M1. (a) (wave) **B** ✓

(the parts of the) spring oscillate / move back and forth **in direction of / parallel to** wave travel
OR
mention of compressions and rarefactions ✓

Second mark can only be scored if first mark is scored

2

(b) (i) (double ended arrow / line / brackets) from between two points in phase ✓

1

(ii) wave A: arrow vertically upwards ✓

wave B: arrow horizontally to the left ✓

2

(c) (transmitted radio waves are often) polarised ✓

aerial (rods) must be aligned in the same plane (of polarisation / electric field) of the wave ✓

2

[7]

M2. (a) the **maximum displacement** (of the wave or medium) ✓

from the equilibrium position ✓

accept 'rest position', 'undisturbed position', 'mean position'

2

(b) (vertically) **down**wards (¼ cycle to maximum negative displacement) ✓

then **upwards** (¼ cycle to equilibrium position and ¼ cycle to maximum po itive di placement) ✓

down (¼ cycle) to **equilibrium position/zero** displacement **and** correct reference to either **maximum** positive **or** negative displacement or correct reference to fractions of the cycle ✓

candidate who correctly describes the motion of a knot 180 degrees out of phase with the one shown can gain maximum two marks
(ie knot initially moving upwards)

3

(c) **max 3 from**

stationary wave formed ✓

by **superposition or interference** (of two progressive waves) ✓

knot is at a **node** ✓

waves (always) cancel **where the knot is** ✓

allow 'standing wave'

3

[8]

M3. (a) (i) particle vibration (or disturbance or oscillation) **(1)**
same as (or parallel to) direction of propagation
(or energy transfer) **(1)**

(ii) (particle vibration)
perpendicular to direction of propagation (or energy transfer) **(1)**

3

(b) variation in intensity between max and min (or light and dark) **(1)**
two maxima (or two minima) in 360° rotation **(1)**

2
QWC 1

[5]

M4. (a) **maximum displacement** from equilibrium/mean position/mid-point/etc **(1)**

1

(b) (i) any **one** from:

surface of water/water waves/in ripple tank **(1)**

rope **(1)**

slinky clearly qualified as transverse **(1)**

secondary ('s') waves **(1)**

max 1

(ii) transverse wave: oscillation (of medium) is perpendicular to wave travel

or transverse can be polarised

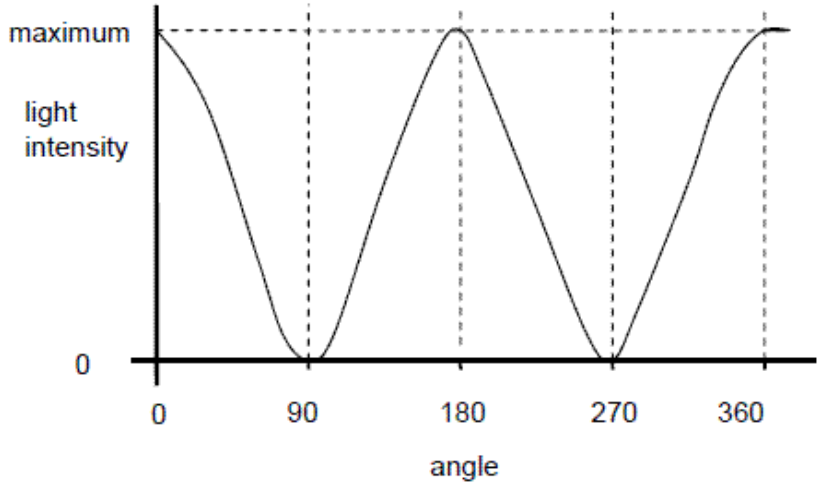
or **all** longitudinal require a medium **(1)**

1

(c) (i) vertical line on B ± 5° **(1)**

1

(ii)



max 0, 180, 360 + min 90, 270 **(1)**

and line reaches same minimum and maximum every time and reasonable shape **(1)**

2

(d) appropriate use **(1)**

reason for Polaroid filter being used **(1)**

eg

Polaroid gla e / **un**gla e / windscreens	to reduce glare
camera	reduce glare/enhance image
(in a) microscope	to identify minerals/rocks
polarimeter	to analyse chemicals/concentration or type of sugar
stress analysis	reveals areas of high/low stress/ other relevant detail
LCD displays	very low power/other relevant detail
3D glasses	enhance viewing experience, etc

2

[8]

M5. (a) (i) 0.4(0) m **(1)**

(ii) speed (= frequency × wavelength) = 22 × 0.4(0) ecf **(1)**
= 8.8 (m s^{-1}) **(1)**

(ii) 90 or 450 (1) ° or **degrees (1)**
or 0.5π or 2.5π or 5π/2 **(1) rad**(ians)
or **r** or ʳ **(1)** no R, Rad, etc

5

(b) displacement of Y will be a **positive (or 'up') maximum** at 1/4 of a period (or cycle) (0.0114 s) **(1)**

returns to original position (at 0.5 of a period or cycle) (owtte) **(1)**

2

[7]

M6. (a) (progressive waves travel from centre) to ends and reflect **(1)**

two (progressive) waves travel in opposite directions along the string **(1)**

waves have the same frequency (or wavelength) **(1)**

wave have the ame (or imilar) **amplitude (1)**

superposition (accept 'interference') **(1)**

max 3

(b) (i) wavelength (= 2 × PQ = 2 × 1.20 m) = 2.4 m **(1)**

speed (= wavelength × frequency = 2.4 × 150) = 360 m s^{-1} **(1)**

(answer only gets both marks)

(ii) diagram to how three 'loop ' **(1) and** of equal length and good shape **(1)** (or loop of one third length **(1)**)

4

[7]

M7. (a) interference or superposition **(1)**
reflection from metal plate **(1)**
two waves of the same frequency/wavelength **(1)**
travelling in opposite directions (or forward/reflected waves) **(1)**
maxima where waves are in phase or interfere constructively **(1)**
minima where waves are out of phase/antiphase or interfere destructively **(1)**
nodes and antinodes or stationary waves identified **(1)**

max 4
QWC 2

(b) (i) (distance between minima = $\frac{\lambda}{2}$)

$\left(\frac{\lambda}{2} = \frac{144}{9} \text{ gives}\right)$ λ = 32.0 mm **(1)**

(ii) $c = f\lambda$ and $c = 3 \times 10^8$ (m s^{-1}) **(1)**

$f = \frac{3 \times 10^8}{32 \times 10^{-3}} = 9.38 \times 10^9$ Hz **(1)**

(allow C.E. for value of λ from (i))

3

[7]

M8. **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of the three levels according to the following criteria.

High Level (good to excellent) 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Mentions **waves** travelling in **opposite directions** or waves of **same frequency** (and amplitude) **and** superpose **or** interfere **or** add together.

Intermediate Level (modest to adequate) 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Mentions **waves** travelling in **opposite directions** (accept 'waves reflect/ rebound back or from clamp') **or superposition/addition/interference of waves or** waves of same frequency/wavelength.

Low Level (poor to limited) 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may only be partly appropriate.

One correct key feature **or** one relevant remark regarding formation given.

The explanation expected in a competent answer should include a coherent account of the following points concerning the physical principles involved and their consequences in this case.

- 4 nodes where there is no movement/zero amplitude
- 3 antinodes where amplitude is maximum
- wavelength 0.80 m
- end antinodes in phase/middle and ends in antiphase
- between node and antinode, amplitude of oscillation increases
- waves reflect off the clamp (and the rod)
- waves travelling in opposite directions superpose/add/interfere
- wave have same wavelength and frequency (similar amplitude)
- always cancellation at nodes/always constructive superposition at antinodes
- energy is not transferred along string

[6]

M9. (a) (i) one 'loop' (accept single line only, accept single dashed line)

+ nodes at each bridge (± length of arrowhead)

+ antinode at centre **(1)**

1

(ii) $\lambda_0 = 2L$ or $\lambda = 0.64 \times 2$ **(1)**

= 1.3 (m) **(1)** (1.28)

2

(iii) ($c = f\lambda$) = 108 × (a)(ii) **(1)**

= 138 to 140(.4) (m s^{-1}) **(1)** ecf from (a) (ii)

2

(b) (i) four antinodes **(1)** (single or double line)

first node on 0.16 m (within width of arrowhead)

+ middle node between the decimal point and the centre of the 'm' in '0.64 m'

+ middle 3 nodes labelled 'N', 'n' or 'node' **(1)**

2

(ii) (4 f_0 =) 430 (Hz) **(1)** (432)

or use of $f = \frac{v}{\lambda}$ gives 430 to 440 Hz correct answer only, no ecf

1

(c) decrease the length/increase tension/tighten string **(1)**

1

[9]

M10. (a) (i) oscillates / vibrates ✓

(allow goes up and down / side to side / etc, repeatedly, continuously, etc)

about equilibrium position / perpendicularly to central line ✓

2

(ii) X and Y: antiphase / 180 (degrees out of phase) / π (radians out of phase) ✓

X and Z: in phase / zero (degrees) / 2π (radians) ✓

2

(b) (i) $v = f\lambda$

= 780 x 0.32 / 2 or **780 x 0.16 OR 780 x 320 / 2** or **780 x 160** ✓

THIS IS AN INDEPENDENT MARK

= 124.8 ✓ (m s^{-1}) correct 4 sig fig answer must be seen

2

(ii) ¼ cycle ✓

T = 1 / 780 OR = 1.28×10^{-3} ✓

$0.25 \times 1.28 \times 10^{-3}$

= 3.2×10^{-4} (s) ✓

Allow correct alternative approach using distance of 0.04m ✓

travelled by progressive wave in ¼ cycle divided by speed.

0.04 /125 ✓ = 3.2×10^{-4} (s) ✓

(c) (i) antinode ✓

1

(ii) 2 x 0.240 ✓

= 0.48 m ✓ '480m' gets 1 mark out of 2

2

(iii) ($f = v/\lambda$ = 124.8 or 125 / 0.48) = **260** (Hz) ecf from cii ✓

1

[13]

M11. (a) reflection (or 2 waves travelling in opposite directions) **(1)**

waves have similar amplitudes **(1)**

waves have similar frequency **(1)**

reflected wave loses only a little energy at the wall **(1)**

max 3

(b) displacement perpendicular to rest position of the string **(1)**

1

(c) **A** larger than **B (1)**

A 180° out of phase with **B (1)**

2

(d) λ = 1.2m **(1)**

$c = f \lambda$ **(1)**

f = 6.2/1.2 **(1)** 5.2Hz **(1)**

4

(e) (i) diagram correct: 6 loops **(1)**

(ii) Q and R correct **(1)**

2

[12]