1. A

[1]

2. C

[1]

3. B

[1]

4. C

[1]

5. D

[1]

6. (a) D 1

(b) **Wavelength**

Use of $v = f\lambda$ **(1)**
Use of $f = 1/T$ **(1)**
Answer T = [0.002 s] **(1)**
[give full credit for candidates who do this in 1 stage T = □/v]

<u>Example of answer</u>
$v = f\lambda$
f = 330 / 0.66
$T = 1/f$ = 0.66 / 330
T = 0.002 s 3

[4]

7. Direction of travel of light is water → air **(1)**
Angle of incidence is greater than the critical angle **(1)** 2

[2]

8. (a) Transverse waves oscillate in any direction perpendicular to wave direction **(1)**
Longitudinal waves oscillate in one direction only OR parallel to wave direction. **(1)**
Polarisation reduces wave intensity by limiting oscillations and wave direction to only one plane OR limiting oscillations to one direction only. **(1)**
(accept vibrations and answers in terms of an example such as a rope passing through slits) 3

(b) Light source, 2 pieces of polaroid and detector e.g. eye, screen, LED OR laser, 1 polaroid and detector **(1)**
Rotate one polaroid **(1)**
Intensity of light varies **(1)** 3

[6]

9. Frequency unaltered **(1)**
Wavelength decreases **(1)**
Speed decreases **(1)** 3

[3]

10. The answer must be clear and the answer must be organised in a logical sequence **(QWC**

- It was known that X penetrated **(1)**
- It was not known that X rays were harmful **(1)**
- Doctors died because of too much exposure **(1)**
- Lack of shielding **(1)**
- New treatments may have unknown side effects **(1)**
- Treatments need to be tested / time allowed for side effects to appear **(1)** Max 4

[4]

11. (a) [1.0 m] **(1)** 1

(b) Ratio of (5 or 6 / 3) × 60 **(1)**
Answer [f = 100 Hz] **(1)** 2

[3]

12. Use of sin i / sin r = μ **(1)**
Use of either 80° or 1.33 **(1)**
[r = 48°] **(1)** 3

Example of answer
sin 80 / sin r = 1.33
[r = 48°]

Both rays refracted towards the normal
Violet refracted more than red 2

[5]

13. (a) Diffraction is the change in direction of wave or shape or wavefront **(1)**
when the wave passes an obstacle or gap **(1)** 2

(b) The energy of the wave is concentrated into a photon **(1)**
One photon gives all its energy to one electron **(1)** 2

(c) Energy of photon increases as frequency increases OR reference to $E = hf$ **(1)**
Electrons require a certain amount of energy to break free and this corresponds to a minimum frequency **(1)** 2

[6]

14. (a) (i) Use of speed = distance over time **(1)**
Distance = 4 cm **(1)**
Answer = [2.7×10^{-5} s] **(1)**

<u>Example of answer</u>
t = 4 cm ÷ 1500 m s^{-1}
t = 2.7×10^{-5} s 3

(ii) Use of $f = 1/T$ **(1)**
Answer = [5000 Hz] **(1)** 2

(iii) Time for pulse to return greater than pulse interval **(1)**
All reflections need to reach transducer before next pulse sent. **(1)**
Will result in an inaccurate image. **(1)** (Max 2)
Need to decrease the frequency of the ultrasound. **(1)** (Max 3) Max 3

(iv) X-rays damage cells/tissue/foetus/baby but ultrasound does not (need reference to both X-rays and ultrasound) **(1)** 1

(b) The answer must be clear, use an appropriate style and be organised in a logical sequence **(QWC)**

Doppler shift is the change in frequency of a wave when the source or the receiver is moving **(1)**
Requirement for a continuous set of waves **(1)**
Two transducers required (one to transmit and one to receive) **(1)**
Change in frequency is directly related to the speed of the blood **(1)** 4

[13]

15. (a) (i) Demonstrating the stationary wave

Move microphone between speaker and wall OR perpendicular to wall OR left to right OR towards the wall [could be shown by labelled arrow added to diagram] **(1)**

Oscilloscope/**trace** shows sequence of maxima and minima **(1)** 2

(ii) How nodes and antinodes are produced

Superposition/combination/interference/overlapping/crossing of emitted/incident/initial and reflected waves **(1)**

Antinodes: waves (always) in phase OR reference to coincidence of two compressions/rarefactions/peaks/troughs /maxima/minima, hence constructive interference/reinforcement **(1)**

Nodes: waves (always) in antiphase/**exactly** out of phase OR compressions coincide with rarefactions etc, hence destructive interference / cancellation **(1)** 3

(iii) Measuring the speed of sound

<u>Measure</u> separation between (adjacent) **nodes** / **antinodes** and double to get λ/this is ½λ [not between peaks and troughs] **(1)**

Frequency known from/produced by signal generator OR measured on CRO / by digital frequency meter **(1)**

Detail on measurement of wavelength OR frequency
e.g. measure several [if a number is specified then ≥3] node spacings and divide by the number [not one several times]
OR measure several (≥3) periods on CRO and divide by the number
OR adjust cro so only one full wave on screen **(1)**

Use v (allow c) = $f\lambda$ 4

(b) (i) Application to concert hall

Little or no sound /amplitude
OR you may be sat at a node **(1)**

(ii) Sensible reason

Examples:
Reflected wave not as strong as incident wave
OR walls are covered to reduce reflections
OR waves arrive from elsewhere [reflections/different speakers]
OR such positions depend on wavelength / frequency **(1)** 2

[11]

16. (a) (i) Condition for reflection

Angle of incidence greater than critical angle [accept $i > c$] **(1)** 1

(ii) Description of path of ray

Any two from:
- Ray refracted at A and C
- Description of direction changes at A and C
- Total internal reflection at B **(1)(1)** 2

(b) (i) Things wrong with the diagram

Angle of refraction can¯t be 0 / refracted too much **(1)**

No refraction on emergence from prism **(1)**
[Allow 1 mark for correct reference to partial reflection] 2

(ii) Corrected diagram
- emergent ray roughly parallel to the rest of the emergent rays **(1)**
- direction of refraction first surface correct **(1)**
- direction of refraction second surface correct **(1)** 3

[8]

17. (a) (i) Add standing waves to diagrams

Mark for each correct diagram **(1)(1)** 2

(ii) Mark place with largest amplitude of oscillation

antinode marked [allow clear indication near centre of wave other than an X, allow correct antinode shown on diagrams B or C] **(1)** 1

(iii) Name of place marked

(Displacement) Antinode [allow ecf from (a) (ii)] **(1)** 1

(b) (i) Calculation of wavelength

Correct answer [5.6 m]

Example of calculation:
$= 2 \times 2.8$ m
$= 5.6$ m **(1)** 1

(ii) Calculation of frequency

Recall of $v = f\lambda$ **(1)**

Correct answer [59 Hz] [ecf] **(1)**

Example of calculation:
$v = f\lambda$
$f = 330 \text{ m s}^{-1} / 5.6 \text{ m}$
$= 58.9$ Hz 2

(c) (i) Explanation of difference in sound

as the room has a standing wave for this frequency / wavelength / it is the fundamental frequency
(allow relevant references to resonance) **(1)** 1

(ii) Suggest another frequency with explanation

Appropriate frequency [a multiple of 59 Hz] [ecf] **(1)**

Wavelength 1/2, 1/3 etc (stated or used) **(1)** 2

(d) Explain change in frequencies

wavelengths (of standing waves) bigger / $f = v/2l$ **(1)**

hence frequencies smaller/lower **(1)** 2

[12]

18. (a) Angles:
Normal correctly added to raindrop (by eye)

An angle of incidence correctly labelled between normal and incident ray and an angle of refraction correctly labelled between normal and refracted ray 2

(b) Angle of refraction:
Use of $\mu = \sin i / \sin r$
Correct answer [20°]
[allow 20°–21° to allow for rounding errors]

eg.
$\sin r = \sin 27° / 1.3$
$r = 20°$ 2

(c) (i) Critical angle:
The angle beyond which total internal reflection (of the light) occurs [allow T.I.R] / r = 90° 1

(ii) Critical angle calculation:

Use of $\mu = 1 / \sin C$
Correct answer [50.3°] [allow 50° – 51°]

Eg.
$\text{Sin } C = 1/1.3$
$C = 50.3°$ 2

(d) Diagram:
$i = 35°$ [allow 33° –37°]

Ray of light shown refracting away from normal on leaving raindrop
Some internal reflection of ray also shown with $i = r$ [by eye]

Reflected ray shown refracting away from the normal as it leaves the front of the raindrop / angle of refraction correctly calculated at back surface 4

(e) Refractive index:
(Red light has) lower refractive index (than violet light) 1

[12]

19. (a) (i) How we know the speed is constant

Crest spacing constant / circular crests
Or wavelength constant / equal wavelength **(1)**

[Accept wavefront for crests]
[Don't accept wave] 1

(ii) Calculation of speed
λ is 10 mm **(1)**
[Allow 9 to 11]
Use of $v = f\lambda$ **(1)**
0.40 m s^{-1} **(1)**

[Allow 0.36 to 0.44
Allow last two marks for correct calculation from wrong wavelength] 3

(40Hz)(10×10^{-3} m)
= 0.40 m s^{-1}

(b) Line X
1st constructive interference line below PQ, labelled X **(1)**

[Accept straight line
Ignore other lines provided correct one is clearly labelled X] 1

(c) (i) Superposition along PQ
Constructive interference / reinforcement / waves of larger amplitude / larger crests and troughs **(1)**
Crests from S_1 and S_2 coincide / waves are in phase / zero phase difference / zero path difference **(1)**
Amplitude is the sum of the individual amplitudes (OR twice the amplitude of the separate waves) **(1)** 3

(ii) Table
A constructive **(1)**
B destructive **(1)** 2

[10]

20. (a) Amplitude

(i) Amplitude remains constant **(1)** 1

(ii) Amplitude decreases then increases **(1)**
Amplitude is zero at node (OR half way between X and Y) **(1)** 2

(b) Phase difference

(i) Phase difference increases / is proportional to distance XP **(1)** 1

(ii) Up to node phase difference is zero / in phase **(1)**
Beyond the node phase difference is / 180° / half a cycle / in antiphase **(1)**

[Do not allow completely out of phase] 2

[6]

21. (a) (i) Name process

Refraction **(1)** 1

(ii) <u>Explanation of refraction taking place</u>

change in speed / density / wavelength **(1)** 1

(b) (i) <u>Draw ray from butterfly to fish</u>

refraction shown **(1)**

refraction correct **(1)** 2

(ii) <u>Explain what is meant by critical angle</u>

Identify the angle as that in the denser medium **(1)**

Indicate that this is max angle for refraction OR total internal reflection occurs beyond this **(1)**
[angles may be described in terms of relevant media] 2

(iii) Explain two paths for rays from fish A to fish B

direct path because no change of medium/refractive index/density **(1)**

(total internal) reflection along other path /
angle of incidence > critical angle **(1)**

direct ray correctly drawn with arrow **(1)**

total internal reflection path correctly drawn with arrow **(1)**

[lack of ruler not penalised directly] [arrow penalised once only] 4

[10]

22. (a) <u>Ultrasound</u>:
High frequency sound / sound **above** human hearing range / sound above 20 kHz / sound too high for humans to hear **(1)** 1

(b) (i) <u>Pulses used:</u>
to prevent interference between transmitted and reflected signals / allow time for reflection before next pulse transmitted / to allow for wave to travel to be determined **(1)**

(ii) High pulse rate:
Greater accuracy in detection of prey¯s motion / position / continuous monitoring / more frequent monitoring **(1)** 2

(c) Size of object:
Use of $\lambda = v/f$ **(1)**
Correct answer (0.0049 m or 4.9 mm) **(1)**
[accept 0.0048 m or 0.005 m]

example:
$\lambda = 340 \text{ m s}^{-1} / 70000 \text{ Hz}$
$= 0.0049$ m $= 4.9$ mm (accept 5 mm) 2

(d) Time interval:
Use of time = distance / speed **(1)**
Correct answer (2.9×10^{-3} s) [allow 3×10^{-3} s]
[allow 1 mark if answer is half the correct value ie. Distance = 0.5m used] **(1)**

example:
time = 1 m / 340 m s^{-1}
$= 2.9 \times 10^{-3}$ s 2

(e) Effect on frequency:
Frequency decreases **(1)**
Greater effect the faster the moth moves / the faster the moth moves the smaller the frequency **(1)** 2

[9]

23. (a) Diffraction diagram:
Waves spread out when passing through a gap / past an obstacle**(1)**
λ stays constant **(1)** 2

(b) Diagrams:
Diagram showing 2 waves in phase **(1)**
Adding to give larger amplitude **(1)** 2

(c) Information from diffraction pattern:
Atomic spacing (similar to λ)
Regular / ordered structure
Symmetrical structure
DNA is a double helix structure **(2)** Max 2

(d) Electron behaviour:
(Behave) as waves **(1)** 1

[7]

24. (a) (i) Diagram:
i and r correctly labelled on diagram **(1)**
i = 25 +/– 2° **(1)**
r = 38 +/– 2° **(1)**
[allow 1 mark if angles measured correctly from interface
ie. i = 65 +/– 2°, r = 52 +/– 2°] **(1)** 3

(ii) Refractive index:
Use of ${}_g\mu_a = \sin i / \sin r$ [allow ecf] **(1)**
Use of ${}_a\mu_g = 1/{}_g\mu_a$ **(1)**

example:
${}_g\mu_a = \sin 25 / \sin 38 = 0.686$
${}_a\mu_g = 1/ {}_g\mu_a = 1.46$ 2

(b) Ray diagram:
Ray added to diagram showing light reflecting at interface with
angles equal (by eye) **(1)** 1

(c) Observation:
Incident angle > critical angle **(1)**
T.I.R occurs **(1)** 2

(d) largest angle:
sin C = 1/1.46 (allow ecf) **(1)**
C = $\sin^{-1}$ (1/1.46) = 43° **(1)** 2

[10]

25. (a) Experiment

[Marks may be earned on diagram or in text]

Named light source plus polaroid (OR polariser OR
polarising filter) / Laser / Named light source and
suitable reflector (e.g. bench) **(1)**
2nd Polaroid plus means to detect the transmitted light **(1)**
(i.e. eye OR screen OR LDR OR light detector OR
instruction to e.g. look through polaroids)
Rotate one Polaroid [Only award if expt would work] **(1)**
Detected intensity varies / No light when polaroids are at 90° **(1)**
Maxima and minima 90° apart / changes from dark to light every 90° **(1)**
[Use of microwaves, slits or “blockers”: 0/5
Use of filters or diffraction gratings: lose first two marks
Use of “sunglasses” to observe: lose mark 2] 5

(b) Why sound can’t be polarised

They are longitudinal / They are not transverse / Only transverse waves can be polarised / Longitudinal waves cannot be polarised / Because the (*) is parallel to the (**) **(1)**

(*) = vibration OR displacement OR oscillation OR motion of particles

(**) = direction of travel OR direction of propagation OR motion of the wave OR direction of energy transfer — 1

[6]

26. (a) (i) Table

λ	f
2.4	(110)
1.2	220
0.8	330

All wavelengths correct **(2)**
[One or two wavelengths correct gets 1]
Both frequencies correct **(1)**
[Accept extra zero following wavelength figure, e.g. 2.40.
Accept units written into table, e.g. “2.4 m”, “220 Hz”] — 3

(ii) Why nodes

String cannot move / no displacement / zero amplitude / no oscillation / phase change of π on reflection / two waves cancel out / two waves are exactly out of phase **(1)**
(OR have phase difference of π OR half a cycle) / destructive interference — 1

(b) Why waves with more nodes represent higher energies

More nodes means shorter wavelength **(1)**
Momentum will be larger **(1)**
[OR Allow 1 mark for “More nodes means higher frequency and $E = hf$”] — 2

[6]

27. (a) Which transition

Use of $(\Delta)E = hc/\lambda$ OR $(\Delta)E = hf$ and $f = c/\lambda$ **(1)**
Use of 1.6×10^{-19} **(1)**
Correct answer [1.9 eV] **(1)**
C to B / –1.5 to – 3.4 **(1)**
[Accept reverse calculations to find wavelengths]

e.g.

$(6.63 \times 10^{-34}$ J s$)(3.00 \times 10^{8}$ m s$^{-1})/$
$(656 \times 10^{-9}$ m$)(1.6 \times 10^{-19}$ J eV$^{-1})$
= 1.9 eV 4

(b) Explanation of absorption line

QOWC **(1)**
Light of this wavelength is absorbed by hydrogen **(1)**
In the outer part of the Sun (OR Sun's atmosphere) **(1)**

Absorbed radiation is reemitted in all directions **(1)**
Transition from B to C (OR –3.4 to –1.5) **(1)** Max 4

(c) Why galaxy receding

Wavelength increased (OR stretched) / red shift /
frequency decreased 1

[9]

28. (a) Describe propagation of longitudinal waves

Particles oscillate / compressions/rarefactions produced **(1)**

oscillation/vibration/displacement parallel to direction of propagation **(1)** 2

(b) Calculation of wave speed

Recall of $v = f\lambda$ **(1)**

Correct answer [7.2 km s^{-1}] **(1)**

Example of calculation:

$v = f\lambda$

$v = 9$ Hz $\times$ 0.8 km

= 7.2 km s^{-1} [7200 m s^{-1}] 2

(c) Determine if elephants can detect waves more quickly

Recall of $v = s / t$ **(1)**

Correct answer for t in minutes or hours [about 6 minutes] or relevant comment with 347 s or calculation of tidal wave speed [0.35 km s^{-1}] with comment [allow ecf] **(1)** 2

Example of calculation:

$v = s / t$

t = 2500 km ÷ 7.2 km s^{-1} OR v = 2500 km ÷ (2 × 60 × 60 s)

t = 347 s OR v = 0.35 km s^{-1}

t = about 6 minutes (stated) / much less than hours / 2 h is 7200 s
OR 7.2 km s^{-1} >> 0.35 km s^{-1}

[6]

29. (a) Meaning of superposition

When vibrations/disturbances/waves from 2 or more sources coincide at same position **(1)**

resultant displacement = sum of displacements due to individual waves **(1)** 2

(b) (i) Explanation of formation of standing wave

description of combination of incident and reflected waves/ waves in opposite directions **(1)**

described as superposition or interference **(1)**

where in phase, constructive interference / antinodes
OR where antiphase, destructive interference / nodes
OR causes points of constructive and destructive interference
OR causes nodes and antinodes **(1)** 3

(ii) Calculate wavelength

Identify 2 wavelengths **(1)**

Correct answer [2.1×10^{-9} m] **(1)** 2

Example of calculation:

(NANANANAN) X to Y is $2 \times \lambda$

$\lambda = 4.2 \times 10^{-9}$ m ÷ 2

$= 2.1 \times 10^{-9}$ m

(iii) Explain terms

amplitude – maximum displacement (from mean position)
(can use diagram with labelled displacement axis) **(1)**

antinode – position of maximum amplitude
OR position where waves (always) in phase **(1)** 2

[9]

30. (a) Plane polarised:
Vibrations / oscillations **(1)**
in one plane **(1)**
OR
double-headed arrow diagram ↕ **(1)**
with vibrations / oscillations labelled **(1)** 2

(b) Polarising filter:
- Intensity goes from maximum to minimum **(1)**
- Twice per rotation / after 90° **(1)**
- As filter only lets through vibrations in a particular plane **(1)** 3

[marks may be gained from a clearly labelled diagram]

(c) Response of beetle:
Changed direction by 90° / turned through a right-angle **(1)** 1

(d) No moon:
Beetle moves in a random direction / in circles / appears disorientated **(1)** 1

[7]

31. (a) Why transverse waves can be polarised but not longitudinal waves
[Marks can be earned in diagram or text]
Transverse waves have * perpendicular to direction of ** **(1)**□

* = vibration/displacement/oscillation/motion of particles

** = travel/propagation/motion of wave/energy transfer/wave

In a transverse wave, * can be in different planes but polarisation restricts it to one plane **(1)**
Longitudinal waves have * parallel to ** **(1)** 3

[Don't accept "motion" for **
Diagrams to earn marks must be clearly labelled, but don't insist on a label "looking along direction of travel" in the usual diagrams to illustrate polarised and unpolarised waves]

(b) (i) <u>Effect of Polaroid on intensity</u>
Intensity is reduced (OR halved) [not zero] **(1)**
[Accept slightly reduced and greatly reduced]
Polaroid stops (OR absorbs) vibrations (OR waves OR light) in one plane/ **(1)**
Polaroid only lets through vibrations (OR waves OR light)in one plane/
Light has been polarised — 2

(ii) <u>Effect of rotating Polaroid</u>
No effect **(1)**
[ignore incorrect reasons accompanying statements of effect] — 1

[6]

32. (a) (i) <u>How the bow causes the wave pattern</u>
EITHER
Bow alternately pulls and releases string (or sticks and slips) **(1)**
Creates travelling wave (OR travelling vibration) (on string) **(1)**
Wave reflects at the end (OR bounces back) **(1)**
Incident and reflected waves (OR waves travelling in opposite **(1)** directions) superpose (OR interfere OR combine)
[Don't accept collide] — max 3

OR
Bow alternately pulls and releases string (or sticks and slips) **(1)**
Produces forced oscillation/acts as a driver/exerts periodic force **(1)**
[Don't accept makes it vibrate] At a natural frequency of the string **(1)**
Causing resonance (OR large amplitude oscillation) **(1)** — max 3

(ii) <u>Determination of wavelength</u>
Use of node to node distance = $\lambda/2$ / recognise diagram shows 2λ] **(1)**
Correct answer [0.4 m] **(1)** — 2

e.g. $\lambda = 2 \times 0.2$ m
$= 0.4$ m

(iii) <u>Differences between string wave and sound wave</u>
Any TWO points from:
– String wave is transverse, sound wave is longitudinal /
…can be polarised, … can't
– String wave is stationary (OR standing), sound wave is travelling (OR progressive) / … has nodes and antinodes, …doesn't /
…doesn't transmit energy, …does…
– The waves have different wavelengths
– Sound wave is a vibration of the air, not the string **(1)(1)** 2

[Don't accept travel in different directions / can be seen, can't be seen / can't be heard, can be heard / travel at different speeds
The first two marking points require statements about both waves, e.g. not just "sound waves are longitudinal"]

(b) <u>Sketch of the waveform</u>
Sinusoidal wave with T = 1 ms **(1)**
[Zero crossings correct to within half a small square
Accept a single cycle]
Amplitude 1.6 cm **(1)**
[Correct to within half a small square] 2

[9]

33. (a) <u>Conditions for observable interference</u>
Any THREE of:
- Same type of wave / must overlap (OR superpose) / amplitude large enough to detect / fringes sufficiently far apart to distinguish [Only one of these points should be credited]
- (Approximately) same amplitude (OR intensity)
- Same frequency (OR wavelength)
- Constant phase difference (OR coherent OR must come from the same source) **(1)(1)(1)** 3

[Accept two or more points appearing on the same line

Don't accept
– must be in phase
– must be monochromatic
– must have same speed
– no other waves present
– must have similar frequencies
– answers specific to a particular experimental situation, e.g. comments on slit width or separation]

(b) (i) Experiment description
[Marks may be scored on diagram or in text]
(Microwave) transmitter, 2 slit barrier and receiver **(1)**
[Inclusion of a screen loses this mark, but ignore a single slit in front of the transmitter]
Barrier, metal sheets **(1)**
[Labels indicating confusion with the light experiment, e.g. slit separations or widths marked as less than 1 mm, lose this mark]
Appropriate movement of receiver relevant to diagram [i.e. move in plane perpendicular to slits along a line parallel to the plane of the slits, or round an arc centred between them] **(1)** 3

(ii) Finding the wavelength
Locate position P of identified maximum/minimum 1st/2nd/3rd etc. **(1)** away from centre
Measure distance from each slit to P **(1)**
Difference = λ OR $\lambda/2$ (consistent with point 1) **(1)** 3

[Accept use of other maxima and corresponding multiple of λ]

[9]

34. (a) Explanation of maximum or minimum

path difference = $2 \times 125 \times 10^{-9}$ m = 250×10^{-9} m **(1)**

= half wavelength /antiphase **(1)**

$\rightarrow$ destructive interference / superposition **(1)** 3

($\rightarrow$ minimum intensity)

(b) Meaning of coherent

remains in phase / constant phase relationship **(1)** 1

[4]

35. Description of sound

Particles/molecules/atoms oscillate/vibrate **(1)**

(Oscillations) parallel to/in direction of wave propagation / wave travel / wave movement [Accept sound for wave] **(1)**

Rarefactions **and** compressions formed [Accept areas of high and low pressure] **(1)** 3

Meaning of frequency

Number of oscillations/cycles/waves per second / per unit time **(1)** 1

Calculation of wavelength

Recall $v = f\lambda$ **(1)**

Correct answer [18 m] **(1)** 2

Example of calculation

$v = f\lambda$

$\lambda = 330 \text{ m s}^{-1} \div 18 \text{ Hz}$

$= 18.3 \text{ m}$

[6]

36. Explanation of standing waves

Waves reflected (at the end) **(1)**

Superposition/interference of waves travelling in opposite directions **(1)**

Where in phase, constructive interference/superposition
OR where antiphase, destructive interference/superposition
OR causes points of constructive and destructive interference/superposition [Do not penalise here if node/antinode mixed up] **(1)** 3

Mark node and antinode

Both marked correctly on diagram **(1)** 1

Label wavelength

Wavelength shown and labelled correctly on diagram **(1)** 1

Explain appearance of string

Any two from:

- light flashes twice during each oscillation / strobe frequency twice that of string [accept light or strobe]
- string seen twice during a cycle
- idea of persistence of vision **(2)** max 2

Calculate speed of waves

Use of $v = \sqrt{T/\mu}$ **(1)**

☐ Correct answer [57 m s^{-1}] **(1)** 2

Example of calculation:

$v = \sqrt{T/\mu}$

$= \sqrt{(1.96\ \text{N} / 6.0 \times 10^{-4}\ \text{kg m}^{-1})}$

$= 57.2\ \text{m s}^{-1}$

[9]

37. Distance to aircraft:

Use of distance = speed × time**(1)**

Correct answer [7.2(km) / 7200(m) is the only acceptable answer. No u.e.] **(1)** 2

e.g.
Distance = speed × time = $3 \times 10^8 \times 24 \times 10^{-6}$
= 7.2 km

Why pulses are used:

Any **two** of the following:

- Allow time for pulse to return before next pulse sent
- To prevent interference/superposition
- A continuous signal cannot be used for timing
- Can't transmit / receive at the same time **(2)** max 2

Doppler shift:

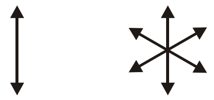
Any **three** of the following

- Change in frequency/wavelength of the signal [allow specified change, either increase or decrease]
- Caused by (relative) movement between source and observer [accept movement of aircraft/observer]
- Size of change **relates** to the (relative) speed of the aircraft [Allow frequency increasing; do not allow frequency decreasing unless linked to aircraft moving away]
- Quote $v/c = \Delta f/f$ **(3)** max 3

[7]

38. Unpolarised and plane polarised light:

Correct diagrams showing vibrations in one plane only and in all planes **(1)**



Vibrations/oscillations labelled on diagrams **(1)** 2

Telescope adaptation:

Fit polarising filter / lens [must be lens **not** lenses] **(1)**
At 90° to polarisation direction to block the moonlight / rotate until cuts out moonlight **(1)** 2

[4]

39. Meaning of plane polarised

Oscillations/vibrations/field variations **(1)**

Parallel to one direction, in one plane [allow line with arrow at both ends] **(1)** 2

Doppler effect

Doppler **(1)**

If source/observer have (relative) movement [reflections off vibrating/moving atoms] **(1)**

Waves would be bunched/compressed/stretched or formula quoted [accept diagram] **(1)**

Thus frequency / wavelength changes [accept red /blue shift] **(1)** 4

Frequency about 3×10^{14} Hz

Evidence of use of 1/wavelength = wavenumber **(1)**

laser wavenumber = 9400 or wavelength change $=7.69\times10^{-4}$ **(1)**

New wavenumber = 10700 [or 8100] or conversion of wavelength change to m [7.69×10^{-6}] **(1)**

New wavelength = 935 nm [or 1240 nm]

Use of frequency = c / wavelength [in any calculation] **(1)**

$f = 3.2 \times 10^{14}$ Hz [note answer of 2.8×10^{14} = 3 , 3.4×10^{14} = 4]**(1)** 5

Model of light

Particle/photon/quantum model **(1)**

Photon energy must have changed / quote E = hf **(1)**

Energy of atoms must have changed [credit vibrating less/more/faster/slower] **(1)** 3

[14]

40. Frequency

(a) (i) $1.0(3) \times 10^{10}$ Hz **(1)** 1

Electromagnetic Spectrum

(ii) IR, microwave & radio in correct order above visible **(1)**
UV with either X rays / Gamma rays / both in correct order below visible **(1)**

(iii) Wavelength at boundary 1×10^{-8} m / 1×10^{-9} m **(1)** 3

Plane polarised

(b) (i) Vibrations/oscillations (of electric field/vector) **(1)**
In one direction/plane (of oscillation) **(1)** 2

Description

(ii) Diagram showing generator labelled transmitter/generator/source/emitter **(1)**
And suitable detector eg shows how signal is observed by using **(1)**
(micro)ammeter/cro/loudspeaker/computer with interface
[Ignore anything drawn between generator and detector but for each mark do not give credit if a grille etc is attached]

To detect max and min **(1)**
(Rotate through) 90° between max and min **(1)** 4

[10]

41. Why microwaves are reflected

Wave is reflected when passing from one medium to another / when density changes / when speed changes **(1)** 1

Varying amplitude

Any two of the following:

Varying differences in density of the two mediums produce different intensities of signal **(1)**

Different distances travelled give different amplitudes **(1)**

Following a reflection there is less energy available **(1)** Max 2

Varying time

Different thicknesses of medium **(1)** 1

What is meant by Doppler shift

Change in frequency/wavelength **(1)**

Caused by movement of a source **(1)** 2

Changes due to Doppler shift

Wavelength increases **(1)**

Frequency decreases **(1)**

[Allow e.c.f. from incorrect wavelength]

Any one of the following:

- Each wave has further to travel than the one before to reach the heart
- The waves are reflected from the heart at a slower rate **(1)** 3

[9]

42. Adding angles to diagram

Critical angle *C* correctly labelled **(1)** 1

Calculation of critical angle

Use of $\mu = 1/\sin C$ **(1)**

Sin C = 1/1.09

C = 66.6° **(1)** 2

Why black mark not always seen

At (incident) angles greater than the critical angle **(1)**

t.i.r. takes place (so black mark not visible) **(1)**

light does not reach X / X only seen at angles less than *C* **(1)** 3

[**OR** opposite argument for why it is seen at angles less than *C*]

Comparison of sugar concentration

Lower μ means greater density **(1)**

Greater density means more sugar **(1)** 2

[8]

43. Table 6

Wavelength of light	in range 390 nm – 700 nm	**(1)**
Wavelength of gamma	$\leq 10^{-11}$ m	**(1)**
Source	(unstable) nuclei	**(1)**
Type of radiation	radio (waves)	**(1)**
Type of radiation	infra red	**(1)**
Source	Warm objects / hot objects / above 0 K	**(1)**

[6]

44. (a) Amplitude
Maximum distance/displacement
From the mean position / mid point / zero displacement line / equilibrium point **(1)** 1
[If shown on a diagram, at least one full wavelength must be shown, the displacement must be labelled "a" or "amplitude" and the zero displacement line must be labelled with one of the terms above.]

(b) Progressive wave

Displacement at A: 2.0 (cm) [accept 2] **(1)**
Displacement at B: 2.5 (cm) to 2.7 (cm) **(1)**
Displacement at C: 1.5 to 1.7 (cm) **(1)** 3

Diagram

[Minimum] one complete sinusoidal wavelength drawn **(1)**

Peak between A and B [accept on B but not on A] **(1)**

y = 0 (cm) at x = +2.6 cm with EITHER x = +6.2 cm OR x = − 1.0 cm **(1)** 3

[7]

45. (a) Transverse wave

(Line along which) particles/em field vectors oscillate/vibrate **(1)**
Perpendicular to **(1)**
Direction of travel or of propagation or of energy flow or velocity **(1)** 3

(b) Differences

Any two:

Standing waves	Progressive waves	
1. store energy	1. transfer energy **(1)**	
2. only AN points have max ampl/displ	2. all have the max ampl/displ **(1)**	
3. constant (relative) phase relationship	3. variable (relative) phase relationship **(1)**	Max 2

(c) (i) Droplets

Formed at nodes / no net displacement at these points **(1)** 1

(ii) Speed

Use of $\upsilon = f\lambda$ **(1)**
Evidence that wavelength is twice node–node distance **(1)**
Wavelength = 1.2 (cm) **(1)**
Frequency = 8.0 [8.2 / 8.16] Hz or s^{-1} only **(1)** 4

[10]

46. Explanation of pressure nodes or antinodes

Pressure constant **(1)**

Node as a result **(1)** 2

Relationship between length and wavelength

$l = \lambda/2$ or $\lambda = 2l$ **(1)** 1

Calculation of fundamental frequency

$\lambda = 2 \times 0.28$ m $= 0.56$ m [ecf for relationship above] **(1)**

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

$f = v/\lambda = 330$ m $s^{-1} \div 0.56$ m

= 590 Hz **(1)** 3

Calculation of time period

$T = 1/f$ **(1)**

$T = 1 \div 590$ Hz [ecf]

= 0.0017 s **(1)** 2

State another frequency and explain choice

e.g. 590 Hz × 2 = 1180 Hz (or other multiple) **(1)**

multiple of f_0 or correct reference to changed wavelength **(1)**

diagram or description, e.g. N A N A N, of new pattern [ecf for A & N] **(1)** 3

[11]

47. Name process of deviation

Refraction **(1)** 1

Completion of ray diagram

B – no deviation of ray **(1)**

A and C – refraction of ray away from normal on entering hot air region **(1)**

A and C – refraction of ray towards normal on leaving hot air region/ **(1)** 3

Show positions of tree trunks

B the same } **(1)**

} [consistent with ray diagram]

A and C closer to B } **(1)** 2

Explanation of wobbly appearance

Hot air layers rise/density varies/layers uneven **(1)**

Change in the amount of refraction [accept refractive index]/change in direction light comes from **(1)** 2

[8]

48. Unpolarised and plane polarised light

Minimum of 2, double-headed arrows indicating more than 1 plane and 1 double-headed arrow indicating 1 plane labelled unpolarised and polarised **(1)**

Vibrations/oscillations labelled **(1)** 2

Appearance of screen

Screen would look white/bright/no dark bits/light [not dark = 0] **(1)**

Explanation

As no planes of light prevented from leaving screen/all light gets through/all polarised light gets through **(1)** 2

Observations when head is tilted

Screen goes between being bright/no image to image/dark bits **(1)**

Every 90°/as the polarising film on the glasses becomes parallel/ perpendicular to the plane of polarisation of the light **(1)** 2

Comment on suggestion

Image is clear in one eye and not the other **(1)**

If plane of polarisation is horizontal/vertical **(1)**

OR
Image is readable in both eyes **(1)**

As the plane of polarisation is not horizontal or vertical **(1)** 2

[8]

49. How sound from speakers can reduce intensity of sound heard by driver

Any 6 from:

- graphs of 2 waveforms, one the inverse of the other
- graph of sum showing reduced signal
- noise detected by microphone
- waveform inverted (electronically)
- and fed through speaker
- with (approximately) same amplitude as original noise
- causing cancellation/destructive superposition
- error microphone adjusts amplification 6

[6]

50. Wavelength

0.30 m **(1)** 1

Letter A on graph

A at an antinode **(1)** 1

Wavespeed

Use of $\upsilon = f\lambda$ **(1)**

11(10.8) m s^{-1} **(1)** 2

[allow ecf λ = 0.15 m ie υ = 5.4 m s^{-1}]

Phase relationship

In phase **(1)** 1

Amplitude

2.5 mm **(1)** 1

[6]

51. Value of wavelength

λ = 13.9 cm – 0.5 cm (using interpolated sine curve) **(1)**

= 13.4 cm [accept 13.2 to 13.6 cm] **(1)** 2

[12.3 to 12.5 cm for distance using rods **(1)**×]

Value of amplitude

Peak to peak = 4.5 cm [Accept 4.3 cm to 4.7 cm] **(1)**

Amplitude = ½ × peak to peak

= 2.25 cm [Accept 2.15 cm to 2.35 cm] [Allow ecf for 2^{nd} mark if **(1)** 2

first part shown]

Calculation of frequency

$f = 1/T$

= 1 ÷ 2 s

= 0.5 Hz **(1)** 1

Explanation of why waves are transverse

Oscillation/vibration/displacement/disturbance at right angle **(1)**

to direction of propagation/travel of wave **(1)** 2

[Oscillation not in direction of wave **(1)**×]

Description of use of machine to illustrate sound wave

Sound is longitudinal/not transverse **(1)**

with oscillation along the direction of propagation / compressions and rarefactions **(1)**

so model not helpful **(1)** 3

[10]

52. Process at A

Refraction [Accept dispersion] **(1)** 1

Ray diagram

Diagram shows refraction away from normal **(1)** 1

Explanation of condition to stop emergence of red light at B

Angle greater than critical angle **(1)**

Correctly identified as angle of incidence [in water] **(1)** 2

Calculation of wavelength of red light in water

$c = f\lambda$ [stated or implied] **(1)**

$\lambda = 2.2 \times 10^8$ m s^{-1} $\div$ 4.2×10^{14} Hz

$= 5.24 \times 10^{-7}$ m **(1)** 2

[6]

53. Difference between polarised and unpolarised light

Polarised: vibrations in one plane (at right angles to direction of travel) **(1)**

Unpolarised: vibrations in all planes [NOT 2 planes] **(1)** 2

OR

Correct drawing **(1)**

Vibrations labelled **(1)**

Meaning of advertisement

(Light vibrations are) in one plane **(1)** 1

Evidence that glare comprises polarised light

Glare is eliminated, so must be polarised light **(1)** 1

Sunglasses turned through 90°

Glare would be seen through glasses **(1)**

since they now transmit the reflected polarised light **(1)** 2

[6]

54. Description + diagram

Diagram to show:
Microwave source/transmitter and detector (not microphone) **(1)**
Transmitter pointing at metal plate/second transmitter from same source **(1)**
Written work to include:
Move detector perpendicular to plate/to and fro between /accept ruler on diagram **(1)**
Maxima and minima detected/nodes and antinodes detected **(1)** 4
[Experiments with sound or light or double slit 0/4]

Observation

In phase/constructive interference → maximum/antinode **(1)**
Cancel out/out of phase/Antiphase/destructive interference → minimum /node **(1)** 2

How to measure wavelength of microwaves
Distance between adjacent maxima/antinodes = $\lambda/2$ **(1)**
Measure over a large number of antinodes or nodes **(1)** 2

[8]

55. Wavelength and wave speed calculation

$\lambda = 0.96$ m **(1)**

seeing $f = 2$ their λ (f = 2.1 Hz) **(1)** 2

Qualitative description

(Coil) oscillates / vibrates **(1)**

With SHM / same frequency as wave (their value) **(1)**

Parallel to spring / direction of wave **(1)** 3

[5]

56. Explanation of emission of radiation by hydrogen atoms

Electrons excited to higher energy levels **(1)**

as they fall they emit photons / radiation **(1)** 2

[Accept 21 cm line arises from ground state electron changing spin orientation **(1)** / relative to proton **(1)**]

Why radiation is at specific frequencies

Photon frequency related to energy / $E = hf$ **(1)**

Energy of photon = energy difference between levels / $hf = E_1 - E_2$ **(1)**

Energy levels discrete/quantised / only certain energy differences possible **(1)** 3

Show that hydrogen frequency corresponds to λ = 21 cm

$f = 4.4623 \times 10^9 \div \pi$
$= 1.42 \times 10^9$ Hz **(1)**

$c = f\lambda$

$\lambda = 3 \times 10^8 \div (1.42 \times 10^9$ Hz) **(1)**

λ = 0.211 m or 21.1 cm [no up] **(1)** 3

[8]

57. Fundamental frequency of note

440 Hz **(1)** 1

Frequencies of first three overtones

880 Hz

1320 Hz

1760 Hz

Two correct frequencies **(1)**

Third correct frequency **(1)** 2

Comment on the pattern

Any 2 from the following:

[Allow ecf]

880 Hz = 2 × 440 Hz

1320 Hz = 3 × 440 Hz

1760 Hz = 4 × 440 Hz

1760 Hz = 2 × 880 Hz **(1) (1)** 2

[OR They are multiples **(1)** of the fundamental (or similar qualification) **(1)**]

[Allow 1 mark for amplitude decreasing with frequency]

Measurement of period

Example: 7 cycles takes (0.841 – 0.825) s [at least 5 cycles] **(1)**

Period = 0.016 s ÷ 7

= 2.3×10^{-3} s [in range 2.2×10^{-3} s to 2.4×10^{-3} s] **(1)** 2

Calculation of frequency

$f = 1/T$ **(1)**
= 1 ÷ 2.2×10^{-3} s [Allow ecf]
= 454 Hz **(1)** 2

[9]

58. Mark on diagram

Correctly drawn normal **(1)**

Correctly labelled angles to candidate's normal **(1)** 2

Show that refractive index of water is about 1.3

Angles correctly measured:

i = 53 (±2)°

r = 39 (±2)° **(1)**

$\mu = \sin i / \sin r = \sin 53° / 39°$

= 1.27 [Allow ecf] [Should be to 2 d.p. min] **(1)** 2

Critical angle

$\mu = 1/\sin C$ **(1)**

so $\sin C = 1/1.27$ so $C = 52°$ [ecf] **(1)** 2
[use of 1.3 gives 50°]

Explanation of reflection of ray

Internal angle of incidence = 39° ± 1° **(1)**

Compare *i* with critical angle **(1)**

Valid conclusion as to internal reflection being total/partial **(1)** 3

Refractive index

It varies with colour **(1)** 1

[10]

59. Explanations

(i) Refraction:
e.g. bending of wave when travelling from one medium to another [OR change of speed] **(1)**

(ii) Diffraction:
e.g. spreading of wave when it goes through a gap **(1)** 2

Diagram of wavefronts near beach

Gradual bend in wavefronts **(1)**

Smaller wavelengths **(1)**

Waves bending upwards as they approach shore **(1)** 3

Diagram of wavefronts in bay

Constant wavelength **(1)**

Waves curve **(1)** 2

Explanation

Refraction/diffraction causes waves to bend towards the beach **(1)** 1

[8]

60. <u>Ultrasound</u>

Ultrasound is very high frequency sound **(1)**

<u>How ultrasound can be used</u>

Any three from:

- gel between probe and body
- ultrasound reflects
- from boundaries between different density materials
- time taken to reflect gives depth of boundary
- probe moved around to give extended picture
- size of reflection gives information on density different **(1) (1) (1)** 3

<u>How reflected ultrasound provides information about heart</u>

Any two from:

- Doppler effect
- frequency changes
- when reflected from a moving surface
- gives speed of heart wall
- gives heart rate **(1) (1)** 2

[6]

61. <u>Physics principles</u>

Requires 9 V battery:

Battery required for electronic circuitry / microphone / speaker **(1)**

Rubberized foam ear cups:

Air filled material / material has large surface area **(1)**

Air molecules collide frequently with material **(1)**

Foam deforms plastically/collisions are inelastic **(1)**

Sound converted to heat in material **(1)**

Active noise attenuation:

Noise picked up by microphone **(1)**

Feedback signal inverted / 180° out of phase with noise / antiphase **(1)**

Amplified [OR amplitude adjusted] and fed to earphones / speaker **(1)**

Sound generated cancels/superimposes/minimum noise **(1)**

Diagrams of superposing waves showing (approx.) cancellation **(1)**

Amplifier gain automatically adjusted if noise remains **(1)**

Device only works over frequency range 20 – 800 Hz **(1)** Max 6

Where does the energy go?

Some places will have constructive interference **(1)**

More intense noise **(1)**

Some noise dissipated as heat in air / foam **(1)**

increased kinetic energy of air [OR foam] molecules **(1)** Max 2

[8]

62. Explanation
Clarity of written communication **(1)**
Wave reflects off bench **(1)**
(Incident and reflected) waves superpose/stationary wave is formed **(1)**
Maxima or antinodes where waves in phase or constructive interference occurs **(1)**
Minima or nodes where waves exactly out of phase or destructive interference occurs **(1)** 5

Speed of sound
See a value between 5.0 and 5.6 (cm) **(1)**
Use of $\upsilon = f\lambda$ **(1)**
$\lambda = 2 \times$ spacing **(1)**
320 m s^{-1} to 360 m s^{-1} **(1)** 4

Explanation of contrast
As height increases, incident wave gets stronger, reflected wave weaker **(1)**
So cancellation is less effective [consequent mark] **(1)** 2

[11]

63. Wavelength

Distance between two points in phase **(1)**

Distance between successive points in phase **(1)** 2

[May get both marks from suitable diagram]

Sunburn more likely from UV

UV (photons) have more energy than visible light (photons) **(1)**

Since shorter wavelength / higher frequency **(1)** 2

What happens to atoms

Move up energy levels/excitation/ionization **(1)**

Correctly related to electron energy levels **(1)** 2

[6]

Explanation of contrast

As height increases, incident wave gets stronger, reflected wave weaker **(1)**

So cancellation is less effective [consequent mark] **(1)** 2

[11]

64. Emitted pulse

Greater amplitude/pulse is larger/taller **(1)** 1

Depth of rail

$2d = vt = 5100 \text{ m s}^{-1} \times 4.8 \times 10^{-5} \text{ s}$

$= 0.24$ m

Hence $d = 0.12$ m

Reading from graph [4.8 or 48 only] **(1)**

Calculation of 2d [their reading × timebase × 5 100] **(1)**

Halving their distance **(1)** 3

Description of trace

A reflected peak closer to emitted/now 3 pulses **(1)**

Exact position e.g. 1.6 cm from emitted **(1)** 2

Diagram

Shadow region **(1)**

Waves curving round crack **(1)** 2

[8]

65. Total internal reflection

Any two points from:

- from a more dense medium to a less dense medium/high to low refractive index
- incident angle greater than the critical angle
- light is reflected not refracted/no light emerges **(1) (1)** Max 2

Critical angle

Sin i / sin r = μ; gives sin 90°/sin C = μ **(1)**

C = 42° **(1)** 2

Diagram

Reflection (TIR) at top surface (air gap) **(1)**

Reflection (TIR) at bottom surface and all angles equal by eye **(1)** 2

Path of ray A

Passing approximately straight through plastic into glass **(1)**

Emerging at glass–air surface **(1)**

Refraction away from normal **(1)** 3

Why there are bright and dark patches on image

Bright where refracted/reference to a correct ray A in lower diagram **(1)**

Dark where air gap (produces TIR)/reference to correct top diagram **(1)** 2

[11]

66.	Polarisation		
	The (wave) oscillations **(1)** occur only in one plane **(1)** [OR shown with a suitable diagram]	2	
	How to measure angle of rotation		
	Any four points from:		
	• Polaroid filter at one/both ends		
	• with no sugar solution, crossed Polaroids (top and bottom of tube) block out light		
	• sugar solution introduced between Polaroids		
	• one Polaroid rotated to give new dark view		
	• difference in angle between two positions read from scale **(1) (1) (1) (1)**	Max 4	
	Graph		
	Points plotted correctly [–1 for each incorrect; minimum mark 0] **(1) (1)**		
	Good best fit line to enable concentration at 38° to be found **(1)**	3	
	Concentration		
	0.57 (± 0.01) kg l^{-1}	1	
			[10]
67.	Explanations of observations		
	Speed of light is much greater than speed of sound **(1)**		
	Speed of sound in soil is greater than speed of sound in air **(1)**	2	
			[2]
68.	Wavefront		
	Line/surface joining points in phase	1	
	Addition to diagrams		
	Wavefront spacing ≈ as for incident waves (min. 3 for each)	1	
	1st diagram: wavefronts nearly semicircular	1	
	2nd diagram: much less diffraction	1	

Reception

L W has long**er** wavelength 1

so is more diffracted around mountains [consequent] 1

[6]

69. Path difference

$2 \times 1.11 \times 10^{-7}$ m = 2.22×10^{-7} m **(1)** 1

Explanation of why light appears dim

Path difference = ½ × wavelength **(1)**

so waves in antiphase/destructive interference/superposition **(1)** 2

Reason for increase in film thickness

Because of gravity/soap runs down **(1)** 1

Explanation of whether film further down appears bright or dark

Path difference = wavelength **(1)**

Waves in phase/constructive interference (so appears bright) **(1)** 2

Explain bright and dark stripes

Different positions have different thicknesses/path differences **(1)**

So some points in phase, some in antiphase/
some points have constructive interference, some destructive **(1)** 2

Movement of bright and dark stripes

Soap flows down/thickness profile changes **(1)**

so positions of destructive/constructive interference changing **(1)** 2

Alternative path added to diagram

One or more extra reflections at each internal soap surface **(1)** 1

[11]

70. Diagram

(i) Any angle of incidence marked and labelled I **(1)**

(ii) Any angle of refraction marked and labelled R **(1)**

(iii) Angle of incidence/reflection at lower surface marked and labelled G **(1)** 3

Refraction of light

Velocity of light is lower in glass **(1)** 1

Velocity of light in hot air

Velocity is greater **(1)** 1

Property of air

(Optical) density / refractive index **(1)** 1

[6]

71. Table

Radio waves	Sound waves
Transverse	Longitudinal
Travel much faster than sound	Travel more slowly
(Can) travel in a vacuum	Cannot travel in a vacuum
Can be polarised	Not polarised
Electromagnetic	Pressure/Mechanical wave

Any three of the above Max 3

Assumption

Attempt to calculate area **(1)**

Intensity = 0.02 kW m^{-2} OR 20 W m^{-2} **(1)**

Efficiency at *collector* is 100%/beam perpendicular to *collector*

Power

Use of $I\ P/4\pi r^2$ **(1)**

Power = 3.3×10^{17} W [ecf their *I*]

No energy “lost” due to atmosphere (not surroundings) OR Inverse square applies to this situation **(1)**

More efficient method

Use a laser (maser) / reference to beaming/ray **(1)** 1

[10]

72. How stationary waves could be produced on a string

Diagram showing:

String and arrangement to **apply** tension **(1)**

Vibration generator **and** signal generator **(1)** 3

Vary *f* / tension / length until wave appears **(1)**

Determination of speed of travelling waves

QOWC **(1)**

Determine node-node spacing; double to obtain λ **(1)**

Read *f* off signal generator / cro / use a calibrated strobe **(1)**

Use $\upsilon = f\lambda$ for υ **(1)** 4

[7]

73. Explanation of superposition

When 2 (or more) waves meet / cross / coincide /interfere...**(1)**

Reference to combined effect of waves, e.g. add displacement / amplitude - may be a diagram [constructive/destructive interference not sufficient without implication of addition] **(1)** 2

Calculation of thickness of fat layer

Thickness = half of path difference

$= 0.5 \times 3.8 \times 10^{-7}$ m

$= 1.9 \times 10^{-7}$ m **(1)** 1

Explanation of constructive superposition

Path difference of 3.8×10^{-7} m same as a wavelength of green light **(1)**

Waves are in phase / phase difference 2π or 360° **(1)** 2

Explanation of what happens to other wavelengths

Path difference greater than/less than/not one wavelength
/ waves not in phase / out of phase **(1)**

Constructive interference will not take place
OR **(1)**
These colours will not appear bright **(1)** 2

Explanation of why colours are seen at other places

Thickness of fat varies
OR
Light seen at a different angle to the meat surface **(1)**

Other wavelengths may undergo constructive interference/be in phase
OR **(1)**
Path difference will vary 2

[9]

74. Diameters of dark ring

Diameter in frame 1 = 9 mm (± 1 mm)
Diameter in frame 2 = 19 mm (± 1 mm) [No ue] **(1)** 1

Show that ripple travels about 25 Mm

Difference between diameters = 19 mm – 9 mm = 10 mm
Distance travelled by one part = 10 mm ÷ 2 = 5 mm **(1)**

Scale: 200 Mm = 40 mm (39 mm to 41 mm)
Distance = 5 mm × 200 Mm ÷ 40 mm
= 25.0 Mm [No ue] **(1)** 2

Calculation of speed of ripple

Speed = distance ÷ time **(1)**

= 25.0×10^6 m ÷ (10 × 60) s **(1)**

= 41 600 m s^{-1} [no ue] **(1)** 3

How to check speed constant

Use third frame to calculate speed in this time interval
OR plot diameter (or radius) against time to get a straight line
OR compare distance travelled between frames 3 and 2 with distance travelled between frames 2 and 1 **(1)** 1

Cross-section of wave

Wavelength **(1)**
Amplitude **(1)** 2

Calculation of frequency of waves

Wavespeed = frequency × wavelength **(1)**

Frequency = wavespeed ÷ wavelength = 41 700 m s^{-1} ÷ 1.4×10^7 m **(1)**
= 3.0×10^{-3} Hz **(1)** 2

[11]

75. Movement of water molecules

Molecules oscillate/vibrate **(1)**

Movement parallel to energy flow **(1)** 2

Pulses

To prevent interference between transmitted and reflected signals **(1)** 1

OR allow time for reflection before next pulse transmitted

Calculation

Time for pulse to travel to fish and back again = distance ÷ speed

$$\Delta t = \frac{\Delta x}{\upsilon}$$

$$= \frac{2 \times 300\,\text{m}}{1500\,\text{ms}^{-1}}\ \textbf{(1)}$$

= 0.4 s **(1)** 2

[0.2 s = 1 mark]

Effect used in method

Doppler effect **(1)**

Any two from:

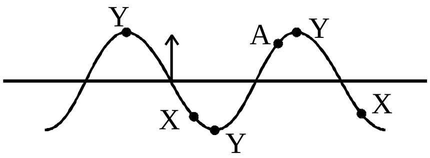
- a change in frequency of the signal
- caused by relative movement between the source and the observer
- size and sign of change relate to the relative speed and direction of the movement between shoal and transmitter
- frequency increase - moving towards
- frequency decrease - moving away **(1) (1)** 3

[8]

76. Wavelength
0.80 m **(1)**

Out of phase
Either X as in diagram below **(1)**

At rest
Y at crest or trough as in diagram below **(1)**



Direction of movement
Arrow at C up the page **(1)** 4

Time calculation **(1)**
Use of $t = \lambda/\upsilon$ **(1)**
0.25 s [ecf λ] 2

[6]

77. Electromagnetic waves experiment

EITHER

'Lamp', 1 polaroid // LASER **(1)**
2^{nd} polaroid, suitable detector [e.g. eye, screen, LDR] **(1)**
Rotate one polaroid [consequent on 2 polaroids] [one if LASER] **(1)**
Varies [consequent] **(1)**

OR

Microwave transmitter (and grille) [not polaroid or grating] **(1)**
Receiver (or and grille) **(1)**
Rotate ANY [if 2 grilles; must rotate a grille] **(1)**
Varies [consequent] **(1)** 4

Nature of waves
ransverse **(1)** 1

[5]

78. Reason for non-destructive testing

Sensible reason e.g.

- destroyed rails would require replacement
- trains continuously using tracks, so removing them would cause greater disruption
- saves money 1

Description of sound wave

Particles oscillate / vibrate (not move)

… in direction of wave propagation/longitudinal

causes rarefactions and compressions

[Marks may be gained from suitable diagram] 3

Show that wavelength about 1.5×10^{-3} m

Wavespeed = frequency × wavelength, $v = f\lambda$, any correct arrang^{t} **(1)**

Wavelength = wavespeed ÷ frequency

$= 5900 \text{ m s}^{-1} \div 4\,000\,000 \text{ Hz}$

$= 1.48 \times 10^{-3}$ m **(1)** 2

Meanings

Frequency:

Number of oscillations/waves per second/unit time (may be 4 000 000 oscillations per second) **(1)**

Wavelength: [may be from diagram]

Distance between 2 points in phase/2 compressions/2 rarefactions **(1)**

Distance between *successive* points in phase etc. **(1)** 3

Calculation of length of track

Length of track = area under graph (or sign of finding area, e.g. shading) or 3 calculated distances using const acceleration formulae **(1)**

Use of 18 m s^{-1} as a speed x a time in a calculation **(1)**

E.g., distance = $0.5 \times (116 \text{ s} + 96 \text{ s}) \times 18 \text{ m s}^{-1}$

= 1908 m **(1)** 3

[12]

79. Explanation of superposition

When 2 (or more) waves meet / cross / coincide … **(1)**

Reference to combined effect of waves, e.g. add displacement / amplitude – may be a diagram [constructive/destructive interference not sufficient without implication of addition] **(1)** 2

Explanation of cancellation effect

Any 3 from the following:

- path/phase difference between direct and reflected waves
- destructive interference/superposition
- path difference is $(n + ½)\lambda$ / phase diff $\pi/180^{\circ}$ / waves in antiphase / out of phase
- "crest" from one wave cancels "trough" from other 3

Reason for changes

Any 3 from the following:

- movement changes path of reflected waves
- so changes path difference
- A movement of 75 cm is about ¼ wavelength
- waves reflected so path difference changed to ½ wavelength
- enough to change from antiphase to in phase / change in phase difference
- causes constructive interference/superposition 3

[8]

80. Speed of ultrasound

Use of $\upsilon = s/t$ **(1)**

$= 150 \times 10^{-3}$ (m) $\div 132 \times 10^{-6}$ (s)

$= 1140$ m s^{-1} **(1)** 2

Change of trace

Extra pulse(s)

OR

Reflected pulse moves closer 1

Principle of Doppler probe

3 points from:

- Arrange probe so that soup is approaching
- Soup reflects ultrasound
- with changed frequency/wavelength
- change in frequency/wavelength depends on speed
- Probe detects frequency of reflected ultrasound
- Use of diagrams showing waves 3

Determination of speed

1 point from:

- Frequency/wavelength change
- Angle between ultrasound direction and direction of flow of soup 1

Comment

Lumps give larger reflections

Lumps travel slower 1

[8]

81. Wavelength range

465 – 720 nm (± ½ square) 1

Sketch graph

Scale (No more than 90 – 100%)

AND all graph between 96% and 99% **(1)**

Inversion – in shape with 2 peaks (at 510 and 680 nm) **(1)** 2

Wavelength

($\mu = \upsilon_1 / \upsilon_2 = f\lambda_1 / f\lambda_2$) λ_1 = 360 nm × 1.38 **(1)**

(= 497 nm) 1

–

Explanation

Thickness = λ/4 OR path difference = 180 nm **(1)**

Path difference = λ/2 **(1)**

Minimum reflection needs destructive interference between reflected rays from front and back of coating **(1)** 3

Difference between unpolarised and plane polarised light

Unpolarised light consists of waves vibrating in all planes(perpendicular to direction of propagation) **(1)**

Polarised light consists of waves vibrating in one plane only **(1)**

OR

Diagrams showing:

Waves / rays in 1 plane **(1)**

Waves / rays in many planes **(1)** Max 2

[9]

82. Explanation of "coherent"

In / constant phase (difference) **(1)**

symbol 51 \f "Monotype Sorts" \s 123 **(1)** 1

Power delivered by laser

$P = \dfrac{40}{400 \times 10^{-15}}$ **(1)**

$= 1 \times 10^{14}$ W **(1)** 2

Energy level change

$\upsilon = f\lambda \,/\, f = \dfrac{3 \times 10^8}{1050 \times 10^{-9}}$ [–1 if omit 10^{-9}] **(1)**

Use of $E = hf$ / $6.6 \times 10^{-34} \times \dfrac{3 \times 10^8}{1050 \times 10^{-9}}$ **(1)**

[If $f = 1/T$ used, give this mark]

$= 1.9 \times 10^{-19}$ J **(1)** 3

[6]

83. Table:

Description	Type of wave	
A wave capable of causing photo-electric emission of electrons	Ultraviolet	**(1)**
A wave whose vibrations are parallel to the direction of propagation of the wave	Sound	**(1)**
A transverse wave of wavelength 5×10^{-6} m	Infrared	**(1)**
The wave of highest frequency	Ultraviolet	**(1)**

4

[4]

84. Explanation:

- waves diffracted from each slit/each slit acts as a source
- these superpose/interfere **(1)**
- maxima/reinforcement – waves in phase/pd = $n\lambda$ **(1)**
  [or on a diagram][crest & crest] **(1)**
- minima/cancellation – waves in antiphase/pd = $(n+1/2)\lambda$ **(1)**
  [or on a diagram][crest and trough] [not just 'out of phase'] **(1)**
- phase or path difference changes as move around AB **(1)** Max 4

Determination of wavelength:
Use of wavelength = p.d. [incorrect use of xs/D 1/3 max] **(1)**
3 × (path difference. e.g.78 – 66 mm) **(1)**
= 36 mm[Range 30 – 42 mm] **(1)** 3

Explanation:
Less/No diffraction/spreading **(1)**
∴ waves will not superimpose/overlap as much **(1)** 2

Explanation:
Fixed phase relationship/constant phase difference **(1)**
Both waves derived from single source [transmitter ⇒] **(1)** 2

[11]

85. Diffraction:

The spreading out of waves when they pass through a narrow slit or around an object **(1)**

Superposition:

Two or more waves adding **(1)**

to give a resultant wave [credit annotated diagrams] **(1)**

Quantum:

A discrete/indivisible quantity **(1)** 4

Particles:

Photon/electron **(1)** 1

What the passage tells us:

Any 2 points from:

- large objects can show wave-particle duality
- quantum explanations now used in "classical" solutions
- quantum used to deal with sub-atomic particles and classical with things we can see Max 2

[7]

86. Wavelength of the microwaves:

λ = 442 mm – 420 mm **(1)**

= 22 mm [2.2 cm, 0.22 m] **(1)**

Frequency of microwaves:

Use of $c = f\lambda$ with λ from above substituted OR if no attempt, then $C = 3. \times 10^8$ substituted **(1)**

1.4×10^{10} Hz [e.c.f. λ above] **(1)**

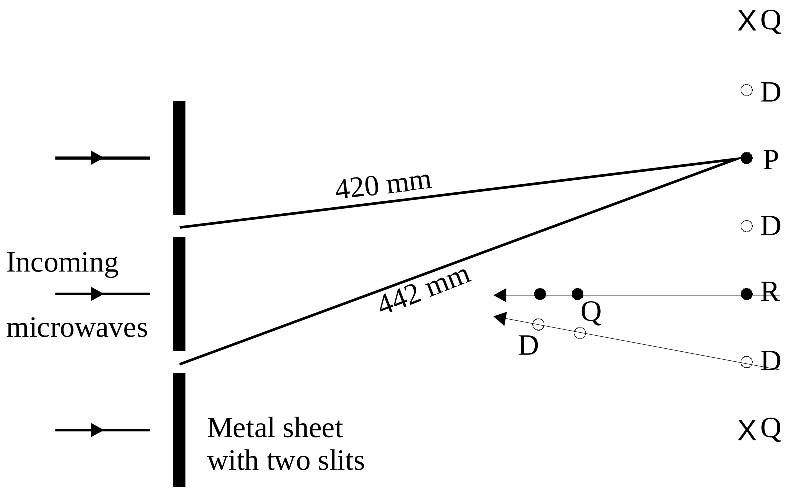
4

Maximum Q and minimum D marked on diagram:

Either Q **(1)**

Any D **(1)**

2



Why a maximum would not be detected at P:

Wavelength of sound wave = 0.3 m **(1)**

Path difference at P is not whole wavelength **(1)**

2

[OR valid reference to phase difference OR λ sound greater so no diffraction with this slit width OR valid reference to λ= *xs/D*]

[8]

87. Explanation of formula:

(For fundamental) λ = 2 *l* **(1)**

$\Rightarrow \upsilon = \lambda \times f$ [stated or used]

H3 2 × B3 × D3 **(1)** 2

How value is calculated:

Volume = $\pi r^2 \times l$

$= \pi \times \left(\frac{2.5 \times 10^{-3}}{2} \right)^2 \times 1\text{m}^3$ **(1)(1)**

OR $\pi \left(\frac{\text{diameter in mm} \times 10^{-3}}{2} \right)^2$

OR P1 * (0.001 * C5/2) Λ 2

OR similar valid route

[✓ for $\frac{(\text{diam})^2}{2} \times \pi$, ✓ for factor 10^{-3}] 2

Value in G4:

Mass/metre = $\rho \times$ volume/metre

OR

= 1150 × 0.000 000 79 kg **(1)**

= 0.00091 kg m $^{-1}$ [no u.e.] **(1)** 2

Formula in cell I3:

$\upsilon = \sqrt{T / \mu}$

$\Rightarrow T = \mu \upsilon^2$ **(1)**

⇒ I3 = H3 * H3 * G3

OR H3 Λ 2 * G3 **(1)** 2

Comment:

No + reason (e.g. 133 >> 47) **(1)**

OR

Yes + reason (e.g. 47, 64, 133 all same order of magnitude) **(1)**

More detail, e.g, f changes by factor 32, OR l by factor of 15. T only by factor 2.5 ⇒ similar Ts. **(1)(1)**

OR other sensible points. 3

[11]

88. Diagrams:

Diagram showing 2 waves π radians out of phase **(1)**

Adding to give (almost) zero amplitude **(1)**

Reference to destructive interference **(1)** Max 2

Wavelength of red light:

For example, red wavelength is 1.5 times blue wavelength **(1)**
[OR red wavelength is 50% more than blue wavelength]

= 1.5 × 460 nm = 690 nm **(1)** 2

Dark bands :

Spacing = 4.0 mm **(1)** 1

Explanation of pattern:

Sunlight has a range of frequencies/colours **(1)**

Gaps between part of feather (act as slits) **(1)**

Different colours [OR gap width] in the sunlight diffracted by different amounts **(1)**

Red light bends more [OR blue less] hence coloured edges **(1)**
[No colours linked to refraction] Max 3

[8]

89. Light from sky:

Light is polarised **(1)** 1

Change in intensity:

Filter allows through polarised light in one direction only **(1)**

When polarised light from the sky is aligned with filter, light is let through **(1)**

When polarised light is at right angles with polarising filter, less light passes **(1)**

Turn filter so that polarised light from blue sky is
not allowed through, so sky is darker **(1)** Max 2

Clouds:

Light from clouds must be unpolarised **(1)** 1

Radio waves:

Radio waves can be polarised OR transverse **(1)** 1

Why radio waves should behave in same way as light:

Both are electromagnetic waves/transverse **(1)**
[Transverse only, credited for 1 answer] 1

[6]

90. Explanation of words:

Coherent

Same frequency and constant phase relationship **(1)** 1

Standing wave

Any **two** points from:

Superposition/interference

Two (or more) wavetrains passing through each other

Having equal A, f, λ

+ system of nodes and antinodes **(1) (1)** 2

Position of one antinode marked on diagram

Correctly marked A (in centre of rings – hot zone) **(1)** 1

Wavelength demonstration:

$\lambda = c/f = 3 \times 10^8 / 2.45 \times 10^9$ m

= 12.2 cm **(1)** 1

Path difference:

(22.1 + 14) – (20 + 10) cm

= 6.1 cm **(1)** 1

Explanation:

6.1 cm = ½ × λ **(1)** 1

Waves at X in antiphase/ destructive interference **(1)** 1

→ node **(1)** 1

Explanation of how two separate microwave frequencies overcomes uneven heating problem:

Different wavelengths **(1)** 1

So a path difference which gives destructive interference at one wavelength may not do so at another **(1)** 1

[11]

91. Why warm surface water floats:

Cold water is denser than warm water **(1)** 1

Explanation of why ultrasound waves reflect thermocline:

This is surface separating layers of different density **(1)** 1

Explanation of why submarine is difficult to detect:

Ultrasound from ship partially reflects upwards from thermocline so little is transmitted **(1)**

Any reflected sonar from submarine partially reflects downwards from thermocline **(1)** 2

Explanation of why sonar cannot be used from a satellite:

Lack of medium to transmit sound waves from satellite 1

Calculation of time between emission and detection of radar pulse:

$2s/c$ **(1)**

$= 2 \times 6.0 \times 10^7$ m $\div 3.0 \times 10^8$ ms^{-1} = 0.4 s **(1)** 2

Calculation of minimum change in height of ocean:

Minimum observable distance

$= ct = 3.0 \times 10^8$ m s$^{-1} \times 1.0 \times 10^{-9}$ s = 0.30 m **(1)**

so change in ocean height = 0.15 m **(1)** 2

Possible problem:

Sensible answer eg **(1)**

atmospheric pressure could change ocean height

bulge not large enough compared with waves

tidal effects

whales 1

[10]

92. Explanation:

Light hits glass–juice boundary at less than the critical angle **(1)**

And is refracted into the juice **(1)** 2

Marking angles on diagram:

the critical angle *C* – between ray and normal on prism/liquid face **(1)**

an incident angle *i* – between incident ray and normal at air/ glass or glass air interface **(1)**

a refracted angle *r* **–** between refracted ray and normal at air/glass or glass air interface **(1)** 3

Explanation of term *critical angle:*

The angle in the more **(1)**

dense medium where the refracted angle in the less dense medium is 90 **(1)** 2

Plot of results on grid:

[NB Axes are labelled on the grid]

Scales: *y*–axis **(1)**

x–axis **(1)**

Points correctly plotted **(1)** 4

Best fit line (curve expected) **(1)**

Refractive index found from graph:

Value = 1.400 ± 0.002 **(1)** 1

[12]

93. Circumstances under which two progressive waves produce a stationary wave:

Both transverse/longitudinal/same type
Waves have same frequency/wavelength
and travel/act in *opposite* directions/reflected back. Max 2 marks

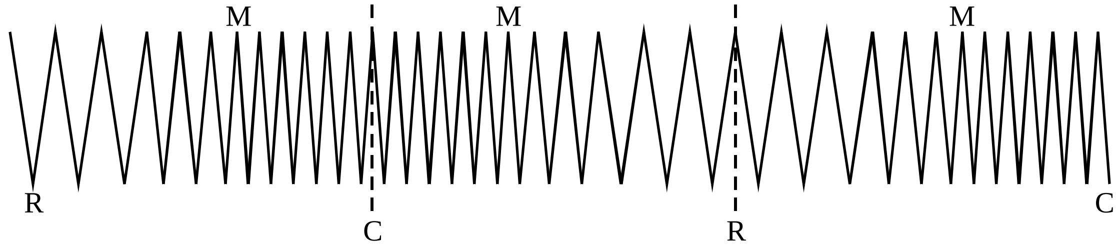
Experiment using microwaves to produce stationary waves:

Transmitter *Metal* plate *or* backwards transmitter

Adjust distance of transmitter/plate
How it could be shown that a stationary wave had been produced:
Note readings on probe/detector/receiver form a *series* of maximum *or* minimum readings *or* zero 3

[5]

94.



One of compression C and one rarefaction R marked as above.
Wavelength of wave = 11 - 11.6 cm **(**u.e.)
One of maximum displacement M marked as above [M, 5th, 6th, 7th].
Amplitude of wave = 8 (± 1 mm) [consequent mark]

[4]

95. Use of graph to estimate work function of the metal:

ϕ= (6.63 × 10^{-34} J s) (6.0 × 10^{14} Hz) – (some value)

Value in brackets: (1.6 × 10^{-19} × 0.5 J)

3.2 × 10^{-19} J *or* 2 eV 3

Addition to axes of graph A obtained when *intensity* of light increased:

A starts at –0.5

A → larger than /max

Addition to axes of graph B obtained when *frequency* of light increased:

B starts at less than – 0.5

B → same of lower than /max 4

[7]

96. Description:

Either	*Or*
Two connected dippers just touching/above the water	Dipping beam or single source **(1)** reaches two slits **(1)**

Vibrated electrically **(1)**
Level tank/shallow water/sloping sides **(1)**

-

Either	*Or*
Illuminate project on to screen	Use stroboscope **(1)** to freeze the pattern **(1)**

Max 5

Diagram:

(i) Correct line A - centre line **(1)**

(ii) Correct line B (above or below A) **(1)**

(iii) Correct line C (between A and B) **(1)**

both B and C correct **(1)** **4**

[Total 9 marks]

97. Ionisation energy:

2810 eV (4.5×10^{-16} J) **(1)**

Calculation of maximum wavelength:

Energy in eV chosen above converted to joules **(1)**

Use of $\lambda = c/f$ **(1)**

Maximum wavelength = 4.4×10^{-10} m **(1)**

Part of electromagnetic spectrum:

γ-ray / X-ray **(1)** **5**

Calculation of the de Broglie wavelength:

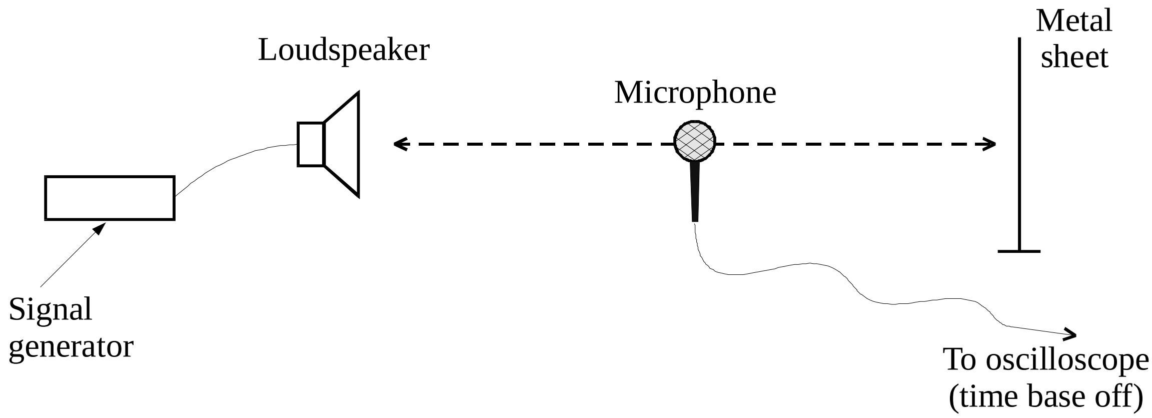
$\lambda = h/p$ p identified as momentum **(1)**

Either m or υ correctly substituted **(1)**

Wavelength = 1.1×10^{-13} m **(1)** **3**

[Total 8 marks]

98. The diagram below shows a loudspeaker which sends a note of constant frequency towards a vertical metal sheet. As the microphone is moved between the loudspeaker and the metal sheet the amplitude of the vertical trace on the oscilloscope continually changes several times between maximum and minimum values. This shows that a stationary wave has been set up in the space between the loudspeaker and the metal sheet.



How has the stationary wave been produced?

by superposition/interference (1)

with a reflected wave/wave of same speed and wavelength in opposite direction (1)

(2 marks)

State how the stationary wave pattern changes when the frequency of the signal generator is doubled. Explain your answer.

Maxima/nodes/equivalent are closer together (1)
since wavelength is halved (1)

(2 marks)

What measurements would you take, and how would you use them, to calculate the speed of sound in air?

Measure distance between minima/equivalent (1)

Repeat/take average (1)

Method of finding frequency (1)

λ = 2 × (node – node)/equivalent (1)

$V = f \times \lambda$ (1)

(Four marks maximum)

Other methods eligible for full marks.

(4 marks)

Suggest why the minima detected near the sheet are much smaller than those detected near the loudspeaker.

Near the sheet there is almost complete cancellation (1)

since incident and reflected waves are of almost equal amplitude (1)

(2 marks)
[Total 10 marks]