

4.6

Waves

Exam-style questions — answers and mark schemes

101 questions • 228 marks

Written in the style of AQA papers, including the required practicals, maths and working scientifically.

How to use this booklet

Each answer gives the creditworthy points; one mark per point unless stated.

Alternative correct wording is credited — these are marking points, not model answers.

Calculations: the equation and the substitution each earn a mark, so a wrong final answer can still score. Error carried forward applies where stated.

Examiner notes flag the mistakes that actually lose marks in real examinations.

Command words used

State, Give, Name, Write down — a short factual answer, no explanation needed

Describe — say what happens, in order, without needing a reason

Explain — give a reason; 'because', 'so' or 'therefore' should appear

Calculate — show your working and give a unit

Determine — use data given, often from a graph or table

Estimate — an approximate value from reasonable assumptions

Suggest — apply what you know to an unfamiliar situation

Compare — say how things are similar and different, in the same sentence

Evaluate — give both sides, then a conclusion

Design, Plan — set out a method others could follow

Questions are labelled beside the marks where they are Higher Tier only, Separate Physics only, or Working scientifically — the apparatus, variables, accuracy, evaluation and maths skills that carry around a third of the marks in every AQA paper.

4.6.1 Waves in air, fluids and solids

1

A wave travels along a stretched rope.

- a** Define the amplitude of a wave. [1]

The maximum displacement of a point on the wave from its undisturbed position (1)

- b** Define the wavelength of a wave. [1]

The distance from a point on one wave to the equivalent point on the next wave (1)

- c** Define the frequency of a wave and give its unit. [2]

The number of waves passing a point each second (1); measured in hertz, Hz (1)

- d** Define the period of a wave. [1]

The time taken for one complete wave to pass a point (1)

- e** State what a wave transfers. [1]

Energy and information, but not matter (1)

- f** Explain the difference between a transverse and a longitudinal wave. [2]

In a transverse wave the oscillations are perpendicular to the direction of energy transfer (1); in a longitudinal wave they are parallel to it (1)

- g** Give one example of each type of wave. [2]

Transverse: light, any electromagnetic wave, or ripples on water (1); longitudinal: sound (1)

Examiner note: Examiners report that sound is frequently and incorrectly described as transverse.

2

A sound wave has a frequency of 440 Hz and travels at 340 m/s in air.

- a** Calculate the wavelength of the sound. Maths skill [3]

$v = f \lambda$, so $\lambda = v \div f$ (1); $= 340 \div 440$ (1); $= 0.77$ m (1)

- b** Calculate the period of the wave. Maths skill [2]

$T = 1 \div f = 1 \div 440$ (1); $= 2.3 \times 10^{-3}$ s (1)

- c** The sound travels into water, where its speed is 1500 m/s. State what happens to the frequency. [1]

It stays the same (1)

- d** Calculate the wavelength of the sound in water. Maths skill [2]

$\lambda = 1500 \div 440$ (1); $= 3.4$ m (1)

- e** Explain why the wavelength changes but the frequency does not. [2]

The frequency is determined by the source, and the number of waves arriving each second must equal the number leaving (1); since $v = f \lambda$ and the speed changes, the wavelength must change instead (1)

3

A radio station broadcasts at a frequency of 198 kHz. Radio waves travel at 3.0×10^8 m/s.

- a** Calculate the wavelength of the radio waves.

Maths skill [3]

Convert: $198 \text{ kHz} = 1.98 \times 10^5 \text{ Hz}$ (1); $\lambda = v \div f = 3.0 \times 10^8 \div 1.98 \times 10^5$ (1); = 1520 m (1)

Examiner note: Failing to convert kHz or MHz into Hz is a frequent source of power of ten errors.

- b** Write your answer in standard form to 2 significant figures.

Maths skill [1]

$1.5 \times 10^3 \text{ m}$ (1)

4

A ship uses sonar to measure the depth of the sea bed. A pulse of sound is sent downwards and the echo returns 0.36 s later. Sound travels at 1500 m/s in sea water.

- a** Calculate the depth of the sea bed.

Maths skill [4]

The pulse travels to the sea bed and back (1); total distance = $v t = 1500 \times 0.36 = 540 \text{ m}$ (1); depth = $540 \div 2$ (1); = 270 m (1)

Examiner note: Forgetting to halve the distance is the single most common error in echo questions.

- b** Suggest why the measured depth may be slightly inaccurate.

Working scientifically [2]

The speed of sound in sea water varies with temperature, salinity and depth (1); so using a single value introduces an error (1)

Required practical 8 • Measuring waves

- 5** A student uses a ripple tank to measure the speed of water waves. A vibrating bar produces waves and a lamp above projects their shadows onto paper below.

- a** Describe how the student should measure the wavelength.

Working scientifically [3]

Place a ruler on the paper alongside the shadows (1); measure the distance across ten wavelengths (1); and divide by ten (1)

- b** Explain why ten wavelengths are measured rather than one.

Working scientifically [2]

The uncertainty in reading the ruler is the same either way (1); so measuring a larger distance reduces the percentage uncertainty in the wavelength (1)

- c** Describe how the student should measure the frequency.

Working scientifically [2]

Count the number of waves passing a fixed point in a measured time, such as 30 s (1); frequency = number of waves ÷ time (1)

- d** The student measures ten wavelengths as 23 cm and counts 45 waves in 30 s.
Calculate the wave speed.

Maths skill [4]

$\lambda = 0.23 \div 10 = 0.023 \text{ m}$ (1); $f = 45 \div 30 = 1.5 \text{ Hz}$ (1); $v = f \lambda = 1.5 \times 0.023$ (1); $= 0.035 \text{ m/s}$ (1)

- e** Suggest one way of making the waves easier to count.

Working scientifically [2]

Use a strobe light to freeze the pattern (1); or photograph the shadows with a ruler in the picture and count from the image (1)

- f** Describe how the student could measure the wavelength of waves on a stretched string instead.

Working scientifically [3]

Use a vibration generator at one end and a hanging mass over a pulley at the other (1); adjust the frequency until a clear pattern of loops is seen (1); measure the length of several loops; each loop is half a wavelength (1)

4.6.1 Reflection and refraction

- 6** A ray of light strikes a plane mirror at an angle of incidence of 35° .

- a** State the law of reflection.

[1]

The angle of incidence equals the angle of reflection (1)

- b** State the angle of reflection.

[1]

35° (1)

- c** Explain where both angles are measured from.

[1]

From the normal, the line drawn at 90° to the surface (1)

- d** Explain the difference between specular and diffuse reflection.

[3]

Specular reflection occurs at a smooth surface, where parallel rays remain parallel after reflection, giving a clear image (1); diffuse reflection occurs at a rough surface (1); where the normals point in different directions so the reflected rays scatter and no image is formed (1)

7

A ray of light passes from air into a glass block.

- a** Explain why the ray changes direction at the boundary. [3]

The light slows down on entering the glass (1); the part of the wavefront entering first slows before the rest (1); so the direction of travel changes, bending towards the normal (1)

- b** State what happens to the frequency and the wavelength of the light in the glass. [2]

The frequency is unchanged (1); the wavelength decreases (1)

- c** Describe what happens to a ray that enters the block along the normal. [2]

It passes straight through without changing direction (1); because the whole wavefront slows at the same moment (1)

- d** Name three things that can happen to a wave at a boundary between two materials. [3]

It can be reflected (1); transmitted or refracted (1); or absorbed (1)

4.6.2 Electromagnetic waves

8

The electromagnetic spectrum is a continuous spectrum of transverse waves.

- a** Name the seven groups in order of increasing frequency. [2]

Radio, microwave, infrared, visible light, ultraviolet, X-rays, gamma rays (2, or 1 for four or more in the correct order)

- b** State what all electromagnetic waves have in common. [2]

They are all transverse (1); and all travel at the same speed in a vacuum, 3×10^8 m/s (1)

- c** State how the wavelength changes across the spectrum from radio to gamma. [1]

It decreases (1)

- d** Give one use of radio waves and one of microwaves. [2]

Radio: television and radio broadcasting (1); microwaves: satellite communications or cooking food (1)

- e** Give one use of infrared and one of visible light. [2]

Infrared: electric heaters, cooking, or thermal imaging cameras (1); visible light: fibre optic communications or photography (1)

- f** Give one use of ultraviolet, X-rays and gamma rays. [3]

Ultraviolet: energy efficient lamps, sun tanning or detecting forged banknotes (1); X-rays: medical imaging of bones (1); gamma rays: sterilising equipment or treating cancer (1)

- g** Give one hazard of ultraviolet radiation and one of X-rays. [2]

Ultraviolet can damage surface cells and cause skin cancer or eye damage (1); X-rays are ionising and can cause gene mutation and cancer (1)

- h** Explain why gamma rays are more hazardous than radio waves. [2]

Gamma rays have a much higher frequency, so each photon carries far more energy (1); they are ionising, so they can damage DNA in cells (1)

9

Radio waves are produced by oscillations in an electrical circuit.

- a** Explain how radio waves are produced and detected. Higher Tier only [4]

An alternating current in a transmitting aerial makes electrons oscillate (1); producing radio waves of the same frequency as the current (1); when the waves reach a receiving aerial they make electrons there oscillate (1); inducing an alternating current of the same frequency as the wave (1)

- b** Explain why some radio waves can be received beyond the horizon. [2]

Long wavelength radio waves are reflected by the ionosphere, or diffract around the curvature of the Earth (1); so they can reach receivers that are not in a direct line of sight (1)

- c** Explain why microwaves rather than radio waves are used for satellite communication. [2]

Microwaves pass through the atmosphere and the ionosphere with little absorption (1); so they can reach the satellite and return, whereas some radio waves are reflected back (1)

Required practical 9 • Infrared radiation

10

A student uses a Leslie cube filled with hot water to compare the infrared radiation emitted by four surfaces.

Surface	Matt black	Shiny black	Matt white	Shiny silver
Detector reading in arbitrary units	92	78	61	34

- a** Identify the best emitter and the worst emitter of infrared radiation. [2]

Best: matt black (1); worst: shiny silver (1)

- b** Name the independent and dependent variables. Working scientifically [2]

Independent: the type of surface (1); dependent: the detector reading (1)

- c** State two variables that must be controlled. Working scientifically [2]

The distance between the detector and the cube face (1); the temperature of the water, and the room temperature (1)

- d** Explain why the distance from the detector to each face must be the same. Working scientifically [2]

The intensity of radiation decreases with distance (1); so a different distance would change the reading and the comparison would not be fair (1)

- e** Predict what the readings would be if the cube were filled with iced water instead, and explain. Working scientifically [3]

All readings would be below the room temperature value (1); the matt black face would show the largest difference (1); because a good emitter is also a good absorber, so it absorbs radiation from the room fastest (1)

- f** Suggest why the cube is left for a few minutes before readings are taken. Working scientifically [2]

To allow all four faces to reach the same steady temperature (1); otherwise the readings would reflect differences in temperature rather than in surface (1)

- 11** A student investigates how the temperature of a black metal can of hot water falls over time, and compares it with a shiny can.

Time in minutes	0	5	10	15	20
Black can in °C	80	66	56	49	44
Shiny can in °C	80	72	65	60	56

- a** Plot both sets of data on the grid provided and draw curves of best fit.

Working scientifically [4]

Sensible scales using over half the grid (1); axes labelled with quantity and unit (1); all points plotted correctly for both cans (1); two smooth curves drawn and clearly labelled (1)

- b** Determine the temperature difference between the two cans after 10 minutes.

Maths skill [1]

$$65 - 56 = 9 \text{ °C (1)}$$

- c** Explain the difference in the cooling of the two cans.

[3]

The black can is a better emitter of infrared radiation (1); so it transfers energy to the surroundings faster (1); and therefore cools more quickly (1)

- d** Calculate the mean rate of cooling of the black can over the 20 minutes.

Maths skill [2]

$$(80 - 44) \div 20 \text{ (1); } = 1.8 \text{ °C per minute (1)}$$

- e** Explain why both cans cool more slowly as time goes on.

[2]

The temperature difference between the can and the surroundings decreases (1); so the rate of energy transfer decreases (1)

- 12** Use the grid to plot the cooling data from the previous question.

No answer is required here — the grid is for your graph.

[0]

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4.6.3 Lenses

13

A convex lens of focal length 8.0 cm is used as a magnifying glass.

- a** State what is meant by the focal length of a lens. Separate Physics only [2]

The distance from the centre of the lens (1); to the principal focus, where parallel rays are brought to a focus (1)

- b** Describe the difference between a convex and a concave lens. Separate Physics only [2]

A convex lens is thicker in the middle and converges parallel rays to a focus (1); a concave lens is thinner in the middle and makes parallel rays diverge (1)

- c** An object 6.0 mm tall produces an image 27 mm tall. Calculate the magnification. Separate Physics only [2]

magnification = image height ÷ object height (1); = $27 \div 6.0 = \times 4.5$ (1)

Examiner note: Examiners report that candidates commonly divide the object height by the image height.

- d** Explain the difference between a real and a virtual image. Separate Physics only [3]

A real image is formed where the rays actually meet, and can be projected onto a screen (1); a virtual image is formed where the rays only appear to come from (1); and cannot be projected onto a screen (1)

- e** State the nature of the image when the object is closer to a convex lens than the focal length. Separate Physics only [2]

Virtual, upright and magnified (1); on the same side of the lens as the object (1)

- f** State the nature of the image formed by a concave lens. Separate Physics only [2]

Always virtual, upright and smaller than the object (1); whatever the object distance (1)

4.6.4 Black body radiation

14

All objects emit and absorb infrared radiation.

- a** Define a perfect black body.

Separate Physics only [2]

An object that absorbs all the radiation incident on it (1); reflecting and transmitting none, and which is also the best possible emitter (1)

- b** Describe how the radiation emitted by an object changes as its temperature increases.

Separate Physics only [2]

The intensity of the radiation emitted increases across all wavelengths (1); and the peak of the emission moves to shorter wavelengths (1)

- c** Explain why a metal bar glows red and then white as it is heated.

Separate Physics only [2]

At a lower temperature the peak is in the infrared and only a little red light is emitted (1); at a higher temperature more of all visible wavelengths is emitted, which together appear white (1)

- d** Explain how the balance between absorbed and emitted radiation determines the temperature of the Earth.

Separate Physics only [4]

The Earth absorbs radiation from the Sun and emits infrared radiation into space (1); if the rates of absorption and emission are equal, the temperature stays constant (1); if more is absorbed than emitted, the temperature rises (1); greenhouse gases absorb some of the outgoing infrared and re-emit it back towards the surface, raising the temperature (1)

Working scientifically

15

A student measures the speed of sound in air by standing 85 m from a large wall, clapping, and timing the echo. The times recorded are 0.52 s, 0.48 s, 0.71 s and 0.50 s.

- a** Identify the anomalous result and explain how it should be treated.

Working scientifically [2]

0.71 s (1); it should be excluded from the mean, and the measurement repeated (1)

- b** Calculate the mean time using the remaining results.

Maths skill [2]

$(0.52 + 0.48 + 0.50) \div 3$ (1); = 0.50 s (1)

- c** Calculate the speed of sound from these results.

Maths skill [3]

Distance = $2 \times 85 = 170$ m (1); $v = s \div t = 170 \div 0.50$ (1); = 340 m/s (1)

- d** Explain why the student's reaction time is a significant source of error.

Working scientifically [3]

The time measured is only about 0.5 s (1); a reaction time of around 0.2 s is a large fraction of this (1); so the percentage uncertainty in the measurement is large (1)

- e** Describe two improvements that would reduce this error.

Working scientifically [2]

Stand further from the wall so the time measured is longer (1); or time ten claps in succession and divide by ten, or use two microphones and a data logger (1)

- 16** A student claims: 'All electromagnetic waves travel at the same speed, so light travels at the same speed in glass as it does in air.'

a Explain why the student's reasoning is wrong.

Working scientifically [3]

All electromagnetic waves travel at the same speed in a vacuum (1); but their speed depends on the material they travel through (1); light travels more slowly in glass than in air, which is why it refracts at the boundary (1)

b Describe evidence that supports the correct explanation.

Working scientifically [2]

A ray entering a glass block at an angle changes direction, bending towards the normal (1); refraction can only occur if the wave changes speed (1)

- 17** A company advertises sunglasses that 'block 100% of all radiation'.

a Explain why this claim cannot be correct.

Working scientifically [2]

If they blocked all radiation, no visible light would pass through and the wearer could not see (1); the claim presumably means ultraviolet radiation only (1)

b Describe how the claim about ultraviolet could be tested.

Working scientifically [3]

Use a UV sensor to measure the intensity with and without the lens in place (1); at a fixed distance from a fixed UV source (1); repeat with several pairs of the sunglasses and compare the means (1)

c Explain why it matters that this testing is carried out independently.

Working scientifically [2]

A manufacturer has a financial interest in the result, which could bias the testing (1); independent testing and peer review make the findings more trustworthy (1)

- 18** The table shows the speed of sound in different materials.

Material	Air	Water	Concrete	Steel
Speed in m/s	340	1500	3200	5900

a Describe the pattern shown by the data.

Working scientifically [2]

Sound travels faster in solids than in liquids, and faster in liquids than in gases (1); the denser, more rigid the material, the faster the sound travels (1)

b Explain this pattern in terms of particles.

[2]

Sound is transmitted by particles colliding and passing on the vibration (1); particles are closer together in solids, so the vibration is passed on more quickly (1)

c A sound of frequency 250 Hz travels through steel. Calculate its wavelength.

Maths skill [2]

$$\lambda = v \div f = 5900 \div 250 \text{ (1); } = 23.6 \text{ m (1)}$$

d An engineer taps one end of a 240 m steel pipe. Calculate the time for the sound to reach the other end through the steel.

Maths skill [2]

$$t = s \div v = 240 \div 5900 \text{ (1); } = 0.041 \text{ s (1)}$$

e Calculate how much later the sound arrives through the air inside the pipe.

Maths skill [3]

$$\text{Through air: } t = 240 \div 340 = 0.706 \text{ s (1); difference} = 0.706 - 0.041 \text{ (1); } = 0.67 \text{ s (1)}$$

19

A student investigates how the frequency of a note from a stretched string depends on its length.

Length in cm	20	30	40	50	60
Frequency in Hz	600	400	300	240	200

- a** Describe the relationship between frequency and length.

Working scientifically [2]

As the length increases the frequency decreases (1); doubling the length halves the frequency, so frequency is inversely proportional to length (1)

- b** Show that the data are consistent with this relationship.

Maths skill [2]

Multiply length by frequency: $20 \times 600 = 12\,000$, $40 \times 300 = 12\,000$, $60 \times 200 = 12\,000$ (1); the product is constant (1)

- c** Predict the frequency for a length of 24 cm.

Maths skill [2]

$f = 12\,000 \div 24$ (1); = 500 Hz (1)

- d** State two variables that must be controlled.

Working scientifically [2]

The tension in the string (1); and the type or thickness of string used (1)

- e** Suggest how the frequency could be measured accurately.

Working scientifically [2]

Use a microphone connected to an oscilloscope or a frequency app (1); measure the period of one wave on the trace and calculate $f = 1 \div T$ (1)

20

A ray of light is shone into a semicircular glass block towards the centre of the flat face.

- a** Describe what happens to the ray as the angle of incidence inside the glass is increased from a small value.

Separate Physics only [3]

At small angles most of the light refracts out, bending away from the normal, with a weak reflected ray (1); as the angle increases the refracted ray bends further and becomes dimmer (1); at a large enough angle no light emerges and all of it is reflected inside the glass (1)

- b** Explain how an optical fibre uses this effect.

Separate Physics only [2]

Light strikes the boundary at an angle large enough that it is totally internally reflected (1); so it travels along the fibre with very little loss, carrying information (1)

21

A student says: 'Infrared and ultraviolet are both types of heat radiation.'

- a** Explain why this statement is incorrect.

Working scientifically [3]

Infrared is the region usually associated with heating, as it is readily absorbed and raises the temperature of an object (1); ultraviolet has a higher frequency than visible light and is ionising, causing damage to cells rather than simple heating (1); all electromagnetic waves transfer energy, so none of them is uniquely 'heat radiation' (1)

- b** Describe an experiment that shows infrared radiation exists beyond the red end of the visible spectrum.

Working scientifically [3]

Use a prism to split white light into a spectrum on a screen (1); place a blackened thermometer bulb just beyond the red end (1); the temperature rises, showing radiation is present there even though nothing is visible (1)

22

A wave on the surface of water has a wavelength of 0.45 m and a period of 0.30 s.

- a Calculate the frequency of the wave.

Maths skill [2]

$$f = 1 \div T = 1 \div 0.30 \text{ (1)}; = 3.3 \text{ Hz (1)}$$

- b Calculate the speed of the wave.

Maths skill [2]

$$v = f \lambda = 3.33 \times 0.45 \text{ (1)}; = 1.5 \text{ m/s (1)}$$

- c The wave passes into shallower water, where its speed falls to 1.0 m/s. Calculate the new wavelength.

Maths skill [3]

$$\text{The frequency is unchanged at } 3.33 \text{ Hz (1)}; \lambda = v \div f = 1.0 \div 3.33 \text{ (1)}; = 0.30 \text{ m (1)}$$

- d State what happens to the direction of the wave if it enters the shallow water at an angle.

[1]

It refracts, changing direction (1)

23

A student is given a signal generator, a loudspeaker, a microphone and an oscilloscope.

- a Describe how the oscilloscope trace changes when the frequency of the note is increased.

Working scientifically [2]

The waves on the trace become closer together (1); because the period of each wave is shorter (1)

- b Describe how the trace changes when the note is made louder.

Working scientifically [1]

The amplitude of the trace increases (1)

- c One complete wave occupies 4 divisions on the screen, and the time base is set at 2 ms per division. Calculate the frequency.

Maths skill [3]

$$T = 4 \times 2 \text{ ms} = 8 \text{ ms} = 0.008 \text{ s (1)}; f = 1 \div T \text{ (1)}; = 125 \text{ Hz (1)}$$

- d Explain why an oscilloscope gives a more reliable measurement of frequency than counting waves by ear.

Working scientifically [2]

The trace gives a direct measurement of the period with a known time base (1); counting by ear depends on human judgement and is not possible at high frequencies (1)

24

Explain why the image in a mirror appears to be behind the mirror, and state the type of image formed.

Give your answer.

[3]

The rays reflect from the mirror and diverge towards the eye (1); the brain traces them back along straight lines to a point behind the mirror (1); the image is virtual, since the rays do not actually meet there (1)

25

State one similarity and one difference between a sound wave and a light wave.

Give your answer.

[2]

Similarity: both transfer energy without transferring matter (allow both can be reflected and refracted) (1); difference: sound is longitudinal and needs a medium, whereas light is transverse and can travel through a vacuum (1)

- 26** An ultrasound scanner sends a pulse into the body and detects the reflection from a boundary between two tissues 0.12 m below the surface. Ultrasound travels at 1500 m/s in tissue.

a Calculate the time taken for the pulse to return.

Maths skill [3]

$$\text{Distance} = 2 \times 0.12 = 0.24 \text{ m (1)}; t = s \div v = 0.24 \div 1500 \text{ (1)}; = 1.6 \times 10^{-4} \text{ s (1)}$$

b Explain why ultrasound rather than X-rays is used to scan a fetus.

[2]

Ultrasound is not ionising, so it does not damage cells or DNA (1); X-rays are ionising and could harm the developing fetus (1)

Extended response

- 27** A hospital uses several parts of the electromagnetic spectrum.

Describe how three different regions of the electromagnetic spectrum are used in a hospital, and explain the hazards associated with each and how they are reduced.

[6]

Level 3 (5–6 marks): three regions described with both uses and hazards, and sensible precautions. Level 2 (3–4 marks): two or three regions with partial detail. Level 1 (1–2 marks): isolated statements.

Indicative content: X-rays are used to image bones and to produce CT scans; they are ionising and can cause gene mutation and cancer, so lead aprons and screens are used, staff stand behind a barrier, and exposure times are kept short; gamma rays are used to sterilise equipment and to treat tumours in radiotherapy, and as tracers; they are also ionising, so sources are shielded with lead and handled remotely; infrared is used in thermal imaging and in heat lamps, and can cause skin burns if the intensity is too high; ultraviolet is used in sterilising cabinets and can damage surface cells and eyes, so cabinets are interlocked and goggles worn; visible light is used in endoscopes through optical fibres and is not hazardous at normal intensities.

- 28** A student is asked to determine the speed of water waves in a ripple tank.

Describe a method the student could use, and explain how the measurements should be taken to reduce uncertainty.

[6]

Level 3 (5–6 marks): a complete method with the calculation and clear uncertainty reduction. Level 2 (3–4 marks): a workable method with some detail. Level 1 (1–2 marks): simple statements.

Indicative content: set up the ripple tank with a vibrating bar at a set frequency and a lamp above so shadows appear on paper below; measure the distance across ten wavelengths with a ruler on the paper and divide by ten; count the number of waves passing a fixed point in 30 s and divide to find the frequency; calculate the speed using $v = f \lambda$; measuring ten wavelengths rather than one reduces the percentage uncertainty; counting over a longer time reduces the effect of miscounting and reaction time; use a strobe light or a photograph to freeze the pattern; repeat the measurements and take means; keep the water depth constant, since the speed of water waves depends on depth.