1. A mass at the end of a vertical spring and a simple pendulum perform oscillations on Earth that are simple harmonic with time period $T$. Both the pendulum and the mass-spring system are taken to the Moon. The acceleration of free fall on the Moon is smaller than that on Earth. What is correct about the time periods of the pendulum and the mass-spring system on the Moon?

<table>
<thead>
<tr>
<th>Simple pendulum</th>
<th>Mass-spring system</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T$</td>
<td>$T$</td>
</tr>
<tr>
<td>greater than $T$</td>
<td>$T$</td>
</tr>
<tr>
<td>greater than $T$</td>
<td>greater than $T$</td>
</tr>
<tr>
<td>$T$</td>
<td>greater than $T$</td>
</tr>
</tbody>
</table>

2. Monochromatic light of wavelength $\lambda$ in air is incident normally on a thin film of refractive index $n$. The film is surrounded by air. The intensity of the reflected light is a minimum. What is a possible thickness of the film?

A. $\frac{\lambda}{4n}$
B. $\frac{3\lambda}{4n}$
C. $\frac{\lambda}{n}$
D. $\frac{5\lambda}{4n}$

 Markscheme

C

Examiners report

[N/A]
3. Monochromatic light is incident on 4 rectangular, parallel slits. The first principal maximum is observed at an angle $\theta$ to the direction of the incident light. The number of slits is increased to 8 each having the same width and spacing as the first 4.

Three statements about the first principal maximum with 8 slits are

I. the angle at which it is observed is greater than $\theta$
II. its intensity increases
III. its width decreases.

Which statements are correct?
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

**Markscheme**

C

**Examiners report**

[N/A]

4. Two lines X and Y in the emission spectrum of hydrogen gas are measured by an observer stationary with respect to the gas sample.

![Emission Spectrum Diagram](attachment:image.png)

The emission spectrum is then measured by an observer moving away from the gas sample. What are the correct shifts $X^*$ and $Y^*$ for spectral lines X and Y?

A. ![Option A](attachment:image.png)
B. ![Option B](attachment:image.png)
C. ![Option C](attachment:image.png)
D. ![Option D](attachment:image.png)

**Markscheme**

C
5. A simple pendulum bob oscillates as shown. [1 mark]

At which position is the resultant force on the pendulum bob zero?
A. At position A
B. At position B
C. At position C
D. Resultant force is never zero during the oscillation

Markscheme
D

Examiners report
[N/A]

6. A beam of monochromatic light is incident on a single slit and a diffraction pattern forms [1 mark] on the screen.

What change will increase θ_b?
A. Increase the width of the slit
B. Decrease the width of the slit
C. Increase the distance between the slit and the screen
D. Decrease the distance between the slit and the screen

Markscheme
B
7. A beam of monochromatic light is incident on a diffraction grating of \( N \) lines per unit length. The angle between the first orders is \( \theta_1 \).

What is the wavelength of the light?

A. \( \frac{\sin \theta_1}{N} \)

B. \( N \sin \theta_1 \)

C. \( N \sin \left( \frac{\theta_1}{2} \right) \)

D. \( \frac{\sin \left( \frac{\theta_1}{2} \right)}{N} \)

**Markscheme**

D

**Examiners report**

[N/A]
A train is approaching an observer with constant speed $c$. The train emits sound of wavelength $\lambda$. What is the observed speed of the sound and observed wavelength as the train approaches?

\[
\frac{c}{34}
\]

where $c$ is the speed of sound in still air. The train emits sound of wavelength $\lambda$. What is the observed speed of the sound and observed wavelength as the train approaches?

<table>
<thead>
<tr>
<th>Speed of sound</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c$</td>
<td>$\frac{33\lambda}{34}$</td>
</tr>
<tr>
<td>$\frac{35c}{34}$</td>
<td>$\frac{33\lambda}{34}$</td>
</tr>
<tr>
<td>$c$</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>$\frac{35c}{34}$</td>
<td>$\lambda$</td>
</tr>
</tbody>
</table>

**Markscheme**

A

**Examiners report**

[N/A]
An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.

The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

9a. At position B the rope starts to extend. Calculate the speed of the block at position B. [2 marks]

\[ v^2 = u^2 + 2as \]

\[ v = \sqrt{2 \times 60.0 \times 9.81} = 34.3 \text{ ms}^{-1} \]

[2 marks]

Examiners report

[N/A]
At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

9b. Determine the magnitude of the average resultant force acting on the block between B and C. [2 marks]

**Markscheme**

use of impulse \( F_{\text{ave}} \times \Delta t = \Delta p \)

OR

use of \( F = ma \) with average acceleration

OR

\[ F = \frac{80.0 \times 34.3}{0.759} \]

3620 N

Allow ECF from (a).

[2 marks]

**Examiners report**

[N/A]
9c. Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block.

**Markscheme**

- upwards
- clearly longer than weight

*For second marking point allow ECF from (b)(i) providing line is upwards.*

[2 marks]

**Examiners report**

[N/A]

9d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. [2 marks]
For the rope and block, describe the energy changes that take place

9e. between A and B.  

Markscheme  
(loss in) gravitational potential energy (of block) into kinetic energy (of block)  

Must see names of energy (gravitational potential energy and kinetic energy) – Allow for reasonable variations of terminology (eg energy of motion for KE).  

[1 mark]  

Examiners report  
[N/A]  

9f. between B and C.  

Markscheme  
[1 mark]  

Examiners report  
[N/A]
9g. The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope.

\[ k \text{ can be determined using } E_{\text{PE}} = \frac{1}{2} kx^2 \]

Correct statement or equation showing
GPE at A = EPE at C

\text{OR}

(GPE + KE) at B = EPE at C

Candidate must clearly indicate the energy associated with either position A or B for MP2.

[2 marks]
An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.

The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

In another test, the block hangs in equilibrium at the end of the same elastic rope. The elastic constant of the rope is 400 Nm$^{-1}$. The block is pulled 3.50 m vertically below the equilibrium position and is then released from rest.

9h. Calculate the time taken for the block to return to the equilibrium position for the first time.

\[ T = 2\pi \sqrt{\frac{80.0}{400}} = 2.81 \text{ s} \]

\[ \text{time} = \frac{T}{4} = 0.702 \text{ s} \]

**Markscheme**

Award [0] for kinematic solutions that assume a constant acceleration.

[2 marks]

**Examiners report**

[N/A]
Calculate the speed of the block as it passes the equilibrium position. [2 marks]

Markscheme

**ALTERNATIVE 1**
\[ \omega = \frac{2\pi}{2.81} = 2.24 \text{ rad s}^{-1} \]
\[ v = 2.24 \times 3.50 = 7.84 \text{ ms}^{-1} \]

**ALTERNATIVE 2**
\[ \frac{1}{2} kx^2 = \frac{1}{2} mv^2 \quad \text{OR} \quad \frac{1}{2} 400 \times 3.5^2 = \frac{1}{2} 80v^2 \]
\[ v = 7.84 \text{ ms}^{-1} \]

Award [0] for kinematic solutions that assume a constant acceleration.
Allow ECF for \( T \) from (e)(i).
[2 marks]

Examiners report

[N/A]
A beam of coherent monochromatic light from a distant galaxy is used in an optics experiment on Earth.

The beam is incident normally on a double slit. The distance between the slits is 0.300 mm. A screen is at a distance $D$ from the slits. The diffraction angle $\theta$ is labelled.

10a. A series of dark and bright fringes appears on the screen. Explain how a dark fringe is formed.

**Markscheme**

superposition of light from each slit / interference of light from both slits

with path/phase difference of any half-odd multiple of wavelength/any odd multiple of $\pi$ (in words or symbols)

producing destructive interference

*Ignore any reference to crests and troughs.*

[3 marks]

**Examiners report**

[N/A]
A beam of coherent monochromatic light from a distant galaxy is used in an optics experiment on Earth.

The beam is incident normally on a double slit. The distance between the slits is 0.300 mm. A screen is at a distance \( D \) from the slits. The diffraction angle \( \theta \) is labelled.

10b. Outline why the beam has to be coherent in order for the fringes to be visible.  

**Markscheme**

Light waves (from slits) must have constant phase difference / no phase difference / be in phase

*OWTTE*

[1 mark]

**Examiners report**

[N/A]

10c. The wavelength of the beam as observed on Earth is 633.0 nm. The separation between a dark and a bright fringe on the screen is 4.50 mm. Calculate \( D \).

[2 marks]
10d. Calculate the angular separation between the central peak and the missing peak in the double-slit interference intensity pattern. State your answer to an appropriate number of significant figures. [3 marks]
Markscheme

\[ \sin \theta = \frac{4 \times 633.0 \times 10^{-9}}{0.300 \times 10^{-3}} \]

\[ \sin \theta = 0.0084401… \]

final answer to three sig figs (eg 0.00844 or 8.44 \times 10^{-3})

Allow ECF from (a)(iii).
Award [1] for 0.121 rad (can award MP3 in addition for proper sig fig)
Accept calculation in degrees leading to 0.481 degrees.
Award MP3 for any answer expressed to 3sf.

[3 marks]

Examiners report

[N/A]

10e. Deduce, in mm, the width of one slit. \[ \text{[2 marks]} \]

Markscheme

use of diffraction formula \( b = \frac{\lambda}{\theta} \)

OR

\[ \frac{633.0 \times 10^{-9}}{0.00844} \]

\( \approx 7.5 \times 10^{-2} \) \( \times \) \( \text{mm} \)

Allow ECF from (b)(i).

[2 marks]
10f. The wavelength of the light in the beam when emitted by the galaxy was 621.4 nm.

Explain, without further calculation, what can be deduced about the relative motion of the galaxy and the Earth.

Markscheme

wavelength increases (so frequency decreases) / light is redshifted
galaxy is moving away from Earth

Allow ECF for MP2 (ie wavelength decreases so moving towards).

[2 marks]
A small ball of mass $m$ is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.

The normal reaction force $N$ makes an angle $\theta$ to the horizontal.

11a. State the direction of the resultant force on the ball. [1 mark]

Markscheme

towards the centre «of the circle» / horizontally to the right

Do not accept towards the centre of the bowl [1 mark]

Examiners report

[N/A]

11b. On the diagram, construct an arrow of the correct length to represent the weight of the ball. [2 marks]
Markscheme

downward vertical arrow of any length
arrow of correct length

Judge the length of the vertical arrow by eye. The construction lines are not required. A label is not required

eg:

[2 marks]

Examiners report

[N/A]

11c. Show that the magnitude of the net force $F$ on the ball is given by the following equation. [3 marks]

$$F = \frac{mg}{\tan \theta}$$
Markscheme

**ALTERNATIVE 1**

\[ F = N \cos \theta \]
\[ mg = N \sin \theta \]

dividing/substituting to get result

**ALTERNATIVE 2**

right angle triangle drawn with \( F, N \) and \( W/mg \) labelled
angle correctly labelled and arrows on forces in correct directions
correct use of trigonometry leading to the required relationship

\[ \tan \theta = \frac{O}{A} = \frac{mg}{F} \]

[3 marks]

Examiners report

[N/A]

11d. The radius of the bowl is 8.0 m and \( \theta = 22^\circ \). Determine the speed of the ball. [4 marks]
11e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl.

\[
\text{Markscheme}
\]

\[
\frac{mg}{\tan \theta} = m\frac{v^2}{r}
\]

\[r = R \cos \theta\]

\[v = \sqrt{\frac{gR \cos \theta}{\sin \theta}} / \sqrt{\frac{gR \cos \theta}{\tan \theta} / \sqrt{0.81 \times 8.0 \cos 22}}\]

\[v = 13.4/13 \text{ ms}^{-1}\]

Award [4] for a bald correct answer
Award [3] for an answer of 13.9/14 «ms\(^{-1}\)». MP2 omitted

[4 marks]

Examiners report

[N/A]
The ball is now displaced through a small distance $x$ from the bottom of the bowl and is then released from rest.

The magnitude of the force on the ball towards the equilibrium position is given by

$$\frac{mgx}{R}$$

where $R$ is the radius of the bowl.

11f. Outline why the ball will perform simple harmonic oscillations about the equilibrium position. 

[1 mark]

Markscheme

the «restoring» force/acceleration is proportional to displacement

Direction is not required

[1 mark]

Examiners report

[N/A]

11g. Show that the period of oscillation of the ball is about 6 s.

[2 marks]
Markscheme

\[ \omega = \sqrt{\frac{g}{R}} = \sqrt{\frac{9.81}{8.0}} \approx 1.107 \text{ s}^{-1} \]

\[ T = \frac{2\pi}{\omega} = \frac{2\pi}{1.107} \approx 5.7 \text{ s} \]

Allow use of or \( g = 9.8 \) or 10

Award [0] for a substitution into \( T = 2\pi \sqrt{\frac{I}{g}} \)

[2 marks]

Examiners report

[N/A]

11h. The amplitude of oscillation is 0.12 m. On the axes, draw a graph to show the variation of the velocity \( v \) of the ball during one period.

![Graph showing velocity variation](image)
12a. Monochromatic light from two identical lamps arrives on a screen. \[1 \text{ mark}\]

The intensity of light on the screen from each lamp separately is \(I_0\).

On the axes, sketch a graph to show the variation with distance \(x\) on the screen of the intensity \(I\) of light on the screen.
Markscheme

horizontal straight line through $I = 2$

$eg. \begin{array}{c}
  6 \\
  4 \\
  2 \\
\end{array}$

Accept a curve that falls from $I = 2$ as distance increases from centre but not if it falls to zero.

[1 mark]

Examiners report

[N/A]
12b. Monochromatic light from a single source is incident on two thin, parallel slits. [3 marks]

The following data are available.

- Slit separation = 0.12 mm
- Wavelength = 680 nm
- Distance to screen = 3.5 m

The intensity $I$ of light at the screen from each slit separately is $I_0$. Sketch, on the axes, a graph to show the variation with distance $x$ on the screen of the intensity of light on the screen for this arrangement.
Markscheme
«standard two slit pattern»
general shape with a maximum at \( x = 0 \)
maxima at \( 4l_0 \)
maxima separated by «
\[
\frac{D\lambda}{s} = \text{»} 2.0 \text{ cm}
\]

Accept single slit modulated pattern provided central maximum is at 4. ie height of peaks decrease as they go away from central maximum. Peaks must be of the same width

[3 marks]

Examiners report
[N/A]

12c. The slit separation is increased. Outline one change observed on the screen. [1 mark]

Markscheme
fringe width/separation decreases
\( OR \)
more maxima seen
[1 mark]

Examiners report
[N/A]
The graph below represents the variation with time $t$ of the horizontal displacement $x$ of a mass attached to a vertical spring.

13a. Describe the motion of the spring-mass system. [1 mark]

Markscheme
damped oscillation / OWTTE
[1 mark]

Examiners report
[N/A]

The total mass for the oscillating system is 30 kg. For this system

13b. determine the initial energy. [1 mark]
Markscheme

\[ E = \frac{1}{2} \times 30 \times \pi^2 \times 0.8^2 \approx 95 \text{ J} \]

Allow initial amplitude between 0.77 to 0.80, giving range between: 88 to 95 J.

[1 mark]

Examiners report

[N/A]

13c. calculate the Q at the start of the motion. [2 marks]

Markscheme

\[ \Delta E = 95 - \frac{1}{2} \times 30 \times \pi^2 \times 0.72^2 = 18 \text{ J} \]

\[ Q = 2\pi \frac{95}{18} = 33 \]

Accept values between 0.70 and 0.73, giving a range of \( \Delta E \) between 22 and 9, giving \( Q \) between 27 and 61.

Watch for ECF from (b)(i).

[2 marks]

Examiners report

[N/A]
14. 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 $3m$ and the amplitude is increased to $2A$?

A. $2E$
B. $4E$
C. $12E$
D. $18E$

**Markscheme**

B

**Examiners report**

[N/A]

15. Monochromatic light is incident on two identical slits to produce an interference pattern on a screen. One slit is then covered so that no light emerges from it. What is the change to the pattern observed on the screen?

A. Fewer maxima will be observed.
B. The intensity of the central maximum will increase.
C. The outer maxima will become narrower.
D. The width of the central maximum will decrease.

**Markscheme**

A

**Examiners report**

[N/A]
16. A transparent liquid forms a parallel-sided thin film in air. The diagram shows a ray I incident on the upper air–film boundary at normal incidence (the rays are shown at an angle to the normal for clarity).

Reflections from the top and bottom surfaces of the film result in three rays J, K and L. Which of the rays has undergone a phase change of \( \pi \) rad?
A. J only
B. J and L only
C. J and K only
D. J, K and L

**Markscheme**
A

**Examiners report**
[N/A]

17. A stationary sound source emits waves of wavelength \( \lambda \) and speed \( v \). The source now moves away from a stationary observer. What are the wavelength and speed of the sound as measured by the observer?

<table>
<thead>
<tr>
<th></th>
<th>Wavelength</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>longer than ( \lambda )</td>
<td>equal to ( v )</td>
</tr>
<tr>
<td>B.</td>
<td>longer than ( \lambda )</td>
<td>less than ( v )</td>
</tr>
<tr>
<td>C.</td>
<td>shorter than ( \lambda )</td>
<td>equal to ( v )</td>
</tr>
<tr>
<td>D.</td>
<td>shorter than ( \lambda )</td>
<td>less than ( v )</td>
</tr>
</tbody>
</table>

**Markscheme**
A

**Examiners report**
[N/A]
There is a proposal to power a space satellite X as it orbits the Earth. In this model, X is connected by an electronically-conducting cable to another smaller satellite Y. Satellite X orbits 6600 km from the centre of the Earth.

Mass of the Earth = 6.0 x 10^{24} kg

Show that the orbital speed of satellite X is about 8 km s^{-1}.

\[ v = \sqrt{\frac{GM_E}{r}} \]
\[ = \sqrt{\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{6600 \times 10^3}} \]
\[ = \sqrt{7800 \text{ m s}^{-1}} \]

Full substitution required
Must see 2+ significant figures.

18b. Satellite Y orbits closer to the centre of Earth than satellite X. Outline why

18b. the orbital times for X and Y are different. [1 mark]
Markscheme

Y has smaller orbit/orbital speed is greater so time period is less

Allow answer from appropriate equation

Allow converse argument for X

Examiners report

[N/A]

18c. satellite Y requires a propulsion system. [2 marks]

Markscheme

to stop Y from getting ahead
to remain stationary with respect to X
otherwise will add tension to cable/damage satellite/pull X out of its orbit

Examiners report

[N/A]
18d. The cable between the satellites cuts the magnetic field lines of the Earth at right angles. [3 marks]

Explain why satellite X becomes positively charged.

Markscheme

cable is a conductor and contains electrons

electrons/charges experience a force when moving in a magnetic field

use of a suitable hand rule to show that satellite Y becomes negative «so X becomes positive»

**Alternative 2**
cable is a conductor

so current will flow by induction flow when it moves through a B field

use of a suitable hand rule to show current to right so «X becomes positive»

*Marks should be awarded from either one alternative or the other.*

*Do not allow discussion of positive charges moving towards X*

Examiners report

[N/A]
Satellite X must release ions into the space between the satellites. Explain why the current in the cable will become zero unless there is a method for transferring charge from X to Y.

**Markscheme**
electrons would build up at satellite Y/positive charge at X
preventing further charge flow
by electrostatic repulsion
unless a complete circuit exists

**Examiners report**
[N/A]

The magnetic field strength of the Earth is 31 µT at the orbital radius of the satellites. The cable is 15 km in length. Calculate the emf induced in the cable.

**Markscheme**
«$\epsilon = Blv =$» $31 \times 10^{-6} \times 7990 \times 15000$
3600 «V»
Allow 3700 «V» from $v = 8000 \text{ m s}^{-1}$. 
The cable acts as a spring. Satellite Y has a mass $m$ of $3.5 \times 10^2$ kg. Under certain circumstances, satellite Y will perform simple harmonic motion (SHM) with a period $T$ of 5.2 s.

18g. Estimate the value of $k$ in the following expression. \[ T = 2\pi \sqrt{\frac{m}{k}} \] [3 marks]

Give an appropriate unit for your answer. Ignore the mass of the cable and any oscillation of satellite X.

\[ T = 2\pi \sqrt{\frac{350}{5.2^2}} \]

\[ T = 2\pi \sqrt{\frac{350}{27.04}} \]

\[ T = 2\pi \sqrt{12.95} \]

\[ T = 2\pi \times 3.6 \]

\[ T = 7.2\pi \]

\[ T = 22.59 \text{ s} \]

Markscheme

use of $k = \frac{4\pi^2 m}{T^2} \Rightarrow \frac{4\times\pi^2 \times 350}{5.2^2}$

510 N m$^{-1}$ or kg s$^{-2}$

Allow MP1 and MP2 for a bald correct answer

Allow 500

Allow N/m etc.
18h. Describe the energy changes in the satellite Y-cable system during one cycle of the oscillation.

Markscheme

\( E_p \) in the cable/system transfers to \( E_k \) of Y and back again twice in each cycle

Exclusive use of gravitational potential energy negates MP1

Examiners report

[N/A]

Yellow light from a sodium lamp of wavelength 590 nm is incident at normal incidence on a double slit. The resulting interference pattern is observed on a screen. The intensity of the pattern on the screen is shown.

19a. Explain why zero intensity is observed at position A.
Markscheme
the diagram shows the combined effect of «single slit» diffraction and «double slit» interference
recognition that there is a minimum of the single slit pattern
OR
a missing maximum of the double slit pattern at A
waves «from the single slit» are in antiphase/cancel/have a path difference of \((n + \frac{1}{2})\lambda\) destructive interference at A

Examiners report
[N/A]

19b. The distance from the centre of the pattern to A is \(4.1 \times 10^{-2}\) m. The distance from the screen to the slits is 7.0 m.

Calculate the width of each slit.

\[
\theta = \frac{4.1 \times 10^{-2}}{7.0} \quad \text{OR} \quad b = \frac{\lambda}{\theta} = \frac{7.0 \times 5.9 \times 10^{-7}}{4.1 \times 10^{-2}}
\]

\(1.0 \times 10^{-4} \text{ m}\)

Award [0] for use of double slit formula (which gives the correct answer so do not award BCA)
 Allow use of sin or tan for small angles
19c. Calculate the separation of the two slits. [2 marks]

Markscheme

use of \( s = \frac{\lambda D}{d} \) with 3 fringes \( \frac{590 \times 10^{-9} \times 7.0}{4.1 \times 10^{-2}} \) 

3.0 \times 10^{-4} \text{ «m»}

Allow ECF.
19d. State and explain the differences between the pattern on the screen due to the grating and the pattern due to the double slit.

Markscheme

- fringes are further apart because the separation of slits is «much» less
- intensity does not change «significantly» across the pattern or diffraction envelope is broader because slits are «much» narrower
- the fringes are narrower/sharper because the region/area of constructive interference is smaller/there are more slits
- intensity of peaks has increased because more light can pass through

Award [1 max] for stating one or more differences with no explanation
Award [2 max] for stating one difference with its explanation
Award [MP3] for a second difference with its explanation
Allow “peaks” for “fringes”

Examiners report

[N/A]
19e. The yellow light is made from two very similar wavelengths that produce two lines in the spectrum of sodium. The wavelengths are 588.995 nm and 589.592 nm. These two lines can just be resolved in the second-order spectrum of this diffraction grating. Determine the beam width of the light incident on the diffraction grating.

\[ \Delta \lambda = 589.592 - 588.995 \]

OR

\[ \Delta \lambda = 0.597 \text{ «nm»} \]

\[ N = \left( \frac{\lambda}{m \Delta \lambda} \right) = \frac{589}{2 \times 0.597} = 493 \]

beam width = \( \frac{493}{600} = 8.2 \times 10^{-4} \text{ «m» or } 0.82 \text{ «mm»} \)

**Markscheme**

20. 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 0.4\( g \)?

A. 0.4\( T \)
B. 0.6\( T \)
C. 1.6\( T \)
D. 2.5\( T \)

\[ \text{Examiners report} \]

[N/A]
21. For fringes to be observed in a double-slit interference experiment, the slits must emit waves that are coherent. What conditions are required for the frequency of the waves and for the phase difference between the waves so that the waves are coherent?

<table>
<thead>
<tr>
<th>Frequency of waves</th>
<th>Phase difference between waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. same</td>
<td>variable</td>
</tr>
<tr>
<td>B. same</td>
<td>constant</td>
</tr>
<tr>
<td>C. constant difference</td>
<td>variable</td>
</tr>
<tr>
<td>D. constant difference</td>
<td>constant</td>
</tr>
</tbody>
</table>

 Markscheme
 B

 Examiners report
 [N/A]

22. A train moving at speed $u$ relative to the ground, sounds a whistle of constant frequency $f$ as it moves towards a vertical cliff face.

The sound from the whistle reaches the cliff face and is reflected back to the train. The speed of sound in stationary air is $c$.

What whistle frequency is observed on the train after the reflection?

A. \( \frac{c+u}{c-u} f \)
B. \( (c + u) f \)
C. \( (c - u) f \)
D. \( \frac{c-u}{c+u} f \)

 Markscheme
 A
23. A mass oscillates with simple harmonic motion (SHM) of amplitude $x_0$. Its total energy is $16 \text{ J}$. 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  

24. Blue light is incident on two narrow slits. Constructive interference takes place along the lines labelled 1 to 5. 

The blue light is now replaced by red light. What additional change is needed so that the lines of constructive interference remain in the same angular positions? 

A. Make the slits wider  
B. Make the slits narrower  
C. Move the slits closer together  
D. Move the slits further apart
25. Two points illuminated by monochromatic light are separated by a small distance. The light from the two sources passes through a small circular aperture and is detected on a screen far away.

Two points illuminated by monochromatic light are separated by a small distance. The light from the two sources passes through a small circular aperture and is detected on a screen far away.

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Size of aperture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>increase</td>
</tr>
<tr>
<td>B.</td>
<td>increase</td>
</tr>
<tr>
<td>C.</td>
<td>decrease</td>
</tr>
<tr>
<td>D.</td>
<td>decrease</td>
</tr>
</tbody>
</table>
26. A train travelling in a straight line emits a sound of constant frequency $f$. An observer at rest very close to the path of the train detects a sound of continuously decreasing frequency. The train is

A. approaching the observer at constant speed.
B. approaching the observer at increasing speed.
C. moving away from the observer at constant speed.
D. moving away from the observer at increasing speed.

**Markscheme**

D

**Examiners report**

[N/A]

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

27a. Describe the conditions required for an object to perform simple harmonic motion (SHM).

**Markscheme**

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

**Examiners report**

[N/A]
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.

27b. Calculate the mass of the wooden block. [2 marks]

\[
\frac{T_1^2}{T_2^2} = \frac{m_1}{m_2}
\]

**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 \(T\)

\[
= 2\pi \sqrt{\frac{m}{k}} \text{ } k = 28 \text{ Nm}^{-1}
\]

«use of \(T\)

\[
= 2\pi \sqrt{\frac{m}{k}} \text{ } m = 0.38 / 0.39 \text{ «kg»}
\]

Allow ECF from MP1.

Examiners report

[N/A]
27c. 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.

\[ 27c. \text{ In carrying out the experiment the student displaced the block horizontally by 4.8 cm from the equilibrium position. Determine the total energy in the oscillation of the wooden block.} \]

\[ \omega = \left( \frac{2\pi}{0.74} \right) = 8.5 \text{ rad}^{-1} \]

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

\[ = 0.032 \text{ J} \]

Allow ECF from (b) and incorrect \( \omega \).
Allow answer using \( k \) from part (b).

**Markscheme**

**Examiners report**

[N/A]

27d. A second identical spring is placed in parallel and the experiment in (b) is repeated.

\[ 27d. \text{ A second identical spring is placed in parallel and the experiment in (b) is repeated.} \]

Suggest how this change affects the fractional uncertainty in the mass of the block.
Markscheme

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

Examiners report

[N/A]

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.

27e. State the direction of motion of P on the spring. [1 mark]

Markscheme

left

Examiners report

[N/A]
27f. 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.*

Examiners report

[N/A]

28a. Outline the conditions necessary for simple harmonic motion (SHM) to occur. [2 marks]
A buoy, floating in a vertical tube, generates energy from the movement of water waves on the surface of the sea. When the buoy moves up, a cable turns a generator on the sea bed producing power. When the buoy moves down, the cable is wound in by a mechanism in the generator and no power is produced.

The motion of the buoy can be assumed to be simple harmonic.

28b. A wave of amplitude 4.3 m and wavelength 35 m, moves with a speed of 3.4 m s\(^{-1}\). Calculate the maximum vertical speed of the buoy.
Markscheme

frequency of buoy movement = \( \frac{3.4}{35} \) or 0.097 «Hz»

OR

time period of buoy = \( \frac{35}{3.4} \) or 10.3 «s» or 10 «s»

\[ v = \frac{2\pi x_0}{T} \] or \[ 2\pi f x_0 \] = \[ \frac{2\times\pi\times4.3}{10.3} \] or \[ 2 \times \pi \times 0.097 \times 4.3 \]

2.6 «m s\(^{-1}\)»

Examiners report

[N/A]

28c. Sketch a graph to show the variation with time of the generator output power. Label the time axis with a suitable scale. [2 marks]

Markscheme

peaks separated by gaps equal to width of each pulse «shape of peak roughly as shown»
on one cycle taking 10 s shown on graph

Judge by eye.
Do not accept cos or sin graph
At least two peaks needed.
Do not allow square waves or asymmetrical shapes.
Allow ECF from (b)(i) value of period if calculated.
Water can be used in other ways to generate energy.

28d. Outline, with reference to energy changes, the operation of a pumped storage hydroelectric system.

Markscheme

PE of water is converted to KE of moving water/turbine to electrical energy «in generator/turbine/dynamo»
idea of pumped storage, i.e.: pump water back during night/when energy cheap to buy/when energy not in demand/when there is a surplus of energy

28e. The water in a particular pumped storage hydroelectric system falls a vertical distance of 270 m to the turbines. Calculate the speed at which water arrives at the turbines. Assume that there is no energy loss in the system.
28f. The hydroelectric system has four 250 MW generators. Determine the maximum time for which the hydroelectric system can maintain full output when a mass of $1.5 \times 10^{10}$ kg of water passes through the turbines.

Markscheme

\[ \text{specific energy available} = gh = 9.81 \times 270 = 2650 \text{J kg}^{-1} \]

**OR**

\[ mgh = \frac{1}{2}mv^2 \]

**OR**

\[ v^2 = 2gh \]

\[ v = 73 \text{ ms}^{-1} \]

*Do not allow 72 as round from 72.8*

---

Examiners report

[N/A]

---

**Markscheme**

\[ \text{total energy} = mgh = 1.5 \times 10^{10} \times 9.81 \times 270 = 4.0 \times 10^{13} \text{ J} \]

**OR**

\[ \text{total energy} = \frac{1}{2}mv^2 = \frac{1}{2} \times 1.5 \times 10^{10} \times (\text{answer (c)(ii)})^2 = 4.0 \times 10^{13} \text{ J} \]

\[ \text{time} = \frac{4.0 \times 10^{13}}{4 \times 2.5 \times 10^8} = 11.1 \text{ h} \text{ or } 4.0 \times 10^4 \text{ s} \]

*Use of $3.97 \times 10^{13} \text{ J}$ gives 11 h.*

*For MP2 the unit must be present.*
28g. Not all the stored energy can be retrieved because of energy losses in the system. Explain two such losses.

1. ........................................................................................................................................
2. ........................................................................................................................................

Markscheme

friction/resistive losses in pipe/fluid resistance/turbulence/turbine or generator «bearings»

OR

sound energy losses from turbine/water in pipe

thermal energy/heat losses in wires/components

water requires kinetic energy to leave system so not all can be transferred

*Must see “seat of friction” to award the mark.*

*Do not allow “friction” bald.*

Examiners report

[N/A]
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.

29a. Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs. [3 marks]
29b. The slits are separated by 1.5 mm and the laser light has a wavelength of $6.3 \times 10^{-7}$ m. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum.

\[
s = \frac{\lambda D}{d} = \frac{6.3 \times 10^{-7} \times 5.0}{1.5 \times 10^{-3}} = 2.1 \times 10^{-3} \text{ m}
\]
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.
As the train continues to move, the first diffraction minimum is observed when the light sensor is at a distance of 0.13 m from the centre of the fringe pattern.

29d. Determine the width of one of the slits. [2 marks]
angular width of diffraction minimum = \( \frac{0.13}{5.0} \) «= 0.026 rad»

slit width = \( \frac{\lambda}{d} = \frac{6.3 \times 10^{-7}}{0.026} \) «= 2.4 \times 10^{-5} m»

Award [1 max] for solution using 1.22 factor.

Examiners report
[N/A]

29e. Suggest the variation in the output voltage from the light sensor that will be observed as the train moves beyond the first diffraction minimum.

Markscheme
«beyond the first diffraction minimum» average voltage is smaller

«voltage minimum» spacing is «approximately» same

OR
rate of variation of voltage is unchanged

OWTTE

Examiners report
[N/A]
29f. 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.

The graph shows the variation with time of the output voltage from the sound sensor.

Explain how this effect arises.

Markscheme

«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

Examiners report

[N/A]
30. A particle is oscillating with simple harmonic motion (shm) of amplitude $x_0$ and maximum kinetic energy $E_k$. What is the potential energy of the system when the particle is a distance $0.20x_0$ from its maximum displacement?

A. $0.20E_k$
B. $0.36E_k$
C. $0.64E_k$
D. $0.80E_k$

**Markscheme**

C

**Examiners report**

[N/A]

31. Monochromatic light is incident on a double slit. Both slits have a finite width. The light then forms an interference pattern on a screen some distance away. Which graph shows the variation of intensity with distance from the centre of the pattern?

**Markscheme**

D

**Examiners report**

[N/A]
32. Light of wavelength $\lambda$ is incident normally on a diffraction grating that has a slit separation of $\frac{7\lambda}{2}$. What is the greatest number of maxima that can be observed using this arrangement?
A. 4  
B. 6  
C. 7  
D. 9

**Markscheme**
C

**Examiners report**
[N/A]

33. A diffraction grating is used to observe light of wavelength 400 nm. The light illuminates 100 slits of the grating. What is the minimum wavelength difference that can be resolved when the second order of diffraction is viewed?
A. 1 nm  
B. 2 nm  
C. 4 nm  
D. 8 nm

**Markscheme**
B

**Examiners report**
[N/A]
34a. Police use radar to detect speeding cars. A police officer stands at the side of the road and points a radar device at an approaching car. The device emits microwaves which reflect off the car and return to the device. A change in frequency between the emitted and received microwaves is measured at the radar device.

The frequency change $\Delta f$ is given by

$$\Delta f = \frac{2fv}{c}$$

where $f$ is the transmitter frequency, $v$ is the speed of the car and $c$ is the wave speed.

The following data are available.
Transmitter frequency $f = 40 \text{ GHz}$ $\Delta f = 9.5 \text{ kHz}$ Maximum speed allowed = $28 \text{ m s}^{-1}$

(i) Explain the reason for the frequency change.
(ii) Suggest why there is a factor of 2 in the frequency-change equation.
(iii) Determine whether the speed of the car is below the maximum speed allowed.
Markscheme

i
mention of Doppler effect
OR
«relative» motion between source and observer produces frequency/wavelength change
Accept answers which refer to a double frequency shift.
Award [0] if there is any suggestion that the wave speed is changed in the process.

the reflected waves come from an approaching “source”
OR
the incident waves strike an approaching “observer”
increased frequency received «by the device or by the car»

ii
the car is a moving “observer” and then a moving “source”, so the Doppler effect occurs twice
OR
the reflected radar appears to come from a “virtual image” of the device travelling at 2 v
towards the device

iii
ALTERNATIVE 1
For both alternatives, allow ecf to conclusion if v OR Δf are incorrectly calculated.

\[ v = \left( \frac{3 \times 10^8}{40 \times 10^9} \right) \times \left( \frac{9.5 \times 10^3}{2} \right) = 36 \text{ «ms}^{-1} » \]
«36> 28» so car exceeded limit
There must be a sense of a conclusion even if numbers are not quoted.

ALTERNATIVE 2
reverse argument using speed limit.

\[ \Delta f = \left( \frac{2 \times 40 \times 10^9 \times 28}{3 \times 10^9} \right) = 7500 \text{ «Hz»} \]
«9500> 7500» so car exceeded limit
There must be a sense of a conclusion even if numbers are not quoted.

Examiners report
[N/A]
34b. Airports use radar to track the position of aircraft. The waves are reflected from the aircraft and detected by a large circular receiver. The receiver must be able to resolve the radar images of two aircraft flying close to each other.

The following data are available.

Diameter of circular radar receiver = 9.3 m Wavelength of radar = 2.5 cm Distance of two aircraft from the airport = 31 km

Calculate the minimum distance between the two aircraft when their images can just be resolved.

\[
x = \frac{31 \times 10^3 \times 1.22 \times 2.5 \times 10^{-2}}{9.3}
\]

Markscheme

Award [2] for a bald correct answer.
Award [1 max] for POT error.

100 «m»
Award [1 max] for 83m (omits 1.22).

Examiners report

[N/A]

35. A mass is connected to a spring on a frictionless horizontal surface as shown. [1 mark]

The spring is extended beyond its equilibrium length and the mass executes simple harmonic motion (SHM). Which of the following is independent of the initial displacement of the spring?

A. The angular frequency of the oscillation
B. The total energy of the mass
C. The average speed of the mass
D. The maximum kinetic energy of the mass
36. A single-slit diffraction experiment is performed using light of different colours. The width of the central peak in the diffraction pattern is measured for each colour. What is the order of the colours that corresponds to increasing widths of the central peak?

A. red, green, blue
B. red, blue, green
C. blue, green, red
D. green, blue, red

Markscheme
C

Examiners report
[N/A]
37. In a double-slit interference experiment, the following intensity pattern is observed for light of wavelength $\lambda$.

![Intensity pattern graph](image)

The distance between the slits is $d$. What can be deduced about the value of the ratio $\frac{\lambda}{d}$ and the effect of single-slit diffraction in this experiment?

<table>
<thead>
<tr>
<th>$\frac{\lambda}{d}$</th>
<th>Single-slit diffraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 100</td>
<td>non-negligible</td>
</tr>
<tr>
<td>B. 0.01</td>
<td>non-negligible</td>
</tr>
<tr>
<td>C. 100</td>
<td>negligible</td>
</tr>
<tr>
<td>D. 0.01</td>
<td>negligible</td>
</tr>
</tbody>
</table>

**Markscheme**

B

**Examiners report**

[N/A]
38. A simple pendulum has mass $M$ and length $l$. The period of oscillation of the pendulum is $T$. What is the period of oscillation of a pendulum with mass $4M$ and length $0.25l$?

A. $0.5T$
B. $T$
C. $2T$
D. $4T$

**Markscheme**

A

**Examiners report**

[N/A]

39. A train moves at constant speed whilst emitting a sound wave of frequency $f_0$. At $t=t_0$, the train passes through a station. Which graph shows the variation with time $t$ of the frequency $f$ of the sound wave as measured by an observer standing on the station platform?

A. \[ \begin{align*}
    &f \\
    &f_0 \\
    &t_0 \\
    &t
\end{align*} \]
B. \[ \begin{align*}
    &f \\
    &f_0 \\
    &t_0 \\
    &t
\end{align*} \]
C. \[ \begin{align*}
    &f \\
    &f_0 \\
    &t_0 \\
    &t
\end{align*} \]
D. \[ \begin{align*}
    &f \\
    &f_0 \\
    &t_0 \\
    &t
\end{align*} \]

**Markscheme**

D

**Examiners report**

[N/A]
40. Which of the following experiments provides evidence for the existence of matter waves?
   A. Scattering of alpha particles
   B. Electron diffraction
   C. Gamma decay
   D. Photoelectric effect

Markscheme

B

Examiners report

[N/A]
Monochromatic light is incident normally on four thin, parallel, rectangular slits.

The graph shows the variation with diffraction angle $\theta$ of the intensity of light $I$ at a distant screen.

$I_0$ is the intensity of the light at the middle of the screen from one slit.

41a. Explain why the intensity of light at $\theta=0$ is $16I_0$. [3 marks]
Markscheme
constructive interference
amplitude/amount of light from 4 slits is $4 \times$ amplitude «from one slit»
intensity is proportional to amplitude$^2$ OR shows $4^2 = 16$ in context of intensity

Examiners report
[N/A]

41b. The width of each slit is 1.0µm. Use the graph to [4 marks]
(i) estimate the wavelength of light.

(ii) determine the separation of two consecutive slits.

Markscheme
(i) «diffraction minimum at» $\theta$=0.43rad
$\lambda = \frac{b \theta}{\sin \theta} = \frac{1.0 \times 10^{-6} \times 0.43}{\sin 0.43} \approx 4.3 \times 10^{-7}$ m
Accept $\theta$ in range 0.41 to 0.45 rad.
Allow $\lambda=bsin\theta$ but do not allow $n\lambda=dsin\theta$.
Award [1 max] for solution using factor of 1.22.
Award [0] if use of $s = \frac{\lambda D}{d}$ seen.

(ii) «first secondary maximum at» $\theta$=0.125rad
$d = \frac{1 \times \text{value from (b)(i)}}{\sin 0.125} = 3.4 \times 10^{-6}$ m
Accept $q$ in range 0.123 to 0.127 rad.
Sine must be seen to award MP2.
Allow ECF from (b)(i).
Allow use of 2nd or 3rd maxima (0.25 rad and 3.46 µm or 0.375 rad and 3.5 µm with appropriate $n$).
41c. The arrangement is modified so that the number of slits becomes very large. Their separation and width stay the same.

(i) State two changes to the graph on page 20 as a result of these modifications.

(ii) A diffraction grating is used to resolve two lines in the spectrum of sodium in the second order. The two lines have wavelengths 588.995 nm and 589.592 nm. Determine the minimum number of slits in the grating that will enable the two lines to be resolved.

\[ N = \left\lfloor \frac{\lambda}{m \Delta \lambda} \right\rfloor \]

\[ N = 494 \text{ or } 500 \]

Allow use of 588.995 nm or 589.592 nm for $\bar{\lambda}$.
A longitudinal wave is travelling in a medium from left to right. The graph shows the variation with distance $x$ of the displacement $y$ of the particles in the medium. The solid line and the dotted line show the displacement at $t=0$ and $t=0.882$ ms, respectively.

The period of the wave is greater than 0.882 ms. A displacement to the right of the equilibrium position is positive.

42a. (i) Calculate the speed of this wave.

(ii) Show that the angular frequency of oscillations of a particle in the medium is $\omega = 1.3 \times 10^3 \text{rads}^{-1}$. 

[4 marks]
Markscheme

(i)

**ALTERNATIVE 1**

«distance travelled by wave =» 0.30 m

\[ v = \frac{\text{distance}}{\text{time}} \Rightarrow 340\text{ms}^{-1} \]

**ALTERNATIVE 2**

evaluates \( T = \frac{0.882 \times 10^{-3} \times 1.6}{0.3} \) «≈4.7ms» to give \( f = 210 \text{ or } 212 \text{ Hz} \)

uses \( \lambda = 1.6 \text{ m} \) with \( v = f \lambda \) to give 340ms\(^{-1}\)

(ii)

**ALTERNATIVE 1**

\( \lambda = 1.60\text{m} \)

\[ \omega = 2\pi \times 340 \times \frac{1.60}{0.3} = 1.3 \times 10^{3} \text{ or } 1.34 \times 10^{3}\text{rads}^{-1} \]

**ALTERNATIVE 2**

«0.882 ms is \( \frac{0.3}{16} \) of cycle so whole cycle is» \( \frac{2\pi \times 3}{16 \times 0.882 \times 10^{-3}} \)

1.35 \times 10^{3}\text{rads}^{-1}

Allow ECF from (b)(i).

Examiners report

[N/A]
42b. One particle in the medium has its equilibrium position at \( x = 1.00 \, \text{m} \).

(i) State and explain the direction of motion for this particle at \( t = 0 \).

(ii) Show that the speed of this particle at \( t = 0.882 \, \text{ms} \) is \( 4.9 \, \text{ms}^{-1} \).

\[
\begin{align*}
\text{Markscheme} \\
\text{(i)} & \quad \text{the displacement of the particle decreases \ OR \ «on the graph» displacement is going in a} \\
& \quad \text{negative direction \ OR \ on the graph the particle goes down \ OR \ on the graph displacement} \\
& \quad \text{moves towards equilibrium/0} \\
& \quad \text{to the left} \\
& \quad \text{\textit{Do not allow “moving downwards”}.} \\
\text{(ii)} & \quad y = -1.5 \, \text{mm} \\
& \quad v = 2\pi \times 212 \times \sqrt{\left(4.0 \times 10^{-3}\right)^2 - \left(1.5 \times 10^{-3}\right)^2} \\
& \quad \approx 4.939 \approx 4.9 \, \text{ms}^{-1} \\
& \quad \text{\textit{Allow ECF from (b)(ii)}.} \\
& \quad \text{\textit{Do not allow}} \\
& \quad \frac{4.3 \, \text{mm}}{0.882 \, \text{ms}} \approx 4.87 \, \text{ms}^{-1}. 
\end{align*}
\]
42c. The travelling wave in (b) is directed at the open end of a tube of length 1.20 m. The other end of the tube is closed.

(i) Describe how a standing wave is formed.

(ii) Demonstrate, using a calculation, that a standing wave will be established in this tube.
Markscheme

(i) the superposition/interference of two oppositely moving/reflected «identical travelling» waves

(ii) the allowed wavelengths in the tube are \( \lambda = \frac{4L}{n} = \frac{480}{n} \), \( n = 1, 3, 5, \ldots \)

OR

diagram showing \( \frac{3}{4} \) of a standing wavelength in the tube

\[
1.6 = \frac{480}{n} \Rightarrow n = 3
\]

OR

justification that \( \frac{3}{4} \times 1.6 = 1.2 \text{m} \)

Allow diagram showing \( \frac{3}{4} \) of a wavelength for MP1.

Examiners report

[N/A]