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IGCSE PHYSICS 0625 · TOPICAL PAST PAPERS

General Wave Properties — Paper 2

Worked Solutions (Theory / Structured)

Fahad H. Ahmad

Contact: +92 323 509 4443

M.Eng NUS Singapore · B.Eng NUST · 15+ years of teaching experience in Singapore, UAE & Pakistan · 60,000+ subscribers and 20 million+ video lecture views.

General Wave Properties — Paper 2 · Worked Solutions

Megalecture worked solutions — model answers with working; please verify before classroom use. These structured-paper answers were solved from first principles by the Megalecture team using the data given in each question (wave equation $v = f\lambda$, period $T = 1/f$, and the rules of reflection, refraction and diffraction). Bold green values are the final answers with units. Question numbers follow the compilation; the exam reference is shown on the right of each question heading.

Question 1

5054/02/M/J/08 Q10

(a)(i) Transverse vs longitudinal. In a **transverse** wave the particles vibrate perpendicular (at 90°) to the direction in which the energy/wave travels (e.g. water, light). In a **longitudinal** wave the particles vibrate parallel to (along) the direction of travel (e.g. sound).
Transverse diagram: a sideways "snake" showing crests and troughs, with the wave-travel arrow along the page and the vibration arrow up/down. *Longitudinal diagram:* a row of lines showing alternating **compressions** (lines close together) and **rarefactions** (lines spread apart), with both the travel arrow and vibration arrow pointing along the page.

(a)(ii) A **compression** is a region where the particles are pushed closer together, so the pressure/density is higher than normal. A **rarefaction** is a region where the particles are spread further apart, so the pressure/density is lower than normal.

(b)(i) Labelled ripple tank: a shallow transparent tray of water; a vibrating bar/dipper driven by a small electric motor (eccentric mass) to make straight wavefronts; a lamp above (or below) to project the wave pattern; a white screen below to view the bright/dark wavefronts. Label: water, vibrating bar/motor, lamp, screen.

(b)(ii) Reflection at a plane barrier: draw straight incident wavefronts approaching the barrier, then straight reflected wavefronts leaving it, with the angle of reflection equal to the angle of incidence (both measured to the normal of the barrier). The wavelength is unchanged on reflection.

(c)(i) The log is 6.0 m long and 5 complete waves fit along it, so $\lambda = 6.0 \div 5$ = **1.2 m**.

(c)(ii) 5 waves pass point A in 10 s, so period $T = 10 \div 5 = 2.0$ s; $f = 1/T = 1 \div 2.0$ = **0.50 Hz**.

(c)(iii) $v = f\lambda = 0.50 \times 1.2$ = **0.60 m/s**.

Question 2

5054/21/M/J/10 Q4

(a) Reflection at the plane barrier (Fig. 4.1). The straight wavefronts strike the tilted barrier and reflect from it. Draw the reflected wavefronts as straight lines making the same angle with the barrier as the incoming wavefronts (angle of reflection = angle of incidence, measured to the normal). The reflected wavefront spacing (wavelength) is the same as the incident wavefronts.

(b)(i) Wavefronts in the shallow water (Fig. 4.2). Over the glass the water is shallower, so the wave slows down. Draw the wavefronts there closer together (shorter wavelength) but still parallel to the boundary (the wave enters straight-on, so it does not change direction here).

(b)(ii)1 The **wave speed** decreases (the shallow water slows the wave).

(b)(ii)2 The **frequency** stays the same (frequency is set by the source and never changes when a wave crosses a boundary).

Question 3

5054/22/M/J/11 Q4

(a) The corks bob up and down; from Fig. 4.2 the displacement of A swings between +2 mm and −2 mm, so the **amplitude** = **2 mm**.

(b) The wavelength is 8.0 cm (distance between A and B). Cork B is one full wavelength from A, so it vibrates exactly in phase with A. Sketch a sine curve identical to A's (same amplitude 2 mm, same period 0.50 s) — i.e. the **same graph as A**.

(c)(i) From Fig. 4.2 one complete cycle of A takes 0.50 s, so period $\mathrm{T = 0.50\ s}$ and $\mathrm{f = 1/T = 1 \div 0.50}$ = **2.0 Hz**.

(c)(ii) Wave speed $\mathrm{v = f\lambda = 2.0 \times 0.080 = 0.16\ m/s}$. Time to travel 40 cm (0.40 m): $\mathrm{t = distance \div v = 0.40 \div 0.16}$ = **2.5 s**.

Question 4

5054/22/M/J/12 Q6

(a) Wave motion is the transfer of energy from one place to another without transferring matter; the particles of the medium simply vibrate to and fro about fixed positions while the energy moves through.

(b) The wave is transverse and travels to the right, so the molecule at X moves up and down (vertically) — draw a short vertical arrow at X (it is at a crest, so it is about to move downwards).

(c)(i) $\mathrm{v = f\lambda = 2.0 \times 2.5}$ = **5.0 cm/s** (= 0.050 m/s).

(c)(ii) In 1.0 s the wave moves a distance equal to its speed, i.e. one wavelength every period. Distance moved in 1.0 s = $\mathrm{v \times t = 5.0 \times 1.0 = 5.0\ cm}$ = two wavelengths. Mark a horizontal distance **D** = **5.0 cm** (two complete wavelengths) along the wave.

Question 5

5054/22/M/J/14 Q4

(a)(i) The hand moves up and down (perpendicular to the rope) — mark a vertical double-headed arrow at the hand.

(a)(ii) Wavelength λ = distance for one complete wave, e.g. crest-to-crest (mark a horizontal arrow spanning one full cycle).

(a)(iii) Amplitude A = maximum displacement from the rest line (mark a vertical arrow from the centre line up to a crest).

(b) Use a stopwatch to time a counted number of complete oscillations (e.g. count 20 up-and-down movements of the hand and record the total time t). Then $\mathrm{f = number\ of\ oscillations \div t}$. Timing many cycles and dividing reduces the timing/reaction error.

(c) To get a longer wavelength the student moves the hand up and down more slowly (lower frequency). At the same wave speed, $\mathrm{\lambda = v/f}$, so a smaller f gives a larger λ.

Question 6

5054/21/M/J/15 Q4

(a) Each particle of the string vibrates up and down (perpendicular to the string), about a fixed position; the particles do not travel along with the wave — only the energy moves to the right.

(b) From the marked distances the wave repeats every 0.40 m (e.g. crest at 0.05 m to the next crest at 0.45 m). **Wavelength** = **0.40 m**.

(c)(i) $f = v/\lambda = 2.0 \div 0.40$ = **5.0 Hz**.

(c)(ii) In 0.10 s the wave moves $v \times t = 2.0 \times 0.10 = 0.20\ m$ to the right = half a wavelength. Redraw the same wave shifted 0.20 m to the right, i.e. crests and troughs swapped over (inverted-looking) compared with the original.

Question 7

5054/22/M/J/15 Q9

(a) The **frequency** of a wave is the number of complete waves (wavefronts) passing a point each second, measured in hertz (Hz). It equals 1/period.

(b)(i) Fig. 9.1 shows 5 wavefronts spanning 6.0 cm, i.e. 4 equal gaps. One wavelength = one gap: $\lambda = 6.0 \div 4$ = **1.5 cm** (= 0.015 m).

(b)(ii) $v = f\lambda = 5.0 \times 0.015$ = **0.075 m/s** (= 7.5 cm/s).

(c)(i) In shallower water the wave slows down. Frequency is unchanged, so from $\lambda = v/f$ a smaller v gives a smaller λ: the **wavelength decreases** (wavefronts get closer together).

(c)(ii) Refraction (Fig. 9.2). In the shallow water draw the wavefronts closer together and bent (changed direction) so they make a smaller angle with the boundary — the wave turns towards the normal as it slows entering the shallow region.

(d)(i) One difference: a sound wave is longitudinal (vibrations along the direction of travel) whereas a water surface wave is transverse (vibrations up/down, perpendicular to travel). (Alternatively: sound needs a medium and can travel through solids/liquids/gases, while a water wave needs a water surface.)

Question 8

5054/21/M/J/16 Q5

(a) Completed table:
• **sound** — direction of vibration: parallel to the direction of transfer of the energy; type of wave: longitudinal.
• **water** — direction of vibration: perpendicular to the direction of transfer of the energy; type of wave: transverse.

(b)(i) At t = 0.25 s the curve is at a crest of height 1.30 m; the mean (rest) level is 1.00 m, so **amplitude** = 1.30 − 1.00 = **0.30 m**.

(b)(ii) The graph shows that the time for one complete cycle (the period) is the same for every cycle — successive crests are equally spaced in time (every 1.0 s). A constant period means a **constant frequency**.

Question 9

5054/21/M/J/17 Q10

(b)(i) A **wavefront** is a line joining all the points of a wave that are in phase (e.g. all the points along a single crest); successive wavefronts are one wavelength apart and the wave travels at right angles to them.

(b)(ii)1 Reflected wavefronts. Some of the wave bounces off the boundary back into the faster region. Draw straight reflected wavefronts at the same angle to the boundary as the incident wavefronts (angle of reflection = angle of incidence), with the **same spacing** (wavelength unchanged).

(b)(ii)2 Refracted wavefronts. In the shaded region the wave is slower, so its wavelength is smaller. Draw the transmitted wavefronts closer together and turned towards the normal (bent to make a smaller angle with the boundary).

Question 10

5054/21/M/J/18 Q11

(a)(i) Ripple tank. Draw a shallow tray of water with a vibrating bar/dipper driven by a small motor to make straight wavefronts, a lamp above and a white screen below. Switching on the motor makes the bar dip up and down, producing waves that are projected as bright (crests) and dark (troughs) lines on the screen, where they can be observed.

(a)(ii) Place a small floating object (e.g. a cork or a small ball) on the water. When the wave reaches it the cork bobs up and down — it gains kinetic/potential energy from the wave, showing that the wave has transferred energy to it (the cork is not carried along, only made to vibrate).

(a)(iii) A **wavefront** is a line joining all the points on the wave that are in phase (e.g. along one crest); consecutive wavefronts are one wavelength apart.

(b)(i) Difference: wave Q has a larger amplitude than wave P (and Q starts below the mean level while P starts on it — i.e. they are out of phase). **Similarity:** they have the same period / frequency (one cycle every 300 ms).

(b)(ii)1 From Fig. 11.1 wave P repeats every 300 ms, so period $\mathrm{T} = 0.300\ \mathrm{s}$ and $\mathrm{f} = 1/\mathrm{T} = 1 \div 0.300$ = **3.3 Hz**.

(b)(ii)2 $\lambda = \mathrm{v}/\mathrm{f} = 0.20 \div 3.33$ = 0.060 m = **6.0 cm** (or λ = vT = 0.20 × 0.300 = 0.060 m).

Question 11

5054/22/M/J/18 Q5

(a) The pulse travels to the satellite and back (total path = 2 × distance) in 0.24 s. Total path $= \mathrm{v}\times\mathrm{t} = (3.0\times10^{8}) \times 0.24 = 7.2\times10^{7}\ \mathrm{m}$. Distance to satellite $= 7.2\times10^{7} \div 2$ = **3.6×10^{7} m**.

(b)(i) Ticks:
• **microwaves** — transverse ✓ and electromagnetic ✓.
• **sound** — longitudinal ✓ only (not electromagnetic).

(b)(ii) A **compression** is a region of a longitudinal wave where the particles are pushed close together, giving a higher-than-normal pressure/density.

Question 12

5054/21/M/J/19 Q10

(a)(i) On the diagram one crest-to-crest spacing (one wavelength) is 1.0 cm. Using the scale 1.0 cm on the diagram = 4.0 cm in the tank: $\lambda = 1.0 \times 4.0$ = **4.0 cm** (= 0.040 m).

(a)(ii) Frequency = the number of complete waves (crests) passing a point each second (unit: hertz, Hz).

(a)(iii) P and Q are 5 wavelengths apart, so the distance P→Q in the tank = 5 × 4.0 = 20 cm = 0.20 m. A crest covers this in 2.0 s, so wave speed $v = 0.20 \div 2.0 = 0.10\ m/s$. Then $f = v/\lambda = 0.10 \div 0.040$ = **2.5 Hz**.

(a)(iv) The wooden bar is laid flat on the water surface and made to vibrate up and down (e.g. by a small motor with an off-centre mass). Its straight edge dips the whole width of the water together, producing the straight parallel wavefronts shown.

(a)(v) In shallower water the wave slows down, so the **speed decreases**; frequency is fixed, so from $\lambda = v/f$ the **wavelength also decreases**.

Question 13

5054/21/M/J/21 Q4

(a)(i) Fig. 4.1 (rope): transverse wave.   Fig. 4.2 (spring): longitudinal wave.

(a)(ii) A wave of **smaller frequency** has a longer wavelength (same speed). Redraw Fig. 4.1 with the crests and troughs further apart (fewer complete waves in the same length), keeping a similar amplitude.

(a)(iii) As the longitudinal wave passes, point X vibrates backwards and forwards along the spring (parallel to the direction of travel), about its fixed rest position; it is not carried along with the wave.

Question 14

5054/22/M/J/21 Q10

(a)(i) The 12 cm dimension spans 4 wavefronts in the shallow water = 3 equal gaps. One gap = one wavelength: $\lambda = 12 \div 3$ = **4.0 cm** (= 0.040 m).

(a)(ii) The bar makes 10 complete up-and-down movements in 5.0 s, so $f = 10 \div 5.0$ = **2.0 Hz**.

(a)(iii) $v = f\lambda = 2.0 \times 4.0$ = **8.0 cm/s** (= 0.080 m/s).

(a)(iv) As the wave enters the deep water it speeds up. So: **wavelength** increases; **frequency** stays the same; **speed** increases (join wavelength→increases and speed→increases on Fig. 10.2).

(a)(v) Refraction at the angled boundary (Fig. 10.3). In the deep water draw the wavefronts further apart (longer wavelength) and turned away from the normal — the wave changes direction because it travels faster in the deeper water.

Question 15

5054/22/M/J/22 Q8

(a)(i) Number of crests in 1.5 s = $f \times t = 2.0 \times 1.5$ = **3** crests.

(a)(ii) Graph (Fig. 8.2). Draw a sine curve starting at 0 at t = 0, with amplitude 3.0 mm (peaks at +3 and −3) and period $T = 1/f = 1/2.0 = 0.50\ s$ — i.e. 3 complete cycles between 0 and 1.5 s.

(b)(i) To raise the frequency, make the wooden bar vibrate faster (more up-and-down movements per second) — e.g. increase the speed of the motor driving it.

(b)(ii) The depth is unchanged, so the **speed stays the same**; with a higher frequency, $\lambda = v/f$ means the **wavelength decreases**.

(c)(i) Additional apparatus: a sheet/block of glass (or plastic) placed flat on the bottom under part of the water to make a shallow region.

(c)(ii) Refraction (Fig. 8.3). Mark the boundary at the edge of the glass; over the shallow region (above the glass) draw the wavefronts closer together (shorter wavelength), and if the boundary is at an angle, also bent towards the normal.

Question 16

5054/02/O/N/04 Q5

(a)(i) The hand moves up and down (perpendicular to the spring) — mark a vertical double-headed arrow at the hand.

(a)(ii) The hand moves up and down at a steady rate, making 4 complete up-and-down movements every second (so that the frequency is 4.0 Hz, i.e. one cycle every 0.25 s).

(b) Formula: $v = f\lambda$, so $\lambda = v/f = 0.80 \div 4.0$ = **0.20 m** (= 20 cm).

(c) To double the wavelength (at the same wave speed), $\lambda = v/f$, so the frequency must be halved — move the hand up and down at half the rate (2.0 Hz).

Question 17

5054/02/O/N/05 Q3

(a) A **wavefront** is a line joining all points of the wave that are in phase (e.g. all along one crest); successive wavefronts are one wavelength apart.

(b)(i) Over the glass the water is shallower, so the wave slows; the **wavelength decreases** (wavefronts get closer together).

(b)(ii) The **speed decreases** (the wave travels slower in the shallow water over the glass).

(b)(iii) The **frequency stays the same** (set by the source; it never changes on crossing a boundary).

Question 18

5054/21/O/N/12 Q5

(a)(i) Measure the crest-to-crest spacing of the deep-water wavefronts on Fig. 5.1 (about 1.0 cm on the diagram). Using the scale 1:8 (1.0 cm on the diagram = 8.0 cm in the tank): $\lambda = 1.0 \times 8.0$ = **8.0 cm** (= 0.080 m). *(Value depends on the exact ruler measurement of the diagram.)*

(a)(ii) $v = f\lambda = 3.6 \times 0.080$ = **0.29 m/s** (= 29 cm/s, to 2 s.f.).

(b)(i) The **frequency stays the same** (unchanged across the boundary).

(b)(ii) The **speed decreases** (the wave travels slower in the shallow water).

Question 19

5054/21/O/N/14 Q4

(a) Wave motion in a ripple tank is the way a disturbance (the up-and-down vibration of the water surface) travels across the tank, carrying energy without carrying the water along with it — the water particles only move up and down on the spot.

(b)(i) Frequency = the number of complete waves passing a point each second (unit Hz).

(b)(ii) Wavelength = the distance between two neighbouring points that are in phase (e.g. crest to crest), i.e. the length of one complete wave.

(c) Reflection at the barrier (Fig. 4.1). For each of the three wavefronts that have hit the barrier, draw the reflected part as a straight line making the same angle with the barrier as the incident wavefront (angle of reflection = angle of incidence), with the same spacing (wavelength unchanged) — the reflected wavefronts move away from the barrier in the mirror-image direction.

Question 20

5054/21/O/N/18 Q9

(a) In a **longitudinal** wave the particles vibrate parallel to (along) the direction the wave travels, whereas in a **transverse** wave they vibrate perpendicular (at 90°) to it.

(b)(i) In the left-hand section λ = 0.019 m and v = 0.17 m/s, so $f = v/\lambda = 0.17 \div 0.019$ = **8.9 Hz** (to 2 s.f.).

(b)(ii) The frequency stays the same in the right-hand section (frequency is fixed by the source and does not change when the depth changes).

(b)(iii) The wavefronts in the right-hand section are drawn closer together, so the wavelength there is smaller. Since frequency is constant, $v = f\lambda$ means a smaller λ gives a smaller v — the **speed decreases** (the water in the right-hand section is shallower).

Question 21

5054/22/O/N/18 Q9

(b)(i) A **wave** is a disturbance that transfers energy from place to place without transferring matter. In a **longitudinal** wave the particles vibrate parallel to the direction of travel (giving compressions and rarefactions), whereas in a **transverse** wave they vibrate perpendicular to the direction of travel (giving crests and troughs).

(b)(ii)1 A **rarefaction** is the region midway between two compressions (where the lines are most spread out). Mark R at the centre of two such low-density regions.

(b)(ii)2 One **wavelength** = the distance from the centre of one compression to the centre of the next (or one rarefaction to the next). Draw the double-headed arrow across one such interval.

(b)(ii)3 Measuring Fig. 9.1 (full scale), one wavelength ≈ 1.4 cm = 0.014 m. Then $v = f\lambda = 25000 \times 0.014$ = **350 m/s** (to 2 s.f.). *(Value depends on the exact ruler measurement.)*

(c)(i) As the sound wave enters the air its **speed decreases** (sound travels slower in air than in the liquid).

(c)(ii) Refraction at the liquid–air boundary (Fig. 9.2). In the air draw the compression lines closer together (shorter wavelength) and bent towards the normal, since the wave slows down on entering the air.

> **Note from Megalecture.** These are original Megalecture worked solutions, prepared from first principles for revision use and not copied from any official mark scheme. Diagram-based answers (drawing wavefronts, reflection, refraction and graphs) are described in words here; where a wavelength is read off a scale diagram (Questions 18 and 21) the final value depends on the exact ruler measurement, so a small spread of answers is acceptable. Always show your formula and working in the exam. Please verify before classroom use.