15. An object undergoes simple harmonic motion. Which graph shows the relationship between the acceleration $a$ and the displacement $x$ from the equilibrium position?

A.  

B.  

C.  

D.  

16. What property of a driving system must be approximately equal to that of the oscillating system for resonance to occur?

A. Amplitude
B. Displacement
C. Frequency
D. Kinetic energy
17. Waves emitted from sources X and Y have equal wavelengths and are initially in phase. The waves interfere destructively at point P, where the path difference is 0.60 m.

\[ X \bullet \quad \bullet_P \]

\[ Y \bullet \]

What is a possible value for the wavelength of the waves?

A. 0.20 m
B. 0.30 m
C. 0.40 m
D. 0.60 m

Part 1  Wave motion

(a) State what is meant by the terms ray and wavefront and state the relationship between them. [3]
(b) The diagram shows three wavefronts, A, B and C, of a wave at a particular instant in time incident on a boundary between media X and Y. Wavefront B is also shown in medium Y.

(i) Draw a line to show wavefront C in medium Y.  

(ii) The refractive index of X is \( n_x \) and the refractive index of Y is \( n_y \). By making appropriate measurements, calculate \( \frac{n_x}{n_y} \).
(c) The wave in (b) is transverse. Describe the difference between transverse waves and longitudinal waves. [2]
(d) The graph below shows the variation of the velocity $v$ with time $t$ for one oscillating particle of medium Y.

(i) Calculate the frequency of oscillation of the particle. [2]

(ii) Identify on the graph, with the letter M, a time at which the displacement of the particle is a maximum. [1]
(iii) Using the graph, determine the approximate amplitude of the oscillation of the particle. [3]

A3. This question is about polarized light.

(a) Describe what is meant by polarized light. [1]

(b) (i) State Brewster's law. [1]
(ii) When light is incident on a plastic surface the angle between the reflected and refracted ray is 90°. The angle of incidence is 56°. Calculate the refractive index of the plastic.

..........................................................
..........................................................
..........................................................
..........................................................
..........................................................

15. A
16. C
17. C
B2. Part 1  Wave motion

(a) *ray*: direction of wave travel / energy propagation;
    *wavefront*: line that joins points with same phase/of same crest/trough;
    ray normal/at right angles/perpendicular to wavefront;  \[3\]

(b) (i) line parallel to existing line in Y and continuous at boundary; *(both needed)*  \[1\]

(ii) measures "wavelength" correctly in media | *(by eye)*
     X and Y;  \{*(look for ratio of 0.5 : 1 in responses)*\}
     \[
     \frac{n_x}{\lambda_x} = \frac{n_y}{\lambda_y};  \\
     0.5:1;  *(accept answers in the range of 0.47 to 0.53)*  \[3\]

     or

     justification that angles needed for calculation are either pair of *i* and *r* as
     shown and angles measured correctly;
     \[
     \frac{n_x}{\lambda_x} = \frac{\sin r}{\sin i};  \\
     0.5:1;  \]

(c) mention of perpendicular/right angle/90\(^\circ\)angle for transverse and parallel for
    longitudinal;
    clear comparison between direction of energy propagation and direction of
    vibration/oscillation of particles for both waves;  \[2\]
(d)  (i)  time period = 6.0 ms;
     167 Hz;                           [2]

     (ii) M where line crosses x-axis;          [1]

     (iii) counts rectangles (14 ± 2) to first peak;
            one rectangle equivalent to 0.5 mm;
            7.2 mm;
     or
     \[ \omega = \left(2\pi f = \right)330\pi; \]
     \[ a = \left(\frac{v}{\omega} = \right)7.5 \]
     \[ 330\pi; \]
     7.2 mm;
     Allow any valid algebraic method, eg \[ v = \omega \sqrt{x_c^2 - x^2}. \]

A3.  (a) the electric field vector oscillates in one plane/direction only;  [1]

     (b)  (i)  \[ n = \tan \phi \text{ (no marks for this alone)} \]
            \( n \) is refractive index of reflecting material and \( \phi \) is the angle of incidence/reflection (in air) for a completely plane polarized reflected ray;
            or
            maximum polarization occurs when the refracted ray is at 90 degrees to the reflected ray;

            (ii) \[ n = \tan \phi = \tan 56; \]
                  \[ n = 1.48; \]
     Award [2] for a bald correct answer.
13. A system, consisting of a mass $M$ connected to a spring, oscillates on a frictionless surface with simple harmonic motion between two points, X and Y. Point O is the centre of the oscillation.

![Diagram of a mass-spring system]

For the system, at which of the following points is the elastic potential energy equal to the kinetic energy?

A. O only
B. X and Y only
C. O, X and Y
D. Neither O, X nor Y

14. Microwave ovens cause the water molecules in food to resonate. Water molecules have a natural frequency of vibration $f$. In order to heat the food most effectively, the frequency of the microwaves should have a value

A. less than $f$.
B. equal to $f$.
C. greater than $f$.
D. as large as possible.

15. Gas particles are equally spaced along a straight line. A sound wave passes through the gas. The positions of the gas particles at one instant are shown below.

Which of the distances shown is equal to the wavelength of the wave?

![Diagram of gas particles and sound wave]
12. Which graph shows how velocity \( v \) varies with displacement \( x \) of a system moving with simple harmonic motion?

A. 

\[
\begin{array}{c}
\text{v} \\
\text{0} \\
\text{x}
\end{array}
\]

B. 

\[
\begin{array}{c}
\text{v} \\
\text{0} \\
\text{x}
\end{array}
\]

C. 

\[
\begin{array}{c}
\text{v} \\
\text{0} \\
\text{x}
\end{array}
\]

D. 

\[
\begin{array}{c}
\text{v} \\
\text{0} \\
\text{x}
\end{array}
\]

13. An object undergoes simple harmonic motion with time period \( T \) and amplitude 0.5 m. At time \( t = 0 \) s the displacement of the object is a maximum.

What is the displacement of the object at time \( t = \frac{3T}{4} \)?

A. \(-0.50 \text{ m}\)

B. \(0.50 \text{ m}\)

C. \(0.25 \text{ m}\)

D. \(0 \text{ m}\)
14. Light of wavelength 600 nm travels from air to glass at normal incidence. The refractive index of the glass is 1.5. The speed of light in air is \( c \). Which of the following correctly identifies the speed of the waves and their wavelength in the glass?

<table>
<thead>
<tr>
<th>Speed</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. ( \frac{2c}{3} )</td>
<td>900 nm</td>
</tr>
<tr>
<td>B. ( c )</td>
<td>900 nm</td>
</tr>
<tr>
<td>C. ( c )</td>
<td>400 nm</td>
</tr>
<tr>
<td>D. ( \frac{2c}{3} )</td>
<td>400 nm</td>
</tr>
</tbody>
</table>

15. Which of the following correctly describes the direction of a ray drawn relative to a wavefront for longitudinal and transverse waves?

<table>
<thead>
<tr>
<th>Longitudinal wave</th>
<th>Transverse wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. parallel</td>
<td>parallel</td>
</tr>
<tr>
<td>B. parallel</td>
<td>perpendicular</td>
</tr>
<tr>
<td>C. perpendicular</td>
<td>parallel</td>
</tr>
<tr>
<td>D. perpendicular</td>
<td>perpendicular</td>
</tr>
</tbody>
</table>
A3. This question is about the superposition of waves.

(a) State what is meant by the principle of superposition of waves. [1]

(b) The diagram shows two point sources of sound, X and Y. Each source emits waves of wavelength 1.1 m and amplitude $A$. Over the distances shown, any decrease in amplitude can be neglected. The two sources vibrate in phase.

[Diagram of two points X and Y, connected by lines X to O and Y to P, with distances marked: X to O = 4.0 m, Y to P = 0.75 m, O to P = 0.75 m, X to Y = 1.6 m, O to X = 1.6 m.

Points O and P are on a line 4.0 m from the line connecting X and Y. O is opposite the midpoint of XY and P is 0.75 m from O.

(i) Explain why the intensity of the sound at O is $4A^2$. [2]
A3. This question is about standing waves in a vibrating string.

A guitar string vibrates at 330 Hz in its fundamental mode.

(a) Describe the formation of standing waves in a string fixed at both ends.

(b) The length of the string is 0.64 m. Calculate the velocity of the wave in the string.
A4. This question is about polarization.

Outline how polarization may be used in stress analysis. [3]

A2. This question is about standing waves.

(a) State one difference between a standing wave and a travelling wave. [1]

(b) A string fixed at both ends oscillates in its fundamental (first harmonic) mode. The diagram shows the displacement of the string at time $t=0$. Point M is the point at the middle of the string.
At \( t=0 \) point M is moving upwards. The frequency of oscillation is 250 Hz. On the diagram, draw

(i) an arrow to indicate the direction of acceleration of point M. \[1\]

(ii) a line to show the position of the string at a time of 2.0 ms. \[2\]

(c) Describe how the string in (b) was made to oscillate in its fundamental mode. \[1\]

(d) State the frequency of oscillation of the string when it oscillates in its second harmonic. \[1\]
A3. (a) (when two similar waves meet) the resultant displacement is the (vector) sum of the individual displacements; \[1\]

(b) (i) (constructive interference gives) amplitude \(2A\);
intensity is proportional to square of total amplitude \((= 4A^2)\); \[2\]

(ii) attempted use of Pythagoras to measure path difference;
path difference \(= 0.55\) m;
path difference \(= \frac{\lambda}{2}\) (so out of phase / destructive interference); \[3\]

Attempted use of Pythagoras may appear on diagram for (b)(i).

A3. (a) wave travels down string and is reflected / OWTE;
incident and reflected waves interfere/add/superpose to give a standing wave; \[2\]

(b) \(\lambda = 2L = 1.28\) m;
\(v = \lambda f = 420\) m s\(^{-1}\); \[2\]
Award [2] for bald correct answer.

A2. (a) standing waves do not transfer energy / travelling waves transfer energy;
(adjacent) points on a standing wave have different amplitudes / travelling waves
have the same amplitude;
points in between nodes have the same phase for standing waves / the phase changes
along the wave for travelling waves;
standing waves have points where the displacement is zero at all times; \[1\ max\]

(b) \[
\begin{array}{c}
\text{M} \\
\downarrow \\
\text{arrow vertically down; (see diagram above)} \quad [1]
\end{array}
\]

(ii) suitable line drawn below equilibrium position;
of amplitude shown; (judge by eye – see diagram above) \[2\]

(c) apply forced vibrations to the string at the fundamental resonant frequency; \[1\]
or

\begin{align*}
\text{displace/pluck middle of string;}
\end{align*}

(d) 500 Hz; \[1\]
14. Which of the following correctly relates the direction of oscillation of the particles in a medium to the direction of energy propagation for transverse and longitudinal waves?

<table>
<thead>
<tr>
<th>Transverse wave</th>
<th>Longitudinal wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>perpendicular</td>
<td>perpendicular</td>
</tr>
<tr>
<td>perpendicular</td>
<td>parallel</td>
</tr>
<tr>
<td>parallel</td>
<td>perpendicular</td>
</tr>
<tr>
<td>parallel</td>
<td>parallel</td>
</tr>
</tbody>
</table>

A.  
B.  
C.  
D.  

15. Which of the following relates the amplitude $A$ of a travelling wave to the intensity $I$?

A. $A \propto I^{-1}$  
B. $A \propto I^{-\frac{1}{2}}$  
C. $A \propto I^{\frac{1}{2}}$  
D. $A \propto I^2$

16. Two identical waves of wavelength $\lambda$ leave two sources in phase. The waves meet and superpose after travelling different distances. Which path difference will result in destructive interference?

A. $\frac{\lambda}{4}$  
B. $\frac{\lambda}{2}$  
C. $\frac{3\lambda}{4}$  
D. $\lambda$
5. This question is in two parts. Part 1 is about simple harmonic motion (SHM) and waves. Part 2 is about voltage–current (V–I) characteristics.

Part 1 Simple harmonic motion (SHM) and waves

(a) A particle P moves with simple harmonic motion. State, with reference to the motion of P, what is meant by simple harmonic motion. [2]

(b) The graph shows how the velocity $v$ of particle P varies with time $t$. 
Use the graph opposite to determine for the motion of P the

(i) period. [1]

(ii) amplitude. [4]

(iii) displacement of P from equilibrium at $t = 0.2\,\text{s}$. [2]
(c) The particle P in (b) is a particle in medium M₁ through which a transverse wave is travelling.

(i) Describe, in terms of energy propagation, what is meant by a transverse wave.  \[1\]

(ii) The speed of the wave through the medium is 0.40 m s\(^{-1}\). Calculate, using your answer to (b)(i), the wavelength of the wave.  \[2\]

(iii) The wave travels into another medium M₂. The refractive index of M₂ relative to M₁ is 1.8. Calculate the wavelength of the wave in M₂.  \[2\]
5. **Part 1**  Simple harmonic motion (SHM) and waves

(a) the acceleration (of a particle/P) is (directly) proportional to displacement; and is directed towards equilibrium/in the opposite direction to displacement;  
*Do not accept “directed towards the centre”.*  

(b) (i)  0.30 s;  

(ii) max velocity = 0.74 (±0.02) m s⁻¹; recognize max velocity = \( \omega x_0 \);  
\[
\omega = \left( \frac{2\pi}{T} = \frac{2\pi}{0.30} \right) 20.9 \text{rad s}^{-1};
\]
\[
x_0 = \left( \frac{0.74}{20.9} \right) 3.5 (\pm 0.2) \times 10^{-2} \text{ m};
\]

*or*
identifies displacement with area; uses one quarter of a cycle; answer in the range of 30 to 40 mm; answer in the range of 33 to 37 mm;  

(iii)  \( v = 0.64 (\pm 0.2) \text{ m s}^{-1}; \)
use \( v = \omega \sqrt{(x_0^2 - x^2)} \) to get \( x = 1.7 (\pm 0.2) \times 10^{-2} \text{ m}; \)

*or*
recognition that \( x = x_0 \cos \omega t \);  
\[
x = 35 \cos \left( \frac{2\pi}{0.3} \times 0.2 \right) = 17.5 \text{ mm};
\]

(c) (i) the direction of energy propagation is at right angles to the motion of the particles/atoms/molecules in the medium;  

(ii) \( \lambda = \frac{v}{f} = vT; \)
\[
= (0.40 \times 0.3) = 0.12 \text{ m};
\]

(iii) \( n/1.8 = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}; \)
to give \( \lambda_2 = 0.067 \text{ m}; \)
13. The diagrams show four different organ pipes drawn to scale. Standing waves in the fundamental (first harmonic) mode are set up inside each pipe. Which pipe produces a fundamental note with the lowest frequency?

A. 

B. 

C. 

D. 

15. The intensity distribution of monochromatic light passing through a narrow slit and then incident on a screen is shown below.

When the slit width is reduced which diagram shows the new intensity distribution? Diagrams are drawn to the same scale as the original.

A.  

B.  

C.  

D.
16. Two polarizing filters are set up so the transmitted light is at a maximum intensity.

Through which angle should polarizer 2 be rotated so that no light is transmitted?

A. 45°
B. 60°
C. 90°
D. 180°

C, B, C
12. A point source of sound is placed behind a soundproof barrier as shown in the diagram.

From where Euan is standing he can hear the sound. Which of the following best explains this observation?

A. Diffraction
B. Interference
C. Polarization
D. Refraction

13. A standing wave of frequency $f$ is established in air in a pipe open at one end, as shown.

Which of the following is the frequency of the next highest harmonic?

A. $\frac{f}{3}$
B. $\frac{f}{2}$
C. $2f$
D. $3f$
15. A parallel beam of monochromatic light of wavelength $\lambda$ passes through a slit of width $b$ and forms a diffraction pattern on a screen far from the slit. The angle at which the first diffraction minimum is formed is $\theta$.

Which of the following changes in $\lambda$ and $b$, carried out separately, will increase the value of $\theta$?

<table>
<thead>
<tr>
<th></th>
<th>$\lambda$</th>
<th>$b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>decrease</td>
<td>increase</td>
</tr>
<tr>
<td>B</td>
<td>increase</td>
<td>increase</td>
</tr>
<tr>
<td>C</td>
<td>decrease</td>
<td>decrease</td>
</tr>
<tr>
<td>D</td>
<td>increase</td>
<td>decrease</td>
</tr>
</tbody>
</table>
17. Unpolarized light of intensity $I_0$ is transmitted through a polarizer which has a transmission axis at an angle $\theta$ to the vertical. The light is then incident on a second polarizer with a transmission axis at an angle $\phi$ to the transmission axis of the first polarizer, as shown below.

The intensity of the light that emerges from the second polarizer is $I$. What is the ratio $\frac{I}{I_0}$?

A. 0.25  
B. $0.5 \cos^3(\theta + \phi)$  
C. $0.5 \cos^3 \phi$  
D. $\cos^3 \theta \cos^3 \phi$

14. Light of wavelength 600 nm travels from air to glass at normal incidence. The refractive index of the glass is 1.5. The speed of light in air is $c$. Which of the following correctly identifies the speed of the waves and their wavelength in the glass?

<table>
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</tr>
<tr>
<td>$c$</td>
<td>900 nm</td>
</tr>
<tr>
<td>$c$</td>
<td>400 nm</td>
</tr>
<tr>
<td>$\frac{2c}{3}$</td>
<td>400 nm</td>
</tr>
</tbody>
</table>
16. The air in a pipe, of length $l$ and open at both ends, vibrates with a fundamental frequency $f$. What is the fundamental frequency of a pipe of length $1.5l$ and closed at one end?

A. $\frac{f}{3}$

B. $\frac{2f}{3}$

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

D. $3f$

18. Unpolarized light of intensity $I_0$ is incident on a polarizer with a vertical transmission axis. The transmitted light is incident on a sheet of material X. After transmission through X the intensity of the light is $\frac{I_0}{2}$.

It is suggested that X could be

I. a polarizer with vertical transmission axis
II. a polarizer with horizontal transmission axis
III. non polarizing glass.

Which of the above suggestions is/are correct?

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