Markscheme-Topic 4.1: Waves-Oscillations

1. A
2. B
3. D
4. C
5. C
6. C

Short answer questions

7. (a) The force acting/accelerating (on the body) is directed towards equilibrium (position);
and is proportional to its/the body's displacement from equilibrium; 2

(b) (i) \(1.5 \times 10^{-10}\) m;
(ii) \(T = 1.1 \times 10^{-14}\) s;
\(f = 1/(1.1 \times 10^{-14}\) s\)
\(= 9.1 \times 10^{13}\) Hz 2 [5]

8.

9.

a) Rearranging the equation we obtain
\[\frac{\text{a}}{\text{x}]\]
Substituting the units for the quantities gives
unit of \(k = \frac{\text{m}^{-1}}{\text{m}} = \text{s}^{-2}\)
So the units of \(k\) are \(\text{s}^{-2}\) or per second squared – this is the same as frequency squared (and could be written as \(\text{Hz}^2\)).

b) Referring to the solution to (a) we can see that for \(S_2\) the square of the frequency would be 4 times that of \(S_1\). This means that \(S_2\) has \(\sqrt{4}\) or twice the frequency (or half the period) of \(S_1\). That is the difference.
10. 
   a) \((0.25 \pm 0.01)\) s
   b) 0.79 radians
   c) 45°
Markscheme-Topic 4.2: Waves- Travelling waves

1. D
2. C
3. C
4. B
5. D
6. A
7. D
8. B
9. B
10. A

Short answer questions

1. Waves on a string
   (a) (i) wavelength = 3.0cm;  
   (ii) period 0.25 ms;  
   hence frequency = 4000Hz;  
   (Bald answer 4000 Hz scores [2])
   (iii) \[ c = \left( \frac{0.03}{0.25 \times 10^{-3}} \right) = 0.03 \times 4000 = 120 \text{ ms}^{-1}; \]
   Watch ecf from (i) and (ii)  

2. Wave properties
   (a) (i)

   (ii)
Markscheme Topic 4.2: Waves - Travelling waves

(b)

(i) downwards; 1
(ii) correct marking of A; 1
(iii) correct marking of \( \lambda \); 1
(iv) +ve sine curve; correct position of N; 2

Watch for ecf from (i).

(c) (i) \( f = \frac{v}{\lambda} \) to give 2.0 Hz; 1

(ii) \( T = 0.5 \text{ s}; \)
\[ s = \frac{vT}{4} = 1.25 \text{ (1.3) cm}; \]

or

in \( \frac{T}{4} \) wave moves forward \( \frac{1}{4} \lambda \);
\[ = \frac{5}{4} = 1.25 \text{ (1.3) cm}; \] 2 max

3. (a) longitudinal; 1
(b) (i) wavelength = 0.5 m; 1
(ii) amplitude = 0.5 mm; 1
(iii) correct substitution into speed = frequency \( \times \) wavelength;
to give \( v = 660 \times 0.5 = 330 \text{ m s}^{-1}; \) 2 max
Markscheme - Topic 4.3: Waves - Wave characteristics

Short answer questions

1. (a) using the equation $I = \frac{p}{4\pi r^2}$ so $I_1 r_1^2 = I_2 r_2^2$  
   
   (b) $\frac{l_1}{l_2} = \frac{A_1^2}{A_2^2}$ and $\frac{l_1}{l_2} = \frac{A_1}{A_2} = 8.0$  

   2. (a) the net displacement of the medium / particles (through which waves travel); is equal to the sum of individual displacements (produced by each wave);  

   Award a good understanding [2 max] and a reasonable one [1 max].

   (b) Wave X and wave Y should be identical.

2. (a) in unpolarized light the electric field vector may vibrate in any plane (normal to the direction of propagation);  

   in polarized light the vector/electric field vibrates in one plane only;  

   correct phase for wave X;  

   correct phase for wave Y;  

   amplitudes the same for each wave;  

   amplitude for each wave is two divisions;  

   4 max

   [6]
To award [2 max] reference must be made to “electric field vector” at least once. Award [2 max] for any relevant correctly labelled diagram. 2

(b) \( \cos^2 \theta \) graph; (judge shape by eye) max \( I_0 \) at 0° and 180° and zero at 90°; 2

[4]
Markscheme-Topic 4.4: Waves-Wave behavior

Markscheme-Topic 4.4: Waves-Wave behavior

1. D
2. A
3. C
4. B
5. A
6. A
7. C
8. D
9. D
10. A
11. C
12. A
13. C
14. C
15. A

Short answer questions

1. (a) (i) when the (transmitted) ray/light in medium 2 is along the boundary/refracted at 90°;
   the angle of incidence in medium 1 is the critical angle; 2
   or
   when a ray/light is incident on the boundary at an angle greater than the critical angle;
   the ray is not transmitted / no light is transmitted but is totally reflected at the boundary / is totally internally reflected;
   (ii) reflected ray with angle of reflection = angle of incidence;
        transmitted ray with angle of refraction greater than angle of incidence; 2
        Judge both by eye.

   (b) $n_1 \sin \theta = n_2 \sin \theta_2$
       $\theta_1 = \phi_c$ and $\theta_2 = 90°$;
       $n_1 \sin \phi_c = n_2$; 2

2. (a) light incident from glass;
      emergent ray along boundary;
      c marked correctly; 3

   (b) $\sin c = \frac{1}{1.5}$;
       for every 1.0 mm length, light travels 1.5 mm;
       path length = $1.2 \times 10^8 \times 1.5$
       = 1.8 km; 4

   Award [4] for any correct calculation that leads to 1.8 km.
Markscheme-Topic 4.4: Waves-Wave behavior

3. (a) medium 1; wavelength is greater than in medium 2; and \( c = f \lambda \) and frequency is same in both media;  
Award \([1]\) if the candidate answers medium 2, because wavelength is greater. Award \([1]\) for correct medium and mention of bending towards normal when entering medium 2. Award \([0]\) for correct medium but incorrect or no explanation.

(b) measurement of wavelength:  
\[ \lambda_1 = 2.5\text{cm}; \]
\[ \lambda_2 = 1.0\text{cm}; \]
\[ \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2} = 2.5(\pm 0.2); \]

or

measurement of incident and refraction angles:  
\[ \theta_1 = 60^0; \]
\[ \theta_2 = 20^0; \]
\[ \frac{c_1}{c_2} = \frac{\sin \theta_1}{\sin \theta_2} = 2.5; \]

Award \([2]\) if the candidate gets it the wrong way round in either method, but they must have answered medium 2 in (a).

4. (a) (i) wavefront parallel to D;  
    (ii) frequency is constant;  
    since, \( v = f \lambda \), \( v \propto \lambda \)  
    wavelength larger in medium 1, hence higher speed in medium 1;  
    Allow solution based on angles marked on the diagram or speed of wavefronts.

(b) (i) velocity / displacement / direction in (+) and (–) directions;  
    idea of periodicity;  
    (ii) period = 3.0 ms;  
    frequency = \( \frac{1}{T} = 330 \text{ Hz}; \)

(iii) Accept any one of the following.  
    at time \( t = 0 / 1.5 \text{ ms} / 3.0 \text{ ms} / 4.5 \text{ ms etc}; \)  
    1 max

(iv) area of half-loop = 140 squares \( \times 10 \) / mean \( v = 4.0 \text{ m s}^{-1} \times 0.2; \]
    \[ = 140 \times 0.4 \times 0.1 \times 10^{-3} / 4.0 \times 1.5 \times 10^{-3}; \]
    \[ = 5.6 \times 10^{-3} \text{ m} / 6.0 \times 10^{-3} \text{ m}; \]
    2 max

Award \([1]\) for area of the triangle.
Markscheme-Topic 4.4: Waves-Wave behavior

(v) (twice) the amplitude;

Allow distance moved in 1.5 m s.

(c) (i) when two (or more) waves meet;
resultant displacement is the sum of the individual displacements; 2
(ii) at M, it is loud;
at P, minimum / not so loud;
at P, path difference is \( \frac{1}{2} \lambda \) and at M, no path difference;
at P, destructive interference and at M, constructive; 4
(iii) because adding in a larger amplitude;
sound is louder at M;
because wave amplitudes no longer equal;
sound louder at P; 4

Award 1[II] for louder at M and at P.

(iv) sources are not coherent 1

(d) (i) wavelength = \( \frac{c}{f} \); 1
(ii) speed relative to observer = \( (c + v) \); 1

5. (a) each element of the slit acts as a point source of light;
the light from these sources interfere;
there will be a zero of intensity (on the screen) when the sum of the path differences between the sources is an integral number of half wavelengths / a maximum when an integral number of wavelengths; 3

(b) \[ \theta = \frac{d}{D} = \frac{\lambda}{b} \];

rearrange to get \( d = \frac{D\lambda}{b} \); 2

(c) central maximum same intensity as single slit maximum;
two other maximum either side about half-intensity of central maximum; 2

Award 1[II] max if lines do not touch x-axis.

There is no need to show maxima within secondary maxima. Do not penalize responses if more than two maxima are shown but they must be symmetrical and with realistic relative intensities. [7]
Markscheme-Topic 4.4: Waves-Wave behavior

6. (a) wider slit gives narrower single-slit diffraction pattern; so fewer fringes observed;  
(b) greater amplitude / intensity from both slits; bright fringes are brighter; dark fringes are unchanged;  

7. (a) \[ d = \frac{\lambda D}{s}; \]
     \[ = \frac{\lambda}{\theta}; \]
     \[ = \frac{6.33 \times 10^{-7}}{4.00 \times 10^{-4}} = 1.58 \text{ mm}; \]
     or
     accept use of \( d \sin \theta = n \lambda \) with \( n = 1; \)
     \( \sin \theta = \theta; \)
     \[ d = \frac{6.33 \times 10^{-7}}{4.00 \times 10^{-4}} = 1.58 \text{ mm}; \]
(b) same number of maxima at the same place but much sharper;
greater intensity than double slit;  

(c) fringes are coloured;
blue on the inside / red on the outside;
also accept:
no fringes will be seen;
light is not coherent;  

[7]
Markscheme-Topic 4.5: Waves-Standing waves

Short answer questions

1. Waves
   (a) no energy is transferred; variable amplitude / variable maximum displacement of particles / OWTTE; points along the wave where amplitude is always zero / reference to phase / OWTTE; 2
   (b) if two or more waves overlap / OWTTE; the resultant displacement at any point is found by adding the displacements produced by each individual wave / eg peak / trough meets peak / trough to give maximum / minimum / OWTTE; 2
   (c) (i) \( t = \frac{T}{4} \): straight-line; (a line must be drawn on the diagram)
       \[ t = \frac{T}{2} \]: negative sine; 2
   (ii) the points of no displacement / nodes (at middle and ends) do not change with time; therefore, the wave cannot be moving forward / does not progress; 2

2. (a) (i) C shown where graph line cuts x-axis; 1
   (ii) time period = 0.30 ms; use of \( v = f \lambda \) and \( f = \frac{1}{T} \) or \( v = \frac{\lambda}{T} \);
       \( \lambda = 380 \times 0.30 \times 10^{-3} = 0.11 \text{ m}; \)
       ECF if time period misread. 3
   (b) (i) superposition of two waves / OWTTE; of same frequency and amplitude travelling in opposite directions; 2
   (ii) stationary/standing wave is set up in the tube; heaps form at the (displacement) nodes / powder pushed away from antinodes; 2
Markscheme: Topic 4.5: Waves-Standing waves

(iii) wavelength = \(2 \times 9.3 = 18.6\) cm;
\[\text{speed} = (1800 \times 0.186) = 330\ m\ s^{-1};\]

ECF if value of wavelength wrong. 2

(c) heaps further apart means longer wavelength;

hence speed increases (as temperature rises);

Do not award if there is no reasoning or reasoning is fallacious or misleading. 2

(d) (i) when two waves meet;

resultant displacement found by summing individual displacements;

\[\text{to give maximum displacement / displacement greater than that of an individual wave;}\]

(ii) line in correct position, labelled C; 1

(iii) line in correct position, labelled D; 1

3. (a) no energy is propagated along a standing wave / OWTTE;

the amplitude of a standing wave varies along the wave / standing wave has nodes and antinodes;

in standing wave particles are either in phase or in antiphase / OWTTE; 2

(b) medium 1;

wavelength is greater than in medium 2;

and \(c = f\lambda\) and frequency is same in both media;

\[\text{Award [1] if the candidate answers medium 2, because wavelength is greater.}\]

\[\text{Award [1] for correct medium and mention of bending towards normal when entering medium 2. Award [0] for correct medium but incorrect or no explanation.}\]

(c) measurement of wavelength:

\[\lambda_1 = 2.5\ cm;\]

\[\lambda_2 = 1.0\ cm;\]

\[\frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2} = 2.5 \pm 0.2;\]

or

measurement of incident and refraction angles:

\[\theta_1 = 60^\circ;\]

\[\theta_2 = 20^\circ;\]

\[\frac{c_1}{c_2} = \frac{\sin \theta_1}{\sin \theta_2} = 2.5;\]

\[\text{Award [2] if the candidate gets it the wrong way round in either method, but they must have answered medium 2 in (b).}\]

(d) Look for these main points.

\[\text{when the tube is vibrated, a wave travels along the tube and is reflected at B;}\]

\[\text{the wave is inverted on reflection;}\]

\[\text{the reflected wave interferes with the forward wave;}\]

\[\text{the maximum displacements occurs midway between A and B;}\]

\[\text{since there is always a node at A and B, then the pattern shown will be produced / OWTTE;}\]

\[\text{Award [1] for essentially two waves in opposite directions, [1] for \(\pi\) out of phase, [1] for interference and [2] for condition to produce shape.}\]
(e) (i) \( f = \frac{v}{\lambda} \); 

\[ \text{to get } f = \text{constant } \sqrt{T} \text{ since } \lambda \text{ constant;} \]

\[ \text{therefore, a plot of } f^2 \text{ against } T \text{ or } f \text{ against } \sqrt{T}; \]

\[ \text{should produce a straight-line through the origin / OWTTE; } \]

(ii) \( \lambda = 4.8 \text{m}; \)

\[ v = f\lambda = 1.8 \times 4.8 = 8.6 \text{ms}^{-1}; \]

\[ k = \frac{v}{\sqrt{T}} = \frac{8.6}{3} = 2.9; \]

\[ \text{Ignore any units.} \]