1)

**(a)** displacement & direction of energy travel normal to one another ... B1 [1]

**(b) (i)** phase angle of 60° correct .. (need to see 1½ wavelengths) ........ B1
lags behind $T_1$ ........................................................ B1 [2]

**(ii)** waves must be in same place (at same time) ........................ B1
resultant displacement = sum of individual displacements ......... B1 [2]

**(iii) 1.** $-\frac{1}{2}A$ ........................................................ B1
**2.** $\frac{1}{2}A$ ...... (allow e.c.f.) ........................................ B1
**3.** zero ..... (allow e.c.f.) .......................................... B1 [3]

2)

**(a)** e.g. both transverse/longitudinal/same type
meet at a point,
same direction of polarisation, etc.......1 *each, max 3* ................ B3 [3]
(allow 1 mark for any condition for observable interference)

**(b) (i)1** allow 0.3 mm → 3 mm.......................................................... B1

**(i)2** $\lambda = ax/D$ (allow any subject)................................................ B1

**(ii)1** separation increased.............................................................. B1
less bright ........................................................................ B1

**(ii)2** separation increased.............................................................. B1
less bright ........................................................................ B1

**(ii)3** separation unchanged............................................................ B1
fringes brighter..................................................................... B1
further detail, i.e quantitive aspect in (ii)1 or (ii)2......................... B1 [7]
(in (b), do not allow e.c.f. from (b)(i)2)

3)

**(a)** Fig. 6.1(a): approximately circular wavefronts .................................. M1
centred on gap ........................................................ A1
constant wavelength (allow this in **(a)** or **(b)** ......................... B1
Fig. 6.1(b): wavefronts plane at centre .......................................... M1
curved at edges ........................................................ A1 [5]

**(b)** $\theta = \frac{1}{2}(162 - 136) = 13°$ .................................................... C1
$d \sin\theta = n\lambda$ ................................................................ C1
$d \sin 13 = 2 \times 630 \times 10^{-9}$ .................................................. C1
$d = 5.6 \times 10^{-6}$ m ........................................................ A1 [4]
(Use of $\theta$ = 162° or 136°, max 2/4)

**(c)** e.g. more slits for light to pass through
narrow so more diffracted light and 'off-axis' fringes clearer ................ B1 [1]

4)

| | | | | |
|---|---|---|---|---|
| **(a)** | **(i)** | $c = f\lambda$ | C1 | |
| | | $\lambda = (3.00 \times 10^{8}) / (4.8 \times 10^{14})$ | | |
| | | $= 625 \times 10^{-9}$ m | C1 | |
| | | number of wavelengths $= (0.1 \times 10^{-3}) / (625 \times 10^{-9})$ | M1 | |
| | | $= 160$ | A0 | **[3]** |
| | **(ii)** | pattern seen due to diffraction (at each slit) | M1 | |
| | | for large amount of diffraction, wavelength is about slit width | A1 | |
| | | not so here, so very little diffraction | A1 | **[3]** |
| **(b)** | | $\lambda = ax / D$ | C1 | |
| | | $x = (625 \times 10^{-9} \times 2.6) / 1.5 \times 10^{-3}$ | C1 | |
| | | $= 1.1$ mm | A1 | **[3]** |
| **(c)** | | fringe separation is unchanged | B1 | |
| | | bright fringes are brighter | B1 | |
| | | dark fringes stay dark | B1 | **[3]** |
| | | (allow $1/2$ for fringes brighter/more contrast but $0/2$ for more intense) | | |

5)

**(i)** 1.7(2) µm ........................................................................ A1

**(ii)** d sin*2* = $n\lambda$ (double slit formula scores 0/2)
$1.72 \times 10^{-6} \times \sin 2 = 590 \times 10^{-9}$ ........................................ C1
*2* = 20.1° (allow 20°) ........................................................ A1

**(iii)** ½L = 1.5 tan20.1 ........................................................ C1
L = 1.1 m ........................................................................ A1 [5]

6)

**(a)** **(i)** frequency: number of oscillations per unit time — M1
of the source / of a point on the wave — A1 [2]

**(ii)** speed: speed at which energy is transferred / speed of wavefront — B1 [1]

**(b)** **(i)** does not transfer energy (along the wave) — B1 [1]

**(ii)** position (along wave) where amplitude of vibration is a maximum — B1 [1]

**(iii)** all three positions marked — B1 [1]

**(c)** wavelength = 2 × 17.8 = 35.6 cm — C1
$v = f\lambda$ — C1
$v = 125 \times 0.356$
$= 44.5\ \text{m s}^{-1}$ — C1
$44.5^2 = 4.00 / m$ — C1
$m = 2.0 \times 10^{-3}\ \text{kg m}^{-1}$ — A1 [5]

7)

**(a)** wave incident at an edge / aperture / slit /(edge of) obstacle — M1
bending / spreading of wave (into geometrical shadow) — A1 [2]
(*award 0/2 for bending at a boundary*)

**(b)** **(i)** apparatus e.g. laser & slit / point source & slit / lamp and slit & slit
microwave source & slit
water / ripple tank, source & barrier — B1
detector e.g. screen
aerial / microwave probe
strobe / lamp — B1
what is observed — B1 [3]

**(ii)** apparatus e.g. loudspeaker, and slit / edge — B1
detector e.g. microphone & c.r.o. / ear — B1
what is observed — B1 [3]

8)

**(a)** *either* phase difference is $\pi$ rad / 180°
*or* path difference (between waves from $S_1$ and $S_2$) is $\frac{1}{2}\lambda / (n + \frac{1}{2})\lambda$ . — B1
*either* same amplitude / intensity at M
*or* ratio of amplitudes is 1.28 / ratio of intensities is $1.28^2$ .................. B1 [2]

**(b)** path difference between waves from $S_1$ and $S_2$ = 28 cm ................. B1
wavelength changes from 33 cm to 8.25 cm ..................................... B1
minimum when $\lambda$ = (56 cm,) 18.7 cm, 11.2 cm, (8.0 cm) ................ B1
so two minima ........................................................................ B1 [4]

9)

| | | | | |
|---|---|---|---|---|
| **(a)** | | When two (or more) waves meet *(not 'superpose' or 'interfere')* | B1 | |
| | | resultant displacement | M1 | |
| | | is the sum of individual (displacements) | A1 | **[3]** |
| **(b)** | **(i)** | any correct line through points of intersection of crests | B1 | |
| | **(ii)** | any correct line through intersections of a crest and a trough | B1 | **[2]** |
| **(c)** | **(i)** | $\lambda = ax/D$ OR $\lambda = a\sin\theta$ and $\theta = x/D$ | C1 | |
| | | $650 \times 10^{-9} = (a \times 0.70 \times 10^{-3})/1.2$ | C1 | |
| | | $a = 1.1 \times 10^{-3}$ m | A1 | **[3]** |
| | **(ii) 1** | no change | B1 | |
| | **2** | brighter | B1 | |
| | **3** | no change *(accept stay/remain dark)* | B1 | **[3]** |
| | | **Total** | | **[11]** |

10)

**(a)** wavelength = 1.50 m **B1** **[1]**

**(b)** $v = f\lambda$ **C1**

speed = 540 m $s^{-1}$ **A1** **[2]**

**(c)** (progressive) wave reflected at the (fixed) ends **B1**

wave is formed by superposition of (two travelling) waves **B1**

this quantity is the speed of the travelling wave **B1** **[3]**

11)

| | | | | |
|---|---|---|---|---|
| **(a)** | | When a wave (front) is incident on an edge or an obstacle/slit/gap | M1 | |
| | | Wave 'bends' into the geometrical shadow/changes direction/spreads | A1 | **[2]** |
| **(b)** | **(i)** | $d = 1/(750 \times 10^3)$ | C1 | |
| | | $= 1.33 \times 10^{-6}$ m | A1 | **[2]** |
| | **(ii)** | $1.33 \times 10^{-6} \times \sin 90° = n \times 590 \times 10^{-9}$ | C1 | |
| | | $n = 2$ (must be an integer) | A1 | **[2]** |
| | **(iii)** | formula assumes no path difference of light before entering grating <u>or</u> there is a path difference before the grating | B1 | **[1]** |
| **(c)** | | e.g. lines further apart in second order<br>lines fainter in second order<br>(allow any sensible difference: 1 each, max 2)<br>(if differences stated but without reference to the orders, max 1 mark) | B2 | **[2]** |

12)

| | | | |
|---|---|---|---|
| **(a)** | **(i)** correct shape drawn | B1 | **[1]** |
| | **(ii)** two nodes marked correctly | B1 | **[1]** |
| **(b)** | $\frac{1}{2}\lambda = 0.324$ m | C1 | |
| | $v = f\lambda$ | C1 | |
| | $= 512 \times 2 \times 0.324$ | | |
| | $= 332$ m s$^{-1}$ | A1 | **[3]** |
| **(c)** | $\frac{1}{4}\lambda = 16.2$ cm | C1 | |
| | *either* antinode is 0.5 cm above top of tube | | |
| | *or* antinode is 16.2 cm above water surface | A1 | **[2]** |

13)

| | | | | |
|---|---|---|---|---|
| **(a)** | **(i)** | when two (or more) waves meet (at a point) | M1 | |
| | | there is a change in overall intensity / displacement | A1 | |
| | **(ii)** | constant phase difference (between waves) | B1 | [3] |
| **(b)** | **(i)** | $d\sin\theta = n\lambda$ | B1 | |
| | | $(10^{-3} / 550) \sin 90 = n \times 644 \times 10^{-9}$ | C1 | |
| | | $n = 2.8$ | C1 | |
| | | so two orders | A1 | [4] |
| | | (*power-of-ten error giving 2800 orders, allow 1/3 only for calculation of n*) | | |
| | **(ii)** | **1.** $d\sin\theta = n\lambda$ (*either here or in* ***(i)*** *– not both*) | | |
| | | $\theta$ is greater so $\lambda$ is greater | B1 | [1] |
| | | **2.** when $n$ is larger, $\Delta\theta$ is larger | M1 | |
| | | so greater in second order | A1 | [2] |

14)

| | | | |
|---|---|---|---|
| **(a)** | amplitude between 6.5 squares and 7.5 squares on 3 peaks | B2 | |
| | (*allow 1 mark if outside this range but between 6.0 and 8.0 squares*) | | |
| | correct phase (ignore lead/lag, look at x-axis only and allow ±½ square | B1 | [3] |
| **(b)** | $\lambda = ax / D$ | C1 | |
| | $540 \times 10^{-9} = (0.700 \times 10^{-3}\, x) / 2.75$ | C1 | |
| | $x = 2.12$ mm | A1 | [3] |
| **(c)** | **(i)** same separation | B1 | |
| | bright areas brighter (1) | | |
| | dark areas, no change (1) | | |
| | (*allow 'contrast greater' for 1 mark if dark/light areas not discussed*) | | |
| | fewer fringes observed (1) *any two, 1 each* | B2 | [3] |
| | **(ii)** smaller separation of fringes | B1 | |
| | no change in brightness | B1 | [2] |