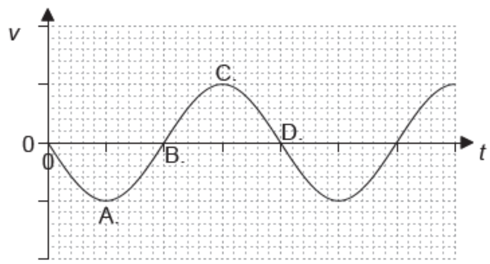
Standing waves *[49 marks]*

1. The graph shows the variation with time *t* of the velocity *v* of an object undergoing simple harmonic motion (SHM). At which velocity does the displacement from the mean position take a maximum positive value? *[1 mark]*



Markscheme

D

2. What is the phase difference, in rad, between the centre of a compression and the centre of a rarefaction for a longitudinal travelling wave? *[1 mark]*

A. 0

B. $\frac{\pi}{2}$

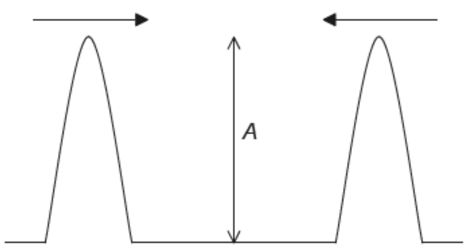
C. π

D. 2π

Markscheme

C

3. Two wave pulses, each of amplitude *A*, approach each other. They then superpose before continuing in their original directions. What is the total amplitude during superposition and the amplitudes of the individual pulses after superposition? *[1 mark]*



	Total amplitude during superposition	Individual amplitudes after superposition
A.	*A*	less than *A*
B.	*A*	*A*
C.	2*A*	less than *A*
D.	2*A*	*A*

Markscheme

D

4. The refractive index for light travelling from medium X to medium Y is $\frac{4}{3}$. The refractive index for light travelling from medium Y to medium Z is $\frac{3}{5}$. What is the refractive index for light travelling from medium X to medium Z? *[1 mark]*

A. $\frac{4}{5}$

B. $\frac{15}{12}$

C. $\frac{5}{4}$

D. $\frac{29}{15}$

Markscheme

A

5. A pipe of fixed length is closed at one end. What is $\frac{\text{third harmonic frequency of pipe}}{\text{first harmonic frequency of pipe}}$? *[1 mark]*

A. $\frac{1}{5}$

B. $\frac{1}{3}$

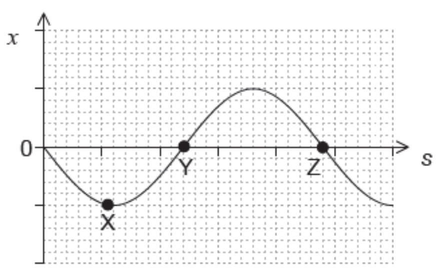
C. 3

D. 5

Markscheme

C

6. The graph shows the variation with position *s* of the displacement *x* of a wave undergoing simple harmonic motion (SHM). *[1 mark]*



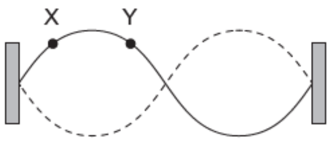
What is the magnitude of the velocity at the displacements X, Y and Z?

	X	Y	Z
A.	maximum	zero	maximum
B.	zero	maximum	maximum
C.	maximum	maximum	zero
D.	zero	maximum	zero

Markscheme

B

7. The diagram shows a second harmonic standing wave on a string fixed at both ends. *[1 mark]*



What is the phase difference, in rad, between the particle at X and the particle at Y?

A. 0

B. $\frac{\pi}{4}$

C. $\frac{\pi}{2}$

D. $\frac{3\pi}{4}$

Markscheme

A

8. A spring loaded with mass *m* oscillates with simple harmonic motion. The amplitude of the motion is *A* and the spring has total energy *E*. What is the total energy of the spring when the mass is increased to 3 *m* and the amplitude is increased to 2 *A*? *[1 mark]*

A. 2*E*

B. 4*E*

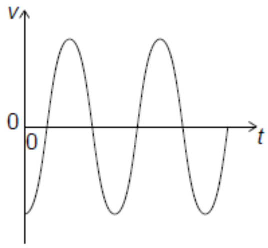
C. 12*E*

D. 18*E*

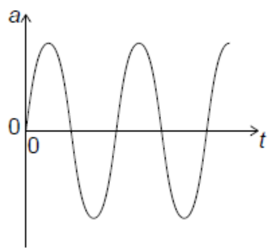
Markscheme

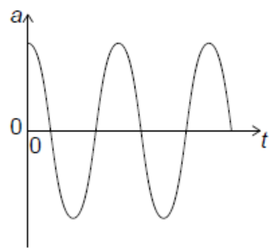
B

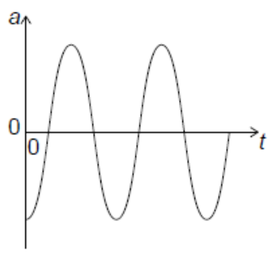
9. A particle undergoes simple harmonic motion (SHM). The graph shows the variation of velocity v of the particle with time t. *[1 mark]*

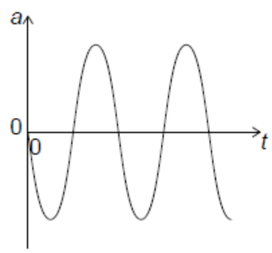


What is the variation with time of the acceleration a of the particle?

A. 

B. 

C. 

D. 

Markscheme

A

10. What statement about X-rays and ultraviolet radiation is correct? *[1 mark]*

A. X-rays travel faster in a vacuum than ultraviolet waves.

B. X-rays have a higher frequency than ultraviolet waves.

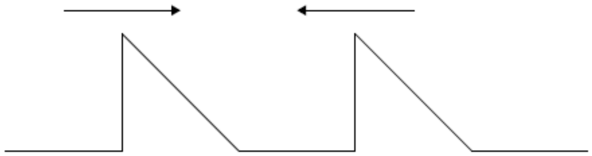
C. X-rays cannot be diffracted unlike ultraviolet waves.

D. Microwaves lie between X-rays and ultraviolet in the electromagnetic spectrum.

Markscheme

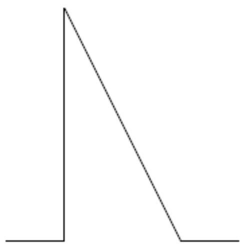
B

11. Two pulses are travelling towards each other. *[1 mark]*

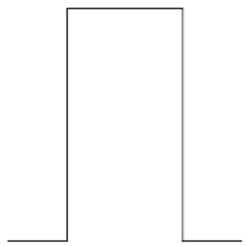


What is a possible pulse shape when the pulses overlap?

A.

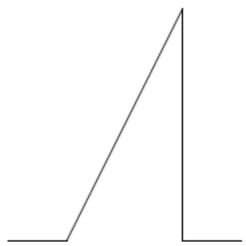


B.



C.

D.



Markscheme

A

12. Unpolarized light of intensity I_0 is incident on the first of two polarizing sheets. Initially the planes of polarization of the sheets are perpendicular. *[1 mark]*

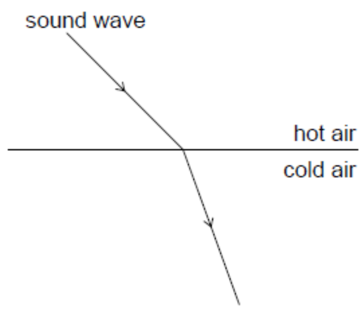
Which sheet must be rotated and by what angle so that light of intensity $\frac{I_0}{4}$ can emerge from the second sheet?

	Rotated sheet	Angle of rotation
A.	1 only	$\cos^{-1}\frac{\sqrt{2}}{2}$
B.	2 only	$\cos^{-1}\frac{1}{2}$
C.	1 or 2	$\cos^{-1}\frac{\sqrt{2}}{2}$
D.	1 or 2	$\cos^{-1}\frac{1}{2}$

Markscheme

C

13. When a sound wave travels from a region of hot air to a region of cold air, it refracts as shown. *[1 mark]*



What changes occur in the frequency and wavelength of the sound as it passes from the hot air to the cold air?

	Frequency	Wavelength
A.	unchanged	increases
B.	unchanged	decreases
C.	increases	increases
D.	decreases	decreases

Markscheme

B

14. In simple harmonic oscillations which two quantities always have opposite directions? *[1 mark]*

A. Kinetic energy and potential energy

B. Velocity and acceleration

C. Velocity and displacement

D. Acceleration and displacement

Markscheme

D

15. A girl in a stationary boat observes that 10 wave crests pass the boat every minute. What is the period of the water waves? *[1 mark]*

A. $\frac{1}{10}$ min

B. $\frac{1}{10}$ min^{-1}

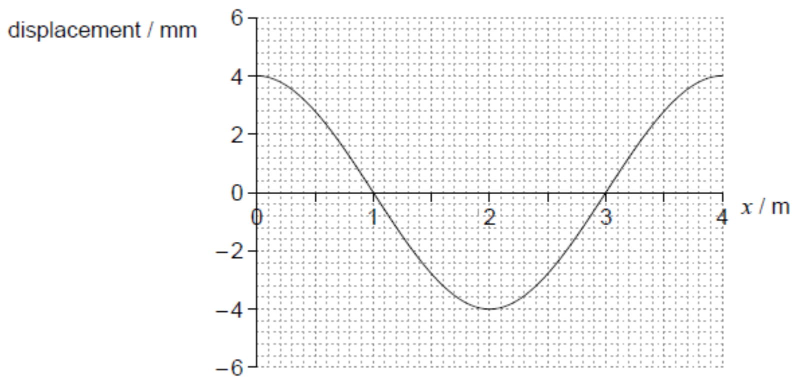
C. 10 min

D. 10 min^{-1}

Markscheme

A

16. The graph shows the variation with distance x of the displacement of the particles of a medium in which a longitudinal wave is travelling from left to right. Displacements to the right of equilibrium positions are positive. *[1 mark]*



Which point is at the centre of a compression?

A. $x = 0$

B. $x = 1$ m

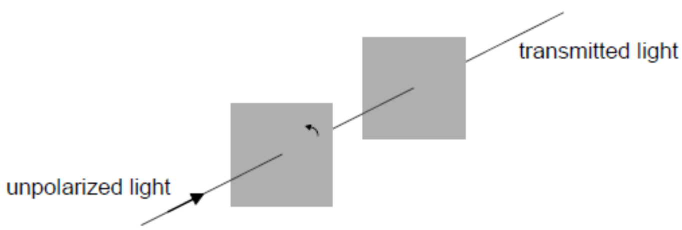
C. $x = 2$ m

D. $x = 3$ m

Markscheme

B

17. A beam of unpolarized light is incident on the first of two parallel polarizers. The transmission axes of the two polarizers are initially parallel. *[1 mark]*



The first polarizer is now rotated about the direction of the incident beam by an angle smaller than 90°. Which gives the changes, if any, in the intensity and polarization of the transmitted light?

	Intensity	Polarization
A.	different	no change
B.	different	different
C.	no change	no change
D.	no change	different

Markscheme

A

18. The frequency of the first harmonic standing wave in a pipe that is open at both ends is 200 Hz. What is the frequency of the first harmonic in a pipe of the same length that is open at one end and closed at the other? *[1 mark]*

A. 50 Hz

B. 75 Hz

C. 100 Hz

D. 400 Hz

Markscheme

C

19. A travelling wave of period 5.0 ms travels along a stretched string at a speed of 40 m s $^{-1}$. Two points on the string are 0.050 m apart. *[1 mark]*

What is the phase difference between the two points?

A. 0

B. $\frac{\pi}{2}$

C. π

D. 2π

Markscheme

B

20. Properties of waves are *[1 mark]*

I. polarization
II. diffraction
III. refraction

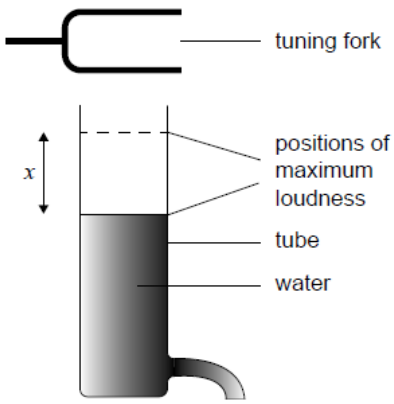
Which of these properties apply to sound waves?

A. I and II
B. I and III
C. II and III
D. I, II and III

Markscheme

C

21. Water is draining from a vertical tube that was initially full. A vibrating tuning fork is held near the top of the tube. For two positions of the water surface only, the sound is at its maximum loudness. *[1 mark]*



The distance between the two positions of maximum loudness is *x*.

What is the wavelength of the sound emitted by the tuning fork?

A. $\frac{x}{2}$

B. x

C. $\frac{3x}{2}$

D. $2x$

Markscheme

D

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22. A pendulum oscillating near the surface of the Earth swings with a time period T. What is the time period of the same pendulum near the surface of the planet Mercury where the gravitational field strength is $0.4g$? *[1 mark]*

A. $0.4T$

B. $0.6T$

C. $1.6T$

D. $2.5T$

Markscheme

C

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23. A mass oscillates with simple harmonic motion (SHM) of amplitude x_0. Its total energy is 16 J. *[1 mark]*

What is the kinetic energy of the mass when its displacement is $\frac{x_0}{2}$?

A. 4 J

B. 8 J

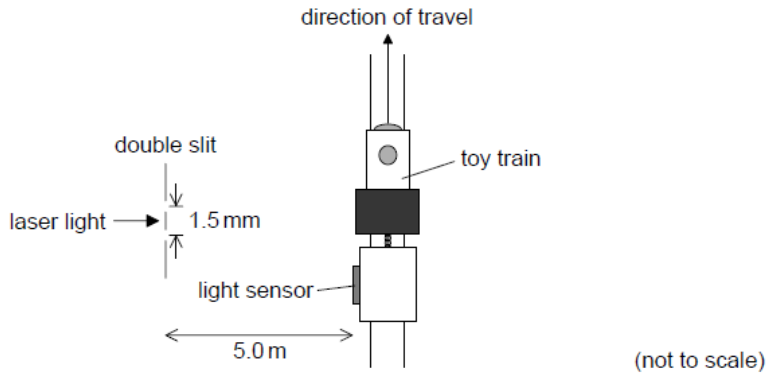
C. 12 J

D. 16 J

Markscheme

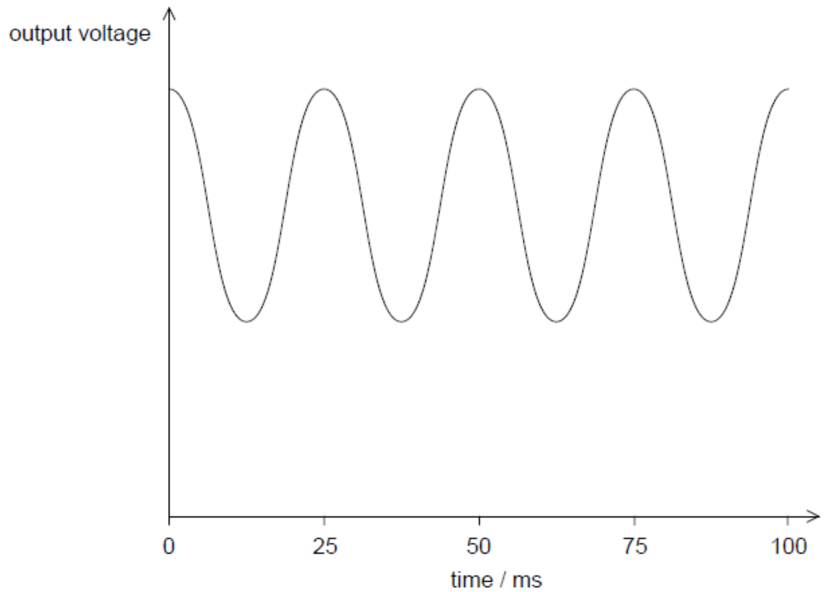
C

A student investigates how light can be used to measure the speed of a toy train.



Light from a laser is incident on a double slit. The light from the slits is detected by a light sensor attached to the train.

The graph shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits. The output voltage is proportional to the intensity of light incident on the sensor.



24a. Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. *[3 marks]*

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Markscheme

«light» superposes/interferes

pattern consists of «intensity» maxima and minima
OR
consisting of constructive and destructive «interference»

voltage peaks correspond to interference maxima

24b. The slits are separated by 1.5 mm and the laser light has a wavelength of 6.3 x 10^{-7} m. The slits are 5.0 m from the train track. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum. *[1 mark]*

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Markscheme

«$s = \frac{\lambda D}{d} = \frac{6.3 \times 10^{-7} \times 5.0}{1.5 \times 10^{-3}} =$» 2.1 x 10^{-3} «m»

If no unit assume m.
Correct answer only.

24c. Estimate the speed of the train. *[2 marks]*

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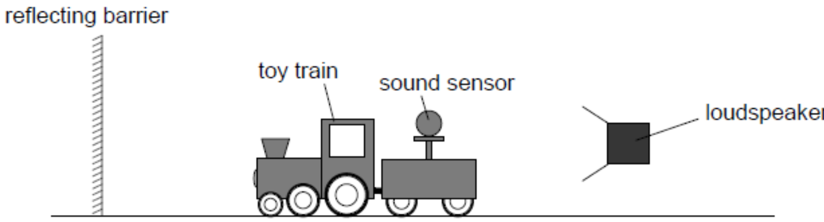
Markscheme

correct read-off from graph of 25 m s

v = «$\frac{x}{t} = \frac{2.1 \times 10^{-3}}{25 \times 10^{-3}} =$» 8.4 x 10^{-2} «m s^{-1}»

Allow ECF from (b)(i)

24d. In another experiment the student replaces the light sensor with a sound sensor. The train travels away from a loudspeaker that is emitting sound waves of constant amplitude and frequency towards a reflecting barrier. *[2 marks]*



The sound sensor gives a graph of the variation of output voltage with time along the track that is similar in shape to the graph shown in the resource. Explain how this effect arises.

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Markscheme

ALTERNATIVE 1

«reflection at barrier» leads to two waves travelling in opposite directions

mention of formation of standing wave

maximum corresponds to antinode/maximum displacement «of air molecules»
OR
complete cancellation at node position

A student is investigating a method to measure the mass of a wooden block by timing the period of its oscillations on a spring.

25a. Describe the conditions required for an object to perform simple harmonic motion (SHM). *[2 marks]*

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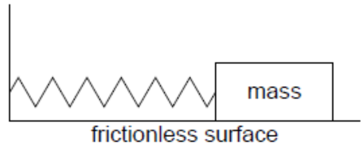
Markscheme

acceleration/restoring force is proportional to displacement
and in the opposite direction/directed towards equilibrium

A 0.52 kg mass performs simple harmonic motion with a period of 0.86 s when attached to the spring. A wooden block attached to the same spring oscillates with a period of 0.74 s.



25b. Calculate the mass of the wooden block. *[2 marks]*

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Markscheme

ALTERNATIVE 1

$\frac{T_1^2}{T_2^2} = \frac{m_1}{m_2}$

mass = 0.38 / 0.39 «kg»

ALTERNATIVE 2

«use of $T = 2\pi\sqrt{\frac{m}{k}}$» k = 28 «Nm^{-1}»

«use of $T = 2\pi\sqrt{\frac{m}{k}}$» m = 0.38 / 0.39 «kg»

Allow ECF from MP1.

25c. In carrying out the experiment the student displaced the block horizontally by 4.8 cm from the equilibrium position. Determine the total energy in the oscillation of the wooden block. *[3 marks]*

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Markscheme

ω = «$\frac{2\pi}{0.74}$» = 8.5 «rads^{-1}»

total energy = $\frac{1}{2} \times 0.39 \times 8.5^2 \times (4.8 \times 10^{-2})^2$

= 0.032 «J»

Allow ECF from (b) and incorrect ω.

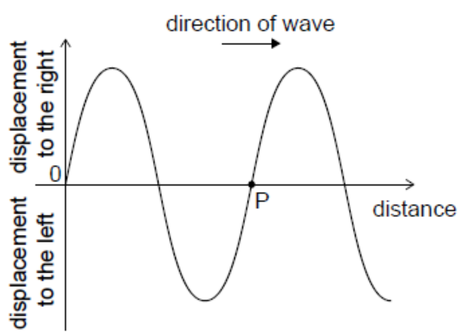
Allow answer using k from part (b).

25d. A second identical spring is placed in parallel and the experiment in (b) is repeated. Suggest how this change affects the fractional uncertainty in the mass of the block. *[3 marks]*

Markscheme

spring constant/k/stiffness would increase
T would be smaller
fractional uncertainty in *T* would be greater, so fractional uncertainty of mass of block would be greater

With the block stationary a longitudinal wave is made to travel through the original spring from left to right. The diagram shows the variation with distance *x* of the displacement *y* of the coils of the spring at an instant of time.



A point on the graph has been labelled that represents a point P on the spring.

25e. State the direction of motion of P on the spring. *[1 mark]*

Markscheme

left

25f. Explain whether P is at the centre of a compression or the centre of a rarefaction. *[2 marks]*

Markscheme

coils to the right of P move right and the coils to the left move left

hence P at centre of rarefaction

Do not allow a bald statement of rarefaction or answers that don't include reference to the movement of coils.

Allow ECF from MP1 if the movement of the coils imply a compression.

26. A body undergoes one oscillation of simple harmonic motion (shm). What is correct for the direction of the acceleration of the body and the direction of its velocity? *[1 mark]*

A. Always opposite
B. Opposite for half a period
C. Opposite for a quarter of a period
D. Never opposite

Markscheme

B

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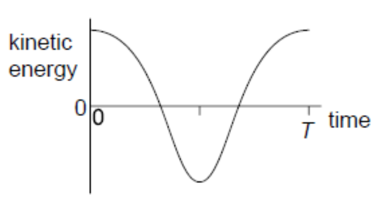
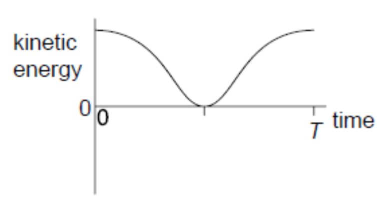
27. A particle oscillates with simple harmonic motion (shm) of period T. Which graph shows the variation with time of the kinetic energy of the particle? *[1 mark]*

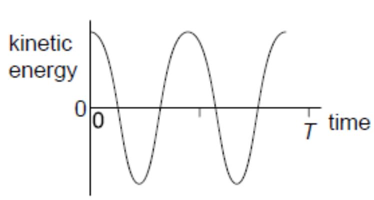
A.



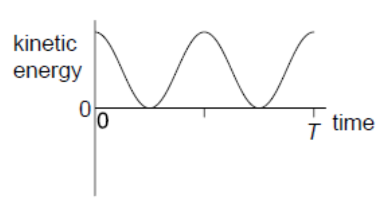
B.



C.



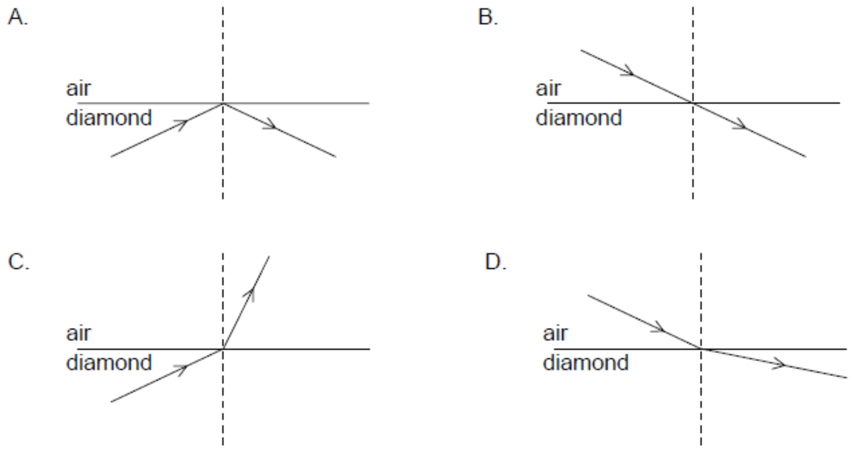
D.



Markscheme

D

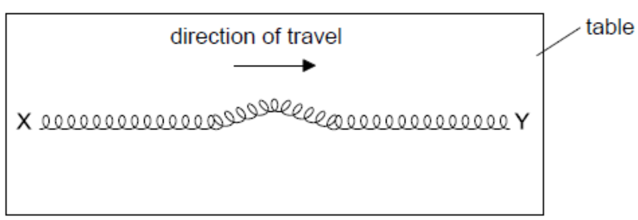
28. A light ray is incident on an air–diamond boundary. The refractive index of diamond is greater than 1. Which diagram shows the correct path of the light ray? *[1 mark]*



Markscheme

A

29. A spring XY lies on a frictionless table with the end Y free. *[1 mark]*



A horizontal pulse travels along the spring from X to Y. What happens when the pulse reaches Y?

A. The pulse will be reflected towards X and inverted.
B. The pulse will be reflected towards X and not be inverted.
C. Y will move and the pulse will disappear.
D. Y will not move and the pulse will disappear.

Markscheme

B

30. A student stands a distance L from a wall and claps her hands. Immediately on hearing the reflection from the wall she claps her hands again. She continues to do this, so that successive claps and the sound of reflected claps coincide. The frequency at which she claps her hands is f. What is the speed of sound in air? *[1 mark]*

A. $\frac{L}{2f}$

B. $\frac{L}{f}$

C. Lf

D. $2Lf$

Markscheme

D