q226. What happens to the amount of infrared radiation emitted as the temperature of a body increases?
Answer: The amount of infrared radiation emitted rises rapidly as the body gets hotter because each surface particle has more internal energy. Greater kinetic energy makes charged particles oscillate

faster, producing electromagnetic waves with higher intensity. The total emitted power is linked to temperature by the Stefan–Boltzmann law, showing a proportionality to the fourth power of absolute temperature, so even a small temperature rise causes a large jump in emitted infrared energy.

Q227. Why does a hotter object emit more radiation in a given time than a cooler one?
Answer: A hotter object's molecules vibrate and collide more vigorously, causing electric charges to accelerate more and release stronger electromagnetic waves. Higher temperature shifts the emission spectrum toward shorter wavelengths and greatly boosts total intensity. This combination means, for every second that passes, a hot body sends out far more photons and at higher average energies than a cooler body, so its radiative power output is significantly larger.

Q228. What is meant by a perfect black body in terms of radiation absorption?
Answer: A perfect black body is an idealised object that absorbs all incident electromagnetic radiation, regardless of wavelength, direction, or polarisation. It reflects or transmits none, so its absorptivity is 1. Because it captures every photon that strikes it, no light escapes, making it appear perfectly black at low temperature. Real materials approach but never reach this ideal; the black body model is invaluable for understanding emission spectra and thermal radiation laws.

Q229. Why is a perfect black body also the best possible emitter of radiation?
Answer: Absorptivity and emissivity are equal for any surface at a given wavelength (Kirchhoff's law of thermal radiation). Since a perfect black body absorbs all wavelengths completely (absorptivity 1), its emissivity is also 1, meaning it is the most efficient possible radiator at every wavelength. Therefore, for a fixed temperature, no real surface can out-radiate a perfect black body; it is the theoretical upper limit for thermal emission.

Q230. How does the surface temperature of an object affect the intensity of the infrared radiation it emits?
Answer: As surface temperature rises, the emitted intensity increases steeply because radiative power is proportional to temperature to the fourth power. Additionally, the peak wavelength of emission shifts to shorter values, packing more energy into higher-frequency infrared bands. A small rise in temperature therefore yields a large gain in total radiant flux and a noticeable change in spectral distribution, making hot objects glow more brightly and, eventually, visibly.

Q231. Why do dark, matt surfaces emit and absorb radiation better than shiny, white surfaces?
Answer: Dark, matt surfaces have microscopic roughness and pigments that trap incoming photons instead of reflecting them, converting more of the light to internal energy; their high absorptivity translates to high emissivity, so they radiate energy efficiently. Shiny, white surfaces reflect a large fraction of incident radiation due to smoothness and lack of pigment absorption, leading to low absorptivity and correspondingly poor emission, which keeps them cooler under the same irradiation.

Q232. How is infrared radiation transferred from the Sun to Earth?
Answer: Infrared radiation, like all electromagnetic waves, travels through the vacuum of space by oscillating electric and magnetic fields that require no medium. The Sun's surface emits a broad spectrum that includes infrared; these photons propagate at the speed of light across 150 million

kilometres, reaching Earth's atmosphere and surface, where they are partly absorbed, warming land, sea, and air without needing any material conduit.

Q233. What happens when an object absorbs more radiation than it emits?
Answer: When absorption exceeds emission, net energy flows into the object, increasing its internal energy. As a result, its temperature rises. The higher temperature then boosts its own radiation output until equilibrium is restored, or until external conditions change. This is why objects placed in strong sunlight warm up: they gain energy faster from the Sun than they can lose by radiating until they become hot enough to re-balance energy flow.

Q234. What happens to the temperature of an object that emits more radiation than it absorbs?
Answer: If an object loses energy faster through radiation than it gains from its surroundings, its internal energy decreases, causing its temperature to fall. As it cools, its radiative power diminishes (following the T^4 relationship), eventually reaching a new steady temperature where emission balances the reduced absorption from the cooler environment, halting further temperature drop unless conditions change again.

Q235. What is meant by a body being in thermal equilibrium with its surroundings?
Answer: Thermal equilibrium occurs when a body absorbs radiation and other energy from its environment at exactly the same rate as it emits radiation and other forms of energy. There is no net energy gain or loss, so its temperature remains constant over time. In this balanced state, the body's temperature matches the effective temperature set by its environment and its own emissive characteristics.

Q236. Why does a hot cup of tea cool down when left on a table?
Answer: The tea's surface is hotter than its surroundings, so it radiates infrared energy, conducts heat to the cup and air, and loses energy by evaporation. Because emission exceeds absorption from the cooler room, its internal energy drops, lowering temperature. Cooling continues until the tea and cup reach thermal equilibrium with the ambient air, where emission, conduction, and evaporation losses equal any minor energy gains from the environment.

Q237. How can you investigate which surface is the best emitter of infrared radiation?
Answer: Coat identical metal cans with different finishes—matt black, gloss black, white, and shiny metal. Fill each with the same volume of hot water at equal temperature, then measure and record the water temperature drop every minute with a thermometer or data logger. The can whose water cools fastest is the best emitter, showing its surface radiated heat away most effectively, confirming how surface colour and texture affect emission.

Q238. Describe a simple experiment to compare radiation emission from different surfaces.
Answer: Use Leslie's cube, a metal box with four differently finished vertical faces: matt black, matt white, shiny metal, and dull metal. Fill the cube with boiling water and allow it to stabilise. Hold an infrared sensor or thermopile at a fixed distance from each face in turn. Record the radiation intensity

reading for each surface. The face giving the highest reading is emitting the most infrared, demonstrating how surface finish alters emissive power.

Q239. Why does a car parked in the sun feel hotter inside than outside?
Answer: Sunlight enters through car windows, which transmit visible and some infrared radiation. Seats and dashboard absorb it, warming up and re-emitting infrared with longer wavelengths that glass does not transmit efficiently, trapping heat inside (greenhouse effect). The enclosed air gains energy faster than it can escape by convection or radiation, so interior temperature rises above outdoor levels.

Q240. Why do pavements feel hot during summer afternoons?
Answer: Pavement materials are dark and have high absorptivity, so they soak up solar radiation all day, converting it to heat. Their high thermal mass stores energy, and because they emit less than they absorb during peak sunlight, their surface temperature climbs. Touching the pavement allows direct conduction of this stored heat to the skin, making it feel hot.

Q241. What factors affect the temperature of the Earth's surface?
Answer: Earth's surface temperature depends on incoming solar radiation intensity, angle of incidence, albedo (fraction reflected), atmospheric composition (greenhouse gases, aerosols), cloud cover, surface properties (water, ice, vegetation), and rates of energy emission as infrared. Heat redistribution by winds, ocean currents, and latent heat of water also modifies local temperatures by moving energy horizontally and vertically.

Q242. Why does the Earth's temperature remain fairly stable over time?
Answer: Earth maintains approximate energy balance: average incoming solar energy absorbed equals average outgoing infrared radiation emitted. Feedback mechanisms regulate this balance—higher temperatures boost emission and cloud formation, while lower temperatures reduce emissions and allow greenhouse gases to trap more heat. Though fluctuations occur, these feedbacks generally keep long-term global temperature within a narrow range suitable for life.

Q243. How does the Earth's atmosphere affect the balance between incoming and outgoing radiation?
Answer: The atmosphere lets most visible sunlight reach the surface but absorbs and scatters some. It strongly absorbs infrared emitted by the surface through greenhouse gases like CO_2 and water vapour, re-radiating part back downward, warming the surface. This greenhouse effect reduces the net outgoing radiation, raising surface temperature compared with a planet with no atmosphere.

Q244. What role do clouds play in the Earth's radiation balance?
Answer: Clouds reflect a significant portion of incoming sunlight back to space, increasing Earth's albedo and cooling the surface. They also absorb and emit infrared, trapping heat like greenhouse gases. Low thick clouds mainly cool by reflection, whereas high thin clouds mainly warm by trapping infrared. The overall effect depends on cloud type, altitude, and coverage.

Q245. Why does the temperature drop quickly at night in a desert?
Answer: Desert skies are usually clear and dry, so little water vapour or cloud cover exists to trap outgoing infrared radiation. After sunset, the hot sand emits energy rapidly into space, losing heat faster than it gains from the cool air, leading to steep temperature drops. Lack of vegetation and moisture means minimal heat retention or transfer from subsurface layers, intensifying cooling.

Q246. How does radiation from the Sun contribute to the Earth's weather systems?
Answer: Uneven solar heating due to latitude, season, and surface type creates temperature gradients that drive atmospheric circulation. Warm air rises in the tropics, cools, and sinks at higher latitudes, forming convection cells. Differential heating also powers sea breezes, monsoons, and storms. Radiation absorbed by oceans fuels evaporation, releasing latent heat when water condenses into clouds, further energising weather.

Q247. How does reflection of solar radiation affect the temperature of the Earth?
Answer: Higher reflectivity (albedo) means more solar energy is bounced back into space, reducing absorbed energy and lowering surface temperatures. Ice, snow, and clouds increase albedo, producing cooling. Conversely, dark forests and oceans have low albedo, absorbing more energy and warming local climates. Changes in land cover or ice extent thus alter Earth's radiation balance and global temperature.

Q248. What happens to incoming solar radiation that is not absorbed by the Earth's surface?
Answer: Unabsorbed solar radiation is either reflected back to space by clouds, atmospheric particles, or bright surfaces, or absorbed by atmospheric gases and re-emitted as infrared in various directions. Reflection does not warm the planet, while atmospheric absorption warms the air but may be radiated away later, participating in complex energy exchanges before eventually escaping to space.

Q249. How do greenhouse gases affect the Earth's radiation balance?
Answer: Greenhouse gases absorb specific wavelengths of infrared radiation emitted by Earth's surface, preventing that energy from escaping directly to space. They re-emit the absorbed energy, roughly half downward, keeping heat in the lower atmosphere and raising surface temperatures. Increased greenhouse gas concentrations strengthen this effect, shifting the radiation balance so Earth must warm until higher emission compensates.

Q250. Why does the Moon have greater temperature extremes than Earth?
Answer: The Moon lacks atmosphere and water, so it has no greenhouse effect, clouds, or air to distribute heat. During lunar day, its surface absorbs intense solar radiation and becomes very hot; at night, with no atmospheric insulation, it radiates energy directly into space and cools rapidly to extremely low temperatures. Earth's atmosphere and oceans moderate such extremes through heat absorption, retention, and redistribution.

Q251. How can satellite data be used to study Earth's radiation balance?
Answer: Weather and climate satellites carry radiometers that measure the intensity of incoming solar radiation reflected from clouds, ice, and land as well as the outgoing infrared radiation emitted

by the planet. By scanning the entire globe many times each day these instruments build maps of short-wave albedo and long-wave emission. Scientists combine the data with surface observations to calculate how much energy Earth gains from sunshine and loses as heat, producing a global radiation budget. Trends in the net balance reveal how volcanic aerosols, greenhouse gases, or cloud changes alter climate. Continuous satellite monitoring is essential for detecting small imbalances—amounting to fractions of a watt per square metre—that drive long-term warming or cooling.

Q252. What effect does surface colour have on the absorption of solar radiation?
Answer: Dark surfaces such as black asphalt possess low albedo, meaning they reflect little sunlight and absorb most of the incoming energy, quickly becoming hot under sunshine. Light-coloured materials such as fresh snow or white paint have high albedo, reflecting a large proportion of visible and near-infrared wavelengths and absorbing far less energy, so they remain comparatively cool. The difference arises because pigments and molecular structures within dark materials convert a broad spectrum of radiation into internal vibrational energy, while bright surfaces scatter photons outward. Urban design, crop selection, and climate models all account for colour-controlled absorption because it strongly influences surface temperature and the local heat island effect.

Q253. Why do white buildings stay cooler in hot climates?
Answer: White buildings reflect most of the Sun’s visible and near-infrared radiation, preventing substantial heating of the walls and roof. The high reflectivity (often above 0.7) limits the proportion of solar energy converted to internal heat, so less warmth is conducted indoors. Consequently interior temperatures remain lower, reducing the need for air conditioning. The reflective coating also radiates heat efficiently at night, allowing stored warmth to escape. For centuries Mediterranean and desert communities have taken advantage of this passive cooling technique, painting exteriors with limewash or other light pigments to maintain comfortable indoor conditions despite intense solar exposure and minimal mechanical cooling technology.

Q254. What is the relationship between the wavelength of radiation emitted and the temperature of the object?
Answer: According to Wien’s displacement law, the wavelength at which a body emits radiation most strongly is inversely proportional to its absolute temperature: $\lambda\_max = b/T$, where b is 2.9×10^{-3} m K. As temperature rises, the peak shifts to shorter wavelengths, so a warm stove emits mainly far-infrared, a red-hot element glows in the visible red, and the sun’s photosphere peaks in the green visible band. This shift reflects the greater average energy of photons from hotter surfaces. The law underpins thermal imaging, incandescent lamp design, and stellar classification by linking colour to surface temperature in a predictable, quantitative way.

Q255. How does increasing temperature affect the peak wavelength of radiation emitted by a body?
Answer: When an object’s temperature increases the distribution of emitted radiation moves toward shorter wavelengths, so the peak wavelength decreases. For example, heating metal from 100 °C to 1000 °C shifts maximum emission from about 8 μm in the mid-infrared to near 2 μm, approaching visible red. This is a direct consequence of Wien’s law: doubling absolute temperature halves λ_max. Simultaneously the total power emitted rises steeply due to the Stefan–Boltzmann law. The combined

effect means hotter bodies not only radiate more energy overall but also emit photons of higher average frequency, changing colour from dull red to bright white as the continuum sweeps into the visible range.

Q256. How does the radiation curve for a hot object differ from that of a cooler object?
Answer: A radiation curve—intensity versus wavelength—broadens and elevates for a hotter object: its area under the curve (total power) grows as T^4 and its peak slides left to shorter wavelengths. A cooler object's curve peaks in the far-infrared with low intensity, while a much hotter curve may extend into visible or ultraviolet regions. The hot curve's higher tail indicates significant emission of short-wave photons, giving incandescent glow, whereas the cool curve's emission is practically invisible to the eye. Thus comparing curves reveals both the temperature and colour characteristics as well as quantitative heat output differences.

Q257. Why are radiators in homes often painted white?
Answer: Despite emitting thermal infrared regardless of colour, white paint on radiators serves practical purposes: it resists discoloration at high temperature, hides dust, and matches interior décor. In rooms radiation is only part of heat transfer; convection dominates as warm air is circulated. Colour has minimal impact on convective heat, so painting radiators dark would not noticeably improve heating efficiency. White coatings provide corrosion protection and aesthetics without compromising performance, and their reflectivity prevents excessive surface cooling through noticeable visible re-radiation that could otherwise waste some thermal energy.

Q258. What materials are best for thermal insulation and why?
Answer: Effective insulators are materials with low thermal conductivity and structures that trap air, a poor heat conductor. Examples include mineral wool, expanded polystyrene, polyurethane foam, and cellulose fibre. These materials use a matrix of fine fibres or closed cells to hinder both conduction and convection within the trapped gas. Additionally reflective foils or coatings can be added to reduce radiant heat transfer by reflecting infrared. Combining low conductivity with radiant barriers gives the best overall insulation performance, keeping buildings warm in winter and cool in summer while saving energy costs.

Q259. How do thermal imaging cameras detect heat from objects?
Answer: Thermal cameras use microbolometer arrays or quantum detectors sensitive to mid- to long-wave infrared photons (typically 8–14 μm). When these photons strike the sensor elements, they raise their temperature or excite electrons, changing electrical resistance or generating charge. The camera electronics convert these tiny changes into pixel intensities, producing a false-colour image where brighter colours represent hotter surfaces. Because every object above absolute zero emits infrared, the camera can show temperature variations in darkness or through light smoke, assisting in search-and-rescue, electrical fault diagnosis, and energy-loss surveys.

Q260. What is the link between the energy of emitted radiation and its frequency?
Answer: Photon energy is directly proportional to frequency via Planck's relation $E = h f$, where h is Planck's constant. Higher-frequency (shorter-wavelength) radiation such as ultraviolet or X-rays carries more energy per photon than lower-frequency infrared or radio waves. Therefore as a body

gets hotter and emits higher-frequency photons, the energy content of each photon increases, contributing to the stronger heating effect and greater potential for ionisation at extreme frequencies.

Q261. Why do astronauts wear reflective suits in space?
Answer: In space, astronauts face intense solar radiation without atmospheric filtering and icy cold shadows where heat radiates away unhindered. Reflective outer layers coated with aluminised Mylar bounce a large proportion of incident sunlight, preventing dangerous overheating, while underlying insulation minimises radiant heat loss. The suit's design balances reflection of external radiation with emission of metabolic heat, ensuring the astronaut's body stays near normal temperature despite the extreme and rapidly changing thermal environment of orbital space.

Q262. Why does a hot object eventually stop getting hotter when left in a cooler room?
Answer: Initially the hot object loses heat to its environment via radiation, convection, and conduction faster than it gains from incoming radiation. Its temperature falls, which reduces emitted power according to the T^4 law and slows convection due to smaller temperature differences. Cooling continues until the object reaches the same temperature as the room air, at which point heat transfer rates in and out balance. Without a net energy flow, the object's temperature stabilises; it cannot cool below room temperature unless additional processes like evaporation remove extra energy.

Q263. What role does radiation play in keeping a greenhouse warm?
Answer: Sunlight passes through the greenhouse glass, warming plants and soil, which then emit longer-wavelength infrared. Glass and plastic glazing transmit visible light but absorb or reflect much of this infrared, trapping heat inside. The warm interior air rises but is confined by the roof, so convection losses are limited. Radiation retention combined with restricted air movement creates a micro-climate hotter than the outside, allowing cultivation of heat-loving crops and early-season growth in cooler regions.

Q264. How does the balance of radiation affect the Earth's climate?
Answer: Earth's climate depends on the equilibrium between absorbed solar energy and emitted infrared. If greenhouse gases rise or albedo falls, absorbed energy exceeds emitted energy, producing a net gain and global warming. Conversely, more reflection by aerosols or ice, or reduced greenhouse trapping, yields a net loss and cooling. Small persistent imbalances modify ocean heat content and atmospheric temperatures over decades, driving climate change. Understanding and monitoring this balance is vital for predicting future temperature trends and guiding mitigation policies.

Q265. What is meant by net radiation gain or loss?
Answer: Net radiation is the difference between all incoming energy (mainly short-wave solar plus atmospheric back-radiation) and all outgoing energy (surface-emitted long-wave infrared plus reflected sunlight). A positive net value indicates the surface or planet is gaining energy and will warm until new balance is reached; a negative value means energy loss and cooling. Meteorologists track daily and seasonal net radiation to model temperature changes at local, regional, and global scales.

Q266. Why is it important to understand radiation in designing buildings?
Answer: Accurate knowledge of radiation helps architects control solar gains, heat losses, and

occupant comfort. Proper orientation, shading, reflective roofing, and low-emissivity glazing reduce cooling loads in hot climates, while high-absorptivity surfaces and strategically placed windows enhance passive solar heating in cold regions. Selecting materials with suitable emissivity and albedo minimises energy consumption for heating and cooling, cutting costs and carbon footprint while meeting building performance regulations.

Q267. How does a vacuum flask reduce energy loss by radiation?
Answer: A vacuum flask has double walls separated by a near-vacuum, eliminating conduction and convection. The inner surfaces are silvered, giving low emissivity, so very little radiative heat passes between the hot liquid and the cooler outer wall. The silvering both reflects infrared back into the liquid and limits outward emission, maintaining temperature for hours. A tight stopper further prevents convective currents, making the flask highly effective at retaining heat or cold.

Q268. Why do metallic surfaces reduce heat loss better than non-metallic ones?
Answer: Polished metals have low emissivity because free electrons reflect incident electromagnetic waves efficiently, so they emit and absorb little infrared radiation. Covering a hot object with a metallic layer reduces radiative losses, keeping it warmer. Conversely, non-metallic matt surfaces with high emissivity radiate energy readily. While metal conducts heat well internally, if it forms only the outer skin it reflects most outgoing radiation, cutting overall heat loss.

Q269. How does wearing light-coloured clothing help in hot weather?
Answer: Light fabrics reflect a larger share of visible and near-infrared solar radiation, reducing the energy absorbed by the cloth and underlying skin. Lower heat gain keeps body temperature down, lessening sweating and discomfort. Additionally, many light garments are made of loose, breathable weaves that enhance convective cooling, but reflectivity is the primary radiative advantage in sunny environments.

Q270. Why does a hot air balloon rise in terms of infrared radiation and heat transfer?
Answer: Heating the balloon's air with burners raises its temperature, decreasing its density relative to surrounding cooler air. While infrared radiation from the hot interior fabric contributes to energy loss, the dominant effect is convective: warm air expands and exerts greater upward buoyant force than its weight. The burners offset radiative and convective cooling, maintaining lift. As long as the internal air remains warmer (and thus less dense) than outside air, the balloon rises.

Q271. What does it mean if an object is a poor emitter of radiation?
Answer: A poor emitter has low emissivity and therefore radiates little thermal energy at a given temperature. Typically shiny, metallic, or highly reflective surfaces fall into this category. Because emission and absorption are linked, such objects also absorb radiation poorly. In practical terms, a poor emitter loses internal heat slowly by radiation, making it useful for thermal insulation when placed as a reflective outer layer.

Q272. What kind of radiation is mainly responsible for heating the Earth?
Answer: Short-wave solar radiation in the visible and near-infrared bands is the chief driver of Earth's heating. These wavelengths penetrate the atmosphere with relatively little absorption,

delivering energy to the surface. The ground and oceans absorb this sunlight, then warm and re-emit energy as long-wave infrared. Greenhouse gases partly trap this reradiated heat, but the original heating comes from absorbed sunlight.

Q273. What everyday examples show the balance between absorption and emission of radiation?

Answer: A tarmac road baking under the sun heats up by absorbing more radiation than it emits; at night it cools as emission exceeds absorption. A person wearing a black T-shirt feels hotter under sunlight than in the shade where emission balances body heat production. A shiny vacuum flask stays warm inside because low emissivity walls emit little radiation, balancing minimal absorption to keep contents hot. These cases illustrate how the temperature of objects changes with the net difference between incoming and outgoing radiation.

Q274. What effect does angle of sunlight have on radiation absorption?

Answer: When sunlight strikes a surface at a low angle, its energy spreads over a larger area, lowering energy per square metre and increasing reflection, reducing absorbed heat. At steep midday angles sunlight is concentrated, providing maximum energy and warming the surface more. This geometric effect explains hotter summers at mid-latitudes and cooler dawn and evening temperatures compared with midday, and why solar panels are angled toward the Sun to maximise absorption.

Q275. Why does standing in the shade feel cooler on a sunny day?

Answer: Shade blocks direct solar radiation, preventing strong short-wave energy from being absorbed by skin and clothing. In the shade only diffuse sky radiation and reflected sunlight reach you, carrying much less energy. Without the direct radiant load, your body loses heat more effectively through sweat evaporation and convection, so skin temperature drops and you feel cooler despite ambient air temperature being the same as in sunlight.