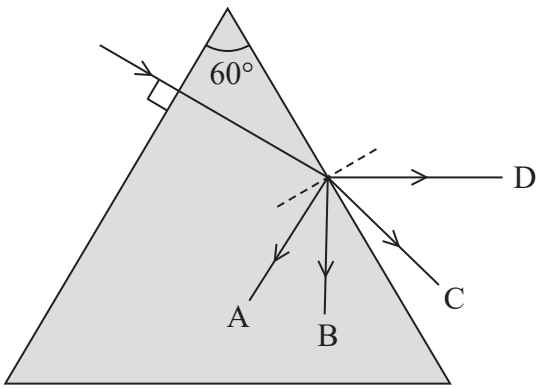
Questions 2 and 3 refer to the following information.

A ray of light, in air, is incident on the edge of a triangular glass prism as shown.
The critical angle for a light ray meeting a glass to air boundary is 35°.



2 Which path, A, B, C or D, will the ray follow?

☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for Question 2 = 1 mark)

3 Which of the following gives the value of the refractive index of the glass?

☒ **A** $\sin 35$

☒ **B** $\dfrac{1}{\sin 35}$

☒ **C** $\sin^{-1}\left(\dfrac{1}{35}\right)$

☒ **D** $\dfrac{1}{\sin^{-1}\left(\dfrac{1}{35}\right)}$

(Total for Question 3 = 1 mark)

Questions 4 and 5 refer to the following information.

The speed v of a transverse wave on a string is given by

$$v = \sqrt{\frac{T}{\mu}}$$

where μ is the mass per unit length of the string and T is the tension in the string.

4 μ can be calculated from measurements of the mass and length of the string.

The percentage uncertainty in the measurement of mass is 0.4%.
The percentage uncertainty in the measurement of length is 0.05%.

Which of the following is the percentage uncertainty in the calculated value for μ?

☒ **A** 0.4 + 0.05

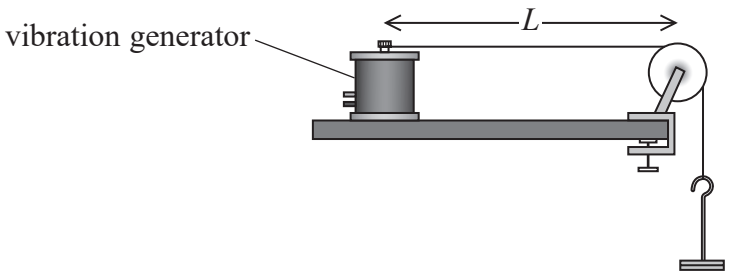
☒ **B** 0.4 − 0.05

☒ **C** 0.4 × 0.05

☒ **D** 0.4 ÷ 0.05

(Total for Question 4 = 1 mark)

5 A fixed length L of string is connected to a vibration generator and held under tension T as shown. The frequency of the vibration generator is varied until, at a frequency f, a standing wave with one antinode is observed. T is increased and the procedure is repeated.



Which of the following describes the variation in f as T increases?

☒ **A** decreases linearly

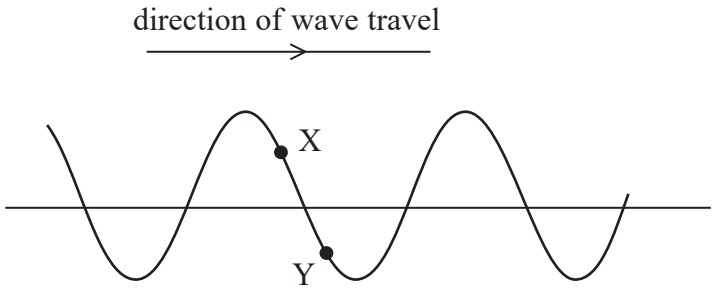
☒ **B** decreases non-linearly

☒ **C** increases linearly

☒ **D** increases non-linearly

(Total for Question 5 = 1 mark)

7 The diagram shows the position of two particles, X and Y, on a transverse wave. The wave is travelling from left to right.



Which of the following describes the directions in which the particles at X and Y are moving at the instant shown?

	Particle X	Particle Y
☒ **A**	down	down
☒ **B**	down	up
☒ **C**	up	down
☒ **D**	up	up

(Total for Question 7 = 1 mark)

8 A beam of light from a torch with power P is shone onto a surface. The light is spread over a circular area with a radius r.

Which of the following gives the intensity of the light on the surface?

☒ **A** $P \times 4\pi r^2$

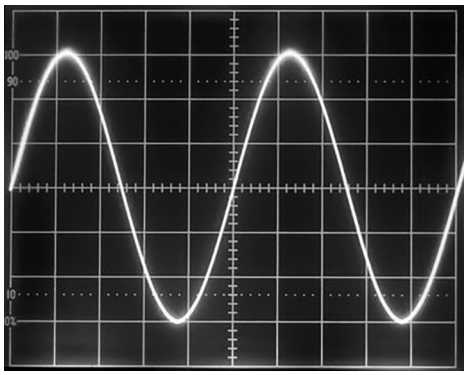
☒ **B** $\dfrac{P}{4\pi r^2}$

☒ **C** $P \times \pi r^2$

☒ **D** $\dfrac{P}{\pi r^2}$

(Total for Question 8 = 1 mark)

9 In an investigation to determine the speed of sound in air, a student sets up an oscilloscope to display the waveform of a sound wave as shown.



The timebase is set to 25 μs / division.

(a) Determine the frequency of the sound wave.

(2)

Frequency = ...

(b) The student sets the timebase on the oscilloscope to a lower value per division.

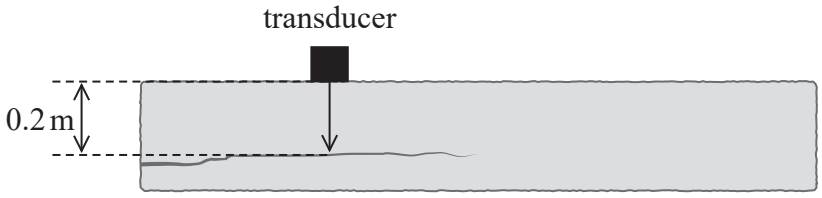
Describe any changes to the appearance of the waveform on the screen.

(1)

(Total for Question 9 = 3 marks)

10 Concrete is a material used in buildings due to its high compressive strength.

(a) A concrete post can be checked for internal cracks using a pulse-echo technique.
A transducer that transmits and receives ultrasound pulses is positioned against the side of the post as shown.



A pulse hits a crack and is reflected and is then detected by the transducer.

Deduce whether a crack at a depth of 0.2 m can be detected.

time between pulses = 160 μs
speed of sound in concrete = 3200 m s^{-1}

(3)

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(b) Another concrete post is reinforced with steel rods, to increase its tensile strength.
A steel rod is under a tensile load of 130 N and extends by 4.0×10^{-4} m.
The steel has not reached its elastic limit.

Calculate the elastic strain energy in the steel rod.

(2)

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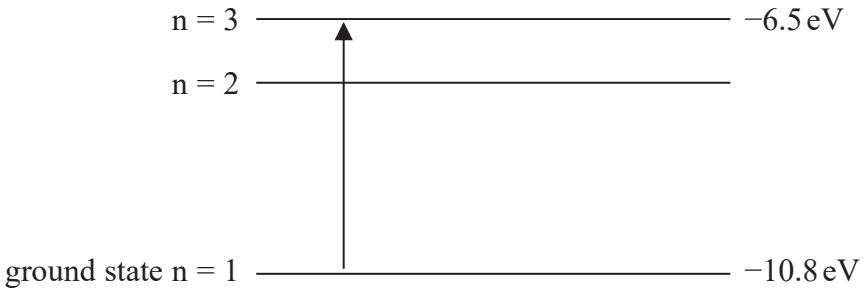
Elastic strain energy = ...

(Total for Question 10 = 5 marks)

11 An electron in its ground state absorbs electromagnetic radiation of wavelength λ.
The energy level diagram represents the resulting energy transition of the electron.



(a) Calculate the wavelength of radiation absorbed by the electron.

(3)

Wavelength = ...

(b) The electron eventually returns to its ground state.

Explain, with reference to the energy level diagram, how this may result in the emission of radiation with a longer wavelength than λ.

(3)

(Total for Question 11 = 6 marks)

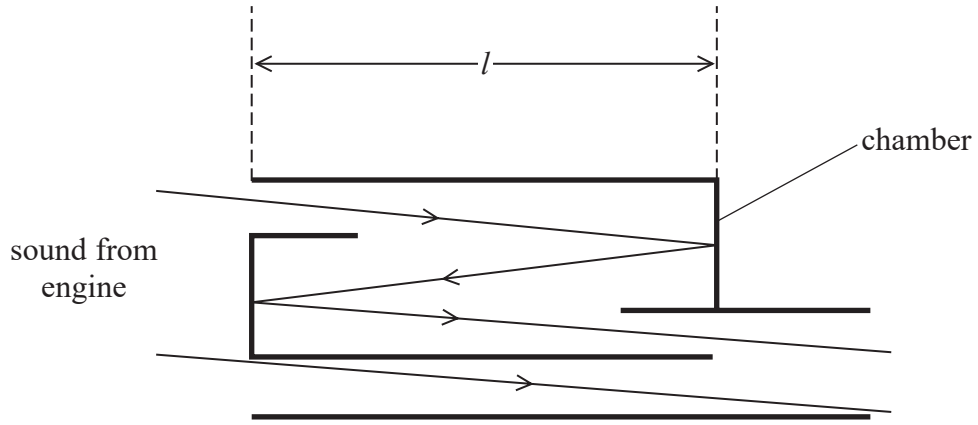
12 Vibrations of a car engine cause a sound wave in air.

(a) Describe how the displacement of air molecules causes pressure variations in the air.

(3)

(b) A silencer is a device fitted to a car to reduce the sound from the engine.
Some sound passes through the silencer chamber and is reflected twice. Some sound passes straight through the chamber without being reflected.

The simplified diagram shows the paths of the sound as it travels through the chamber. Sound leaving the chamber is a combination of sound waves from the two paths. The sound waves are in phase as they enter the chamber.



An engine produces sound with a frequency of about 140 Hz.

Explain why, to reduce this sound, the length l of the chamber should be about 60 cm.

speed of sound in air = 340 m s^{-1}

(4)

(Total for Question 12 = 7 marks)

***13** A student views a laptop screen through a polarising filter. Initially the screen appears normal brightness. He rotates the filter to 90° and observes that the screen appears dark.

Explain what the student observes as he gradually rotates the filter to 180° and then to 270°.

(6)

(Total for Question 13 = 6 marks)

15 The human eye acts as a converging lens system that produces an image on the retina at the back of the eye as shown.

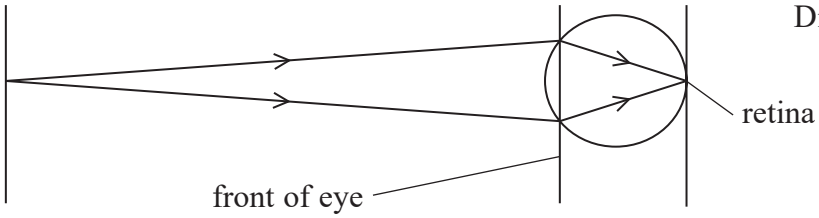
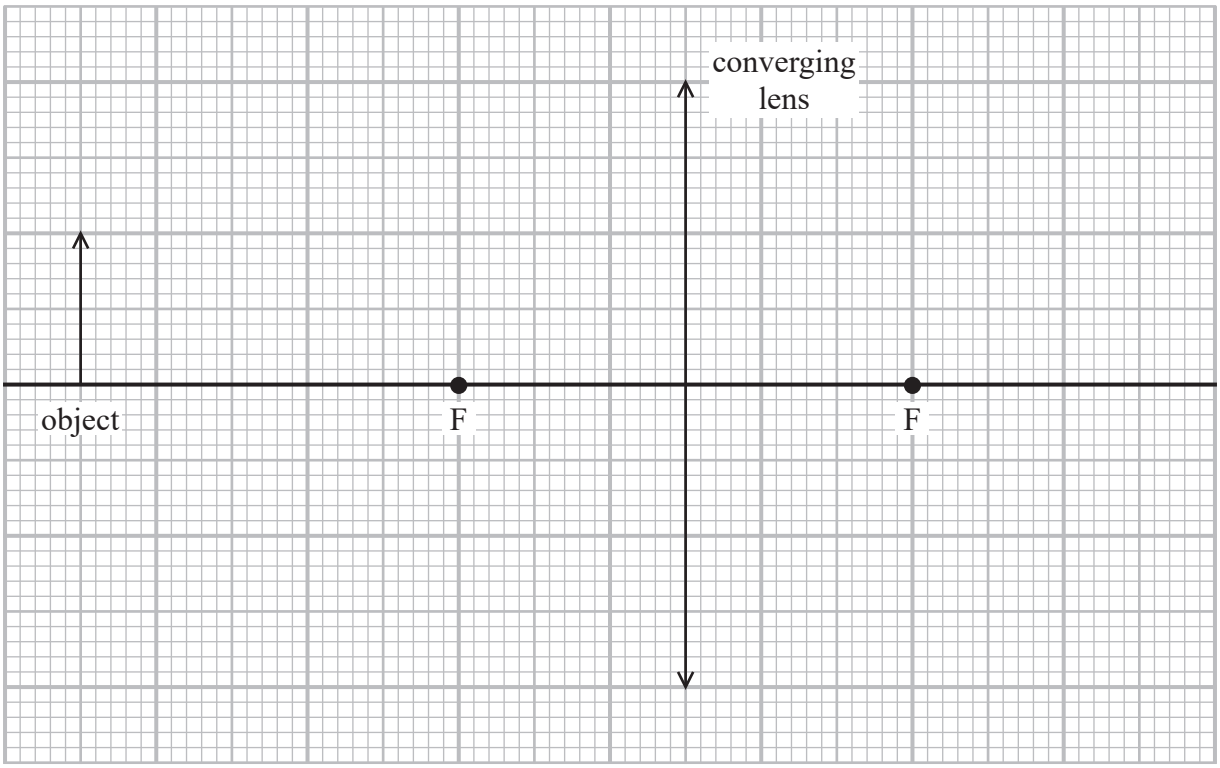


Diagram **NOT** to scale

A person with eyesight problems may wear either diverging or converging contact lenses.

(a) The diagram below shows an object in front of a converging lens.

F is the principal focus.



Determine the position and magnification of the image produced by the lens, by completing a ray diagram.

(4)

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Magnification = ...

(b) A short-sighted eye cannot focus on distant objects, because the power of the eye is too great.

One student with short sight cannot focus on objects further than 1.5 m without wearing her contact lenses.

To view distant objects, it is determined that the combined power of her eye and her contact lens should be 41.7 D.

Determine the power and type of lens needed to correct her vision. Assume the equations for thin lens apply to both lenses.

distance from eye lens to retina = 2.4 cm

(4)

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.....

.....

.....

Power = ...

Type of lens .....

(Total for Question 15 = 8 marks)

TOTAL FOR SECTION A = 56 MARKS

SECTION B

Answer ALL questions in the spaces provided.

16 Read the extract and answer the questions that follow.

In the 17th century there were two proposed theories to explain the refraction of light. Using a wave model, Huygens stated that light slows down when it passes from air to water. Using a particle model, Newton stated that light speeds up when it passes from air to water. Newton's theory was more readily accepted until the speed of light in water was measured in the 19th century.

In the early 20th century, Einstein used observations from the photoelectric effect to provide evidence for the particle model of light.

Nowadays, both the wave model of light and the particle model of light are accepted, as each can be used to explain different aspects of the behaviour of light.

(a) Give two reasons why Huygens' theory for the refraction of light eventually became accepted.

(2)

(b) A ray of light travelling in air is incident on some water with an angle of incidence of 35°. The angle of refraction is 26°.

Deduce whether this is consistent with Huygens' statement about the speed of light as it passes from air to water. Your answer should include a calculation.

(3)

(c) Diffraction and interference can be explained using the wave model of light.

In an investigation to determine the wavelength of light from a laser, the light passed through a diffraction grating with 300 lines per millimetre.
A diffraction pattern consisting of a series of bright dots was observed on a screen.

The following data were recorded:

distance between grating and screen = 2.00 m
distance from central maximum to 2nd order maximum = 89.0 cm.

Calculate the wavelength of light from the laser.

(3)

Wavelength = ...

(d) In a demonstration of the photoelectric effect, electromagnetic radiation is shone onto a clean metal surface. It can be shown that the metal loses negative charge when the radiation has a frequency above a certain threshold frequency.

Explain how the particle model of light is consistent with this observation.

(3)

(e) In the 1920s, experiments demonstrating diffraction of electrons confirmed de Broglie's work on the wave nature of particles.

In one such experiment an electron had a momentum of $4.8 \times 10^{-24}\,\text{kg m s}^{-1}$. Measurements confirmed that the de Broglie wavelength of the electron was $1.40 \times 10^{-10}\,\text{m}$.

Deduce that these observations are consistent with the value of h given on the data sheet at the back of this exam paper.

(3)

(Total for Question 16 = 14 marks)

SECTION A

Answer ALL questions.

All multiple choice questions must be answered with a cross in the box ☒ for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which of the following provides evidence for the particle model of electromagnetic radiation?

☒ **A** diffraction

☒ **B** interference

☒ **C** polarisation

☒ **D** visible line spectra

(Total for Question 1 = 1 mark)

2 In an investigation to determine the Young modulus of steel in the form of a wire, a student plots a straight line graph. The Young modulus is numerically equal to the gradient of the graph.

What quantities did the student plot on each axis on the graph?

	y-axis	*x*-axis
☒ **A**	strain	stress
☒ **B**	stress	strain
☒ **C**	$\frac{1}{\text{strain}}$	stress
☒ **D**	$\frac{1}{\text{stress}}$	strain

(Total for Question 2 = 1 mark)

3 Which of the following is the SI base unit for the Planck constant?

☒ **A** $\text{N m}^{-1}\text{ s}^{-1}$

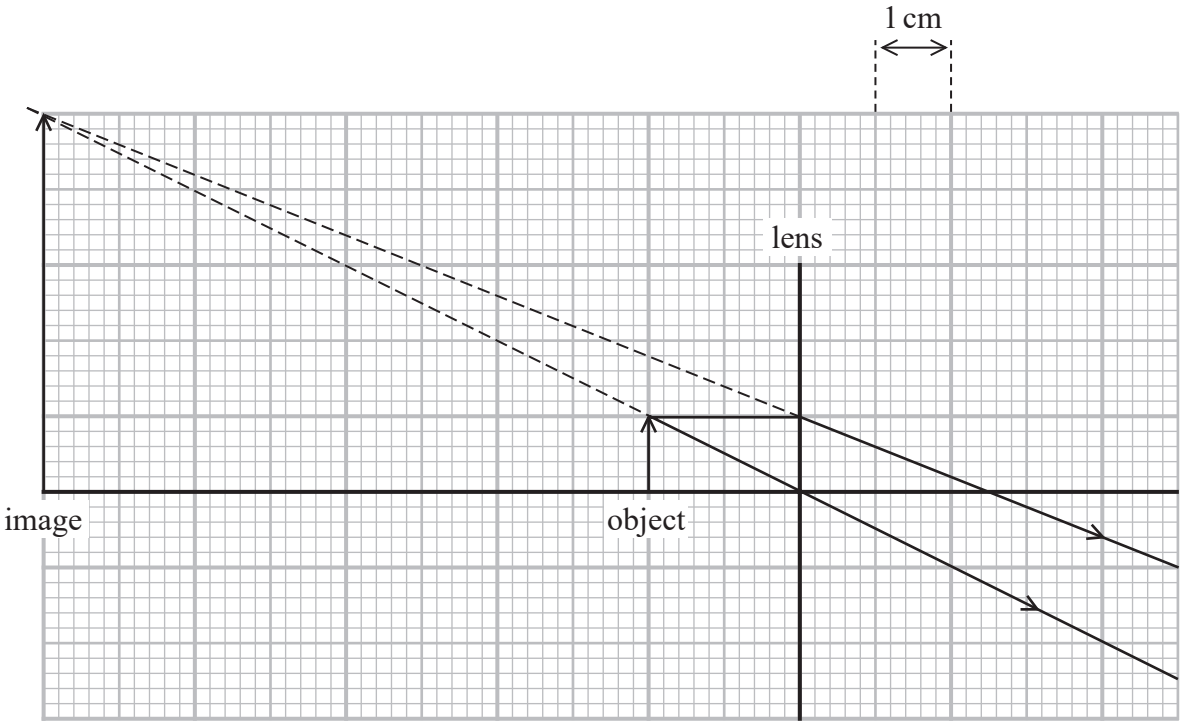
☒ **B** N m s

☒ **C** $\text{kg m}^{2}\text{ s}^{-1}$

☒ **D** $\text{kg m}^{-2}\text{ s}$

(Total for Question 3 = 1 mark)

4 A ray diagram, drawn to scale, is used to locate the size and position of an image formed by a lens as shown.



Which row in the table gives the focal length and the type of lens?

	Focal length / cm	Type of lens
☒ **A**	2.5	converging
☒ **B**	2.5	diverging
☒ **C**	10	converging
☒ **D**	10	diverging

(Total for Question 4 = 1 mark)

5 A student measures the diameter of a steel wire in order to determine the cross-sectional area of the wire. The percentage uncertainty in the measurement of the diameter was 1.8%.

Which of the following is the percentage uncertainty in the value for the cross-sectional area?

☒ **A** 1.8%

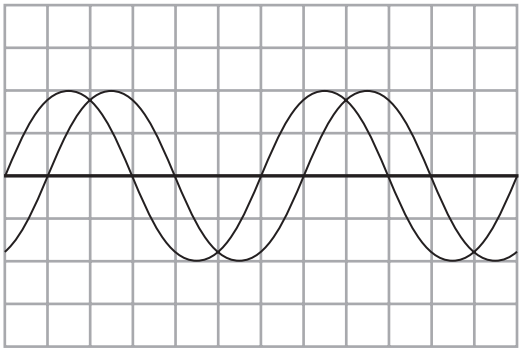
☒ **B** (1.8 + 1.8)%

☒ **C** (1.8 + 1.8 + 1.8)%

☒ **D** (1.8 × 1.8)%

(Total for Question 5 = 1 mark)

6 A two-beam oscilloscope is used to display signals from two microphones as shown.

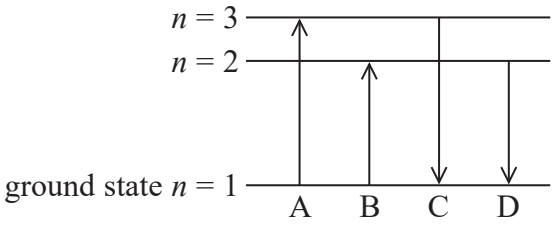


Which of the following could be the phase difference in radians between the traces?

- ☒ **A** $\frac{\pi}{6}$
- ☒ **B** $\frac{\pi}{4}$
- ☒ **C** $\frac{\pi}{3}$
- ☒ **D** $\frac{\pi}{2}$

(Total for Question 6 = 1 mark)

7 The energy level diagram shows four possible energy transitions for an electron in an atom.

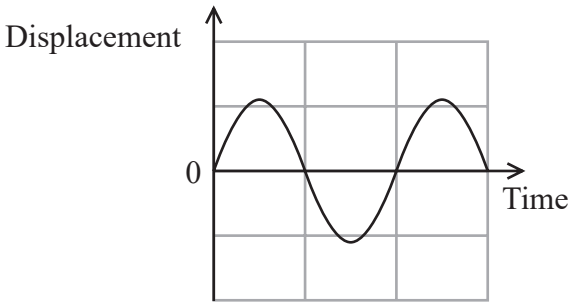


Which arrow shows the transition made by the electron when the atom emits radiation with the longest wavelength?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for Question 7 = 1 mark)

8 A displacement-time graph is shown for a particle in a transverse wave.

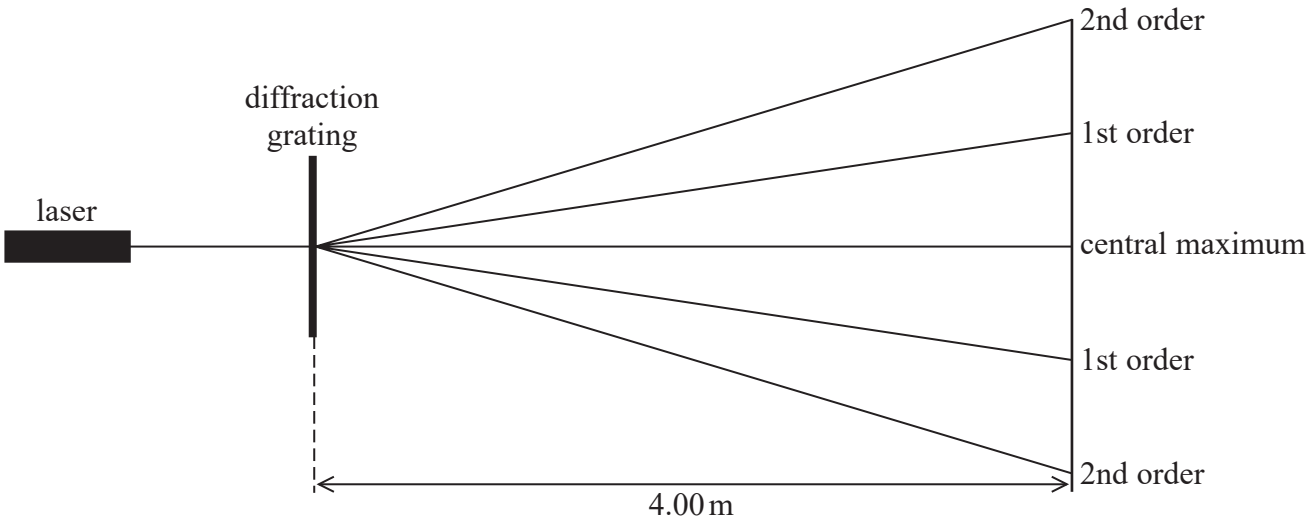


Which property of the wave can **not** be determined directly from the displacement-time graph?

- ☒ **A** amplitude
- ☒ **B** frequency
- ☒ **C** time period
- ☒ **D** wavelength

(Total for Question 8 = 1 mark)

9 A student used a diffraction grating to determine the wavelength of the light emitted by a laser. Light from the laser passed through the diffraction grating and the student observed a pattern on a wall 4 m away. The pattern consisted of a central maximum and 1st and 2nd order maxima as shown.



The student measured the distance between the central and a 2nd order maximum as 1350 mm. The diffraction grating had 300 slits mm^{-1}.

(a) The colours and corresponding wavelengths of light emitted by commonly used lasers are given in the table.

blue	450–490 nm
green	520–560 nm
red	635–700 nm

Deduce the colour of the laser light the student used in this experiment.

(4)

(b) Measuring the distance between the two 2nd order maxima would produce a smaller percentage uncertainty in the value of wavelength.

Give a reason why.

(1)

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(Total for Question 9 = 5 marks)

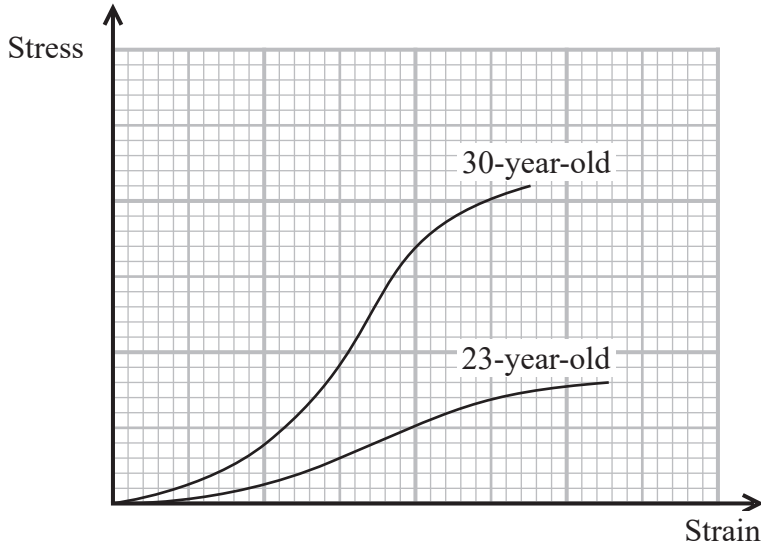
***10** In 1969, astronauts placed an array of mirrors on the surface of the Moon. Scientists can use these to monitor the distance from Earth to the Moon. Light from a laser is used with a pulse-echo technique.

Describe how the distance of the Moon from Earth can be determined using a pulse-echo technique.

(Total for Question 10 = 6 marks)

12 The power of the lens in the human eye changes as the lens changes shape. This enables a person to see objects at different distances clearly. To change the shape, muscles in the eye put the lens under stress.

(a) A stress-strain graph for the eye lens for people of different ages is shown.



(i) State one difference between the lens of a 23-year-old and the lens of a 30-year-old.

(1)

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.....

(ii) Give a reason for your answer, making reference to the graph.

(1)

.....

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(b) A teacher was modelling the human eye. He placed an object 60 cm from a converging lens system. A real image of the object was observed with a magnification of 0.5

The converging lenses that were available to the teacher had powers of 2D, 3D and 4D.

Deduce which lens, or combination of lenses, the teacher used.

(4)

(Total for Question 12 = 6 marks)