AS Physics Unit 2 Revision Packs Mark Scheme

1. Single wavelength/frequency **(1)**
Waves in antiphase superimpose giving complete or partial cancellation **(1)** 2

$f = c/\lambda = 3 \times 10^8$ m s^{-1}/ 780 × 10^{-9} m **(1)**
= 3.85 × 10^{-4} Hz **(1)**

$n = \upsilon_{\text{air}}/\upsilon_{\text{plastic}}$
$\upsilon_{\text{plastic}} = 3 \times 10^8$ m s^{-1}/ 1.55
= 1.94 × 10^8 m s^{-1} **(1)**

$\lambda = \upsilon\ /f = 1.94 \times 10^8$ m s^{-1}/3.85 × 10^{14} Hz
= 5.04 × 10^{-7} m **(1)** 4

Path difference between two sets of waves = 2 × ridge height **(1)**
= 2 × 125 nm = 250 nm or approx. $\lambda/2$ **(1)**

Waves are in antiphase when they combine and produce small amplitude **(1)** 3

No. Path difference is now ≈λ so waves from ridge and valley almost in phase when they recombine **(1)**

The pattern of ridges and valleys will not give an on/off signal **(1)**

[‘No’ must have an attempt at an explanation for a mark] 2

[11]

2. Calculate υ or υ^2 and t and plots correct **(1)(1)(1)** 3

M/kg	f/Hz	λ/m	υ/ms^{-1}	υ^2/m^2 s^{-2}	T/N
0.16	30.6	0.37	12.3	151	1.96
0.20	30.0	0.41	11.3	128	1.57

Best fit line **(1)** 1

Yes **(1)**
Best fit line *through origin* is near all plots **(1)** 2

Large Δ drawn **(1)**

Gradient = $\frac{160}{2.01}$ =79.6 **(1)**

$\mu = \frac{1}{\text{Gradient}}$ = 0.0126 kg m^{-1} (accept 0.12 – 0.013) **(1)** 3

[9]

3. $P = \frac{1}{f} = \frac{1}{0.018\,\text{m}} = 55.6$ m^{-1}

Power = 55.6 m^{-1} **(1)(1)** 2

Lens shape diverging **(1)**
New rays meet at retina **(1)** 2

$P = \dfrac{1}{0.020\,\text{m}} = 50\ \text{m}^{-1}$

Power = 50 m^{-1} **(1)** 1

55.6 m^{-1} + P = 50 m^{-1} **(1)**

$P = -5.6\text{m}^{-1}$

$f = \dfrac{1}{-5.6\,\text{m}}$ = -0.18 m **(1)** 3

[8]

4. Time **(1)** 1

Reflections occur at boundary between head and surrounding fluid **(1)**
1st reflection entering head, 2nd reflection on leaving **(1)** 2

Time between peaks found from trace **(1)**
Knowing speed of ultra sound, ν in head, distance can be calculated $l = ut$ **(1)**
Width of head = $l/2$ **(1)** 3

A change in frequency **(1)**
caused by relative movement between transducer and object **(1)** 2

[8]

5. Polarised – vibrations of transverse wave in 1 plane only (or E or B field)
Non –polarised – vibrations can be in any plane perpendicular to direction of travel **(1)** 1

No light **(1)** 1

Align sunglasses so that axis allows absorption of polarised light **(1)** 1

$r + 90° + \theta = 180°$ (on straight line)
$r = 180 - 90 - \theta$
$= 90 - \theta$ **(1)**

$$\mu = \frac{\sin\theta}{\sin r} = \frac{\sin\theta}{\sin(90-\theta)}$$

$$1.33 = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

$\theta = \tan^{-1} 1.33$

= 53° **(1)** 3

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6. Redshift (accept Doppler shift) **(1)** 1

It is receding/moving away **(1)** 1

Award marks for calculation using any one line:

Observed λ read from graph [Allow ± 10 nm] **(1)** **3**
Calculation of $\Delta\lambda$; calculation of $\Delta\lambda/\lambda$ **(1)**
Calculation of υ **(1)**

Emit λ/nm	Obs λ/nm	$\Delta\lambda$/nm	$Z = \Delta\lambda/\lambda$	$V = c\Delta\lambda/\lambda = cz$/m s^{-1}
410	475	65	0.159	4.8×10^7
434	505	71	0.164	4.9×10^7
486	560	74	0.152	4.6×10^7
656	760	104	0.159	4.8×10^7

Doppler shift would be doubled [Accept relative velocity of the galaxy doubled]/ appropriate change in λ or colour, e.g. more red-shifted **(1)**

Assumption: expansion rate of the Universe is (approximately) constant across the Universe (at this moment) **(1)** 2

[7]

7. Energy:

Potential energy = $mgh = 40 \times 10 \times 0.3 = 120$ J **(1)**
Kinetic energy as child hits rubber pillow is about the same value (120 J) **(1)**
$m\upsilon^2 = 2 \times 120$ gives $\upsilon = 2.5$ m s^{-1} **(1)**
Kinetic energy transferred to air in pillow, gets warm **(1)**
Use of $3kT/2$ **(1)**

Oscillations:

Oscillations because to and fro motion about a point **(1)**
Damped oscillations **(1)**
$F = kx$ to $400 = k$ 0.2 gives $k = 2000$ N m^{-1} **(1)**
$T = 2\sqrt{k/m}$ gives about 6 s **(1)**
Idea that oscillations are not simple harmonic **(1)** Max 7

[7]

8. 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

$\rightarrow$ 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]

9. 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)**

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

Calculation of minimum change in height of ocean:

Minimum observable distance

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

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10. 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]

11. **E** 3 waves in one second ⇒ 3kHz
C ⇒ 3 Hz not 3 kHz

E 3 waves in one second
C 1 ½ waves in one second

E Wavelength AND time both on *x*-axis
C *x*-axis: time OR distance, not both

E	Amplitude = crest to trough distance	
C	A = middle to crest OR middle to trough distance	
E	All waves require a medium	
C	Some waves OR all longitudinal waves require a medium	
E	Waves carry the medium	
C	Waves carry energy/waves travel through the medium/medium oscillates to carry the wave	Max 8

[8]

12. Explanation of formula:

(For fundamental) $\lambda = 2\,l$ **(1)**

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

H3 $\quad 2 \times$ B3 $\times$ 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)**

$\Rightarrow$ 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]

13. 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]

14. Type of lens:

Diverging (since distant objects forms virtual image) **(1)** 1

Focal Length:

Focal length = –2.0 m **(1)** 1

Power:

Power = – 0.5 D [Allow e.c.f.] **(1)** 1

Ray diagram:

ray parallel to axis bent and ray traced backwards to F **(1)**

Ray through centre of lens goes straight on **(1)**

Virtual image drawn where rays meet **(1)** 3

New power:

–0.3 D [allow e.c.f] **(1)** 1

Explanation :

Improved since correction lens is weaker [allow e.c.f] **(1)** 1

[8]

15. 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]

16. Frequency:

Natural frequency/fundamental frequency **(1)** 1

[Not resonant]

Explanation:

Resonance occurs when driving frequency = natural frequency **(1)**

causing maximum energy <u>transfer</u>**(1)**

increased/maximum amplitude **(1)** Max 2

Graph:

<u>Undamped - marked A</u>

Acceptable shape - narrow peak **(1)**

Resonant frequency marked under graph max. **(1)**

<u>Damped - marked B</u>

B - entire graph below A **(1)**

[Accept touching graphs] **(1)** 4

Peak covers greater frequency range than A

Prevention of resonance:

Damps oscillations **(1)**

Fewer forced oscillations **(1)**

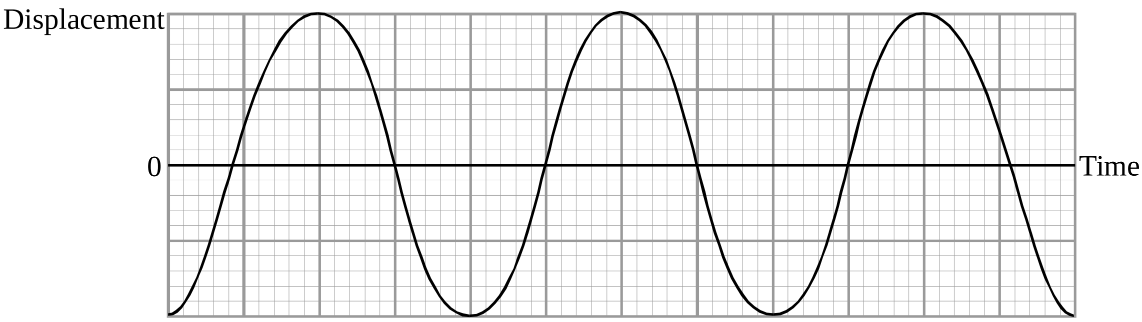
Explanation of damping [e.g. in terms of energy transfers] **(1)** Max 2

[9]

17. Displacement-time graph:

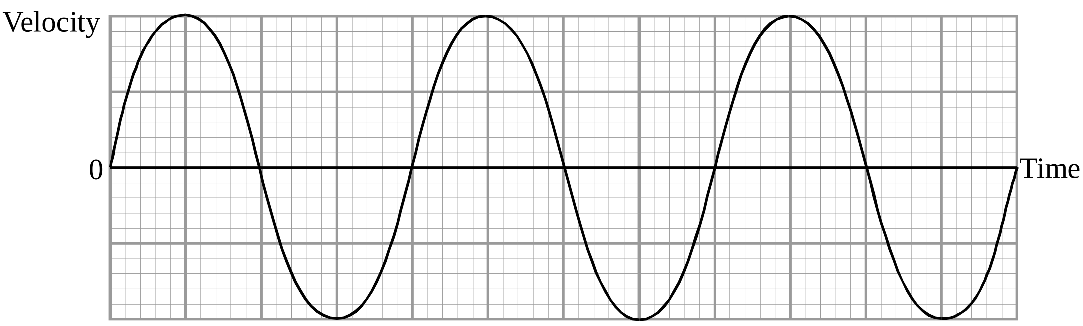
Cosine curve **(1)**

Constant period and amplitude **(1)** 2

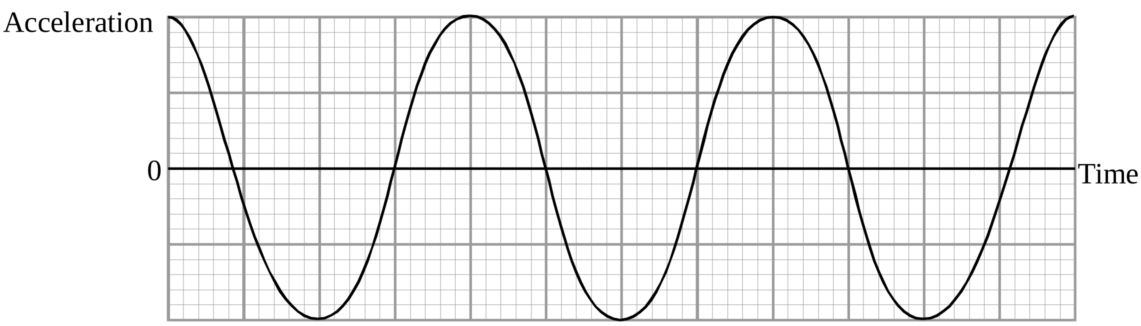


Velocity-time and acceleration-time graphs:

Velocity: sine curve; 90° out of phase with displacement-time **(1)**



Acceleration: cosine curve; 180° out of phase with displacement-time **(1)** 2



Two requirements:

Force towards centre **(1)**

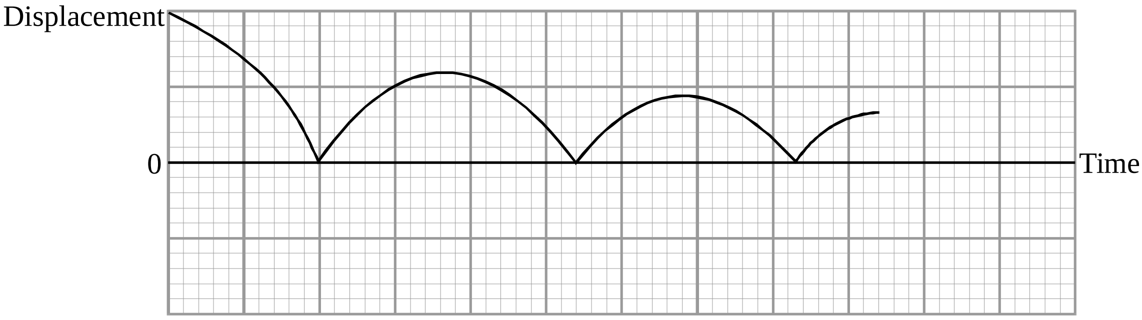
a (or F) $\propto x$ **(1)**

opposite direction [acceleration and displacement acceptable] **(1)** Max 2

Displacement-time and acceleration-time:

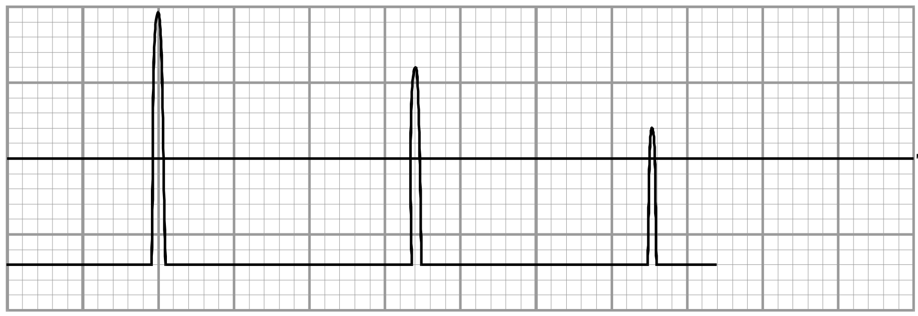
Starts positive, curved, always > 0 **(1)**

Period same as velocity **(1)** 2



Acceleration constant not equal to 0 **(1)**

Sharp peak when ball in contact with floor **(1)** 2



Explanation:

Not simple harmonic motion **(1)**

Reason e.g. acceleration constant when ball in free fall / period not constant / acceleration not $\propto$ displacement. **(1)** 2

[12]

18. (a) Electron / X-ray diffraction **(1)**

Clear structured pattern indicates order/random pattern disorder **(1)** 2

(b) $1.65 = 3 \times 10^8 / \upsilon$ **(1)**

$\upsilon = 1.8 \times 10^8$ m s^{-1} [–1 if 1.5 used] **(1)** 2

(c) Vibrations / oscillations (parallel) to one direction / diagram to this effect **(1)** 1

(d) (Start with) polarised light / light source plus polariser **(1)**

Second polariser rotated until max transmission

[OR similar for minimum transmission] **(1)**

Insert liquid between each polariser **(1)**

No longer a maximum / second polariser needs rotating to re-establish maximum transmission. **(1)** 4

(e) $d = 1.05 \div \Delta n$ **(1)**

$d = 7$ μ m [–1 if unit omitted or misunderstood] **(1)** 2

(f) $(E = V/d)$ [use of] **(1)**

$E = 1.5 / 7 = 2.1 \times 10^5$ V m [–1 if 0.21; –1 if no unit] **(1)**

Assumption: uniform E field **(1)** 3

(g) 25 Hz means that display covered every 1/25 s **(1)**

= 40 ms **(1)**

Time taken to react switch on is 10 ms **(1)**

So only four parts of screen can react before start of next scan **(1)** 4

(h) Multiplexing: more than one signal **(1)**

on same medium / channel / or named example – optic fibres **(1)**

Explanation of *fdm*: different frequencies can carry different information **(1)**
signal (through same medium) **(1)**

OR *t d m*: period of time can be divided so that information / **(1)**
signals (through same medium) **(1)**

Need to synchronise transmitter / receiver to ensure correct signal **(1)** Max 4

(i) At higher temperature molecules become disordered / a gas / might conduct **(1)**

At lower temperature molecules become ordered in all directions / solid **(1)**

At lower temperature viscosity increases T_{on} becomes too large **(1)** Max 2

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19. Completion of table:

	A	B	C	D	E	F
stands	**0.0s**	**0.7s**	**1.4s**	2.1s	2.8s	3.5s
sits	**2.0s**	**2.7s**	3.4s	4.1s	4.8s	5.5s

Each row correct 1 mark 2

Completion of diagram: 2

	A	**B**	**C**	D	E	F	
ABC correct			**0**	0	0		**(1)**
DEF correct	**0**	**0**				0	**(1)**

Type of wave:

Transverse **(1)**

Displacement/disturbance/oscillations perpendicular to direction of propagation/movement/motion/travel **(1)**

OR

Travelling/progressive **(1)**

Pattern of displacement moves in one direction/not standing wave
[but not answer depending on reference to energy transfer in this case] **(1)** 2

Show that speed is about 0.9 m s^{-1}:

$u = s \div t$ OR 0.6 m ÷ 0.7 s OR 3.0 m ÷ 3.5 s etc. **(1)**

= 0.86 m s^{-1} [No u.e.] **(1)** 2

[Answer based on $\upsilon = f\lambda$, only if f and λ consistent and answer
υ = approx 0.9 m s^{-1} 1 mark max]

Reason for faster speed:

Sensible reason, e.g. anticipation of turn to stand up / reaction time shorter/faster/quicker [not just varying] / seats further apart [not just spacing wrong] 1

[9]

20. Definition of focal length:

Distance from lens to focal point **(1)**

Focal point/which is point at which **parallel** rays/rays from (object)
at infinity focused to point **(1)**

[Do not need the reference to focal point for 1st mark if correctly 2

Completion of diagrams 2 and 3:

Either diagram –

Ray through centre of "lens" undeviated **(1)**

Diagram 2 –

Fewer rays striking pupil than in diagram 1, with refraction in correct direction **(1)**

Diagram 3 –

All rays striking pupil – rays must not touch/

come to focus before/on surface of eye **(1)** 3

Completion of brightness diagram:

3 brighter than normal **(1)**

4 less bright than normal **(1)** 2

Explanation of variation in brightness:

No refraction / normal in diagram 1 **(1)**

Correct statement about rays or refraction for diagram 2 or 3,
e.g. fewer rays/light refracted away in diagram 2/ more rays in diag 3 **(1)**

Correct link to brightness in diagram 2 or 3, e.g. therefore
diagram 2 less bright/diagram 3 brighter **(1)** 3

Explanation of Sun not twinkling:

Sensible explanation, e.g.

- Larger (visual area) so will not all be affected by such a region of cold air
- Variation in intensity a tiny fraction of total intensity

Sun not a point source so variations in intensity from
all points will "average out" 1

[11]

21. ${}_{w}\mu_{h} = 1.0$ 1

Eye diagram:

Both rays bend inwards on entering spherical lens **(1)**

Then inwards again on leaving spherical lens to cross at retina **(1)** 2

Explanation:

Object distance reduced, so image distance must be increased **(1)**

so lens must move away from the retina **(1)**

Use of $\frac{1}{u} + \frac{1}{\upsilon} = \frac{1}{f}$ to explain

OR good use of diagrams for maximum marks **(1)** 3

Lake diagram

Ray of light drawn from person, refracting in correct direction at water surface **(1)**

Ray drawn from below fish, reflecting at water surface [angles approximately correct] **(1)**

Arrows on both rays towards fish **(1)** 3

Critical angle calculation:

$\sin C = 1/{}_a\mu_w$ **(1)**

$= 1/1.33$

$\therefore C = 49°$ **(1)** 2

[11]

22. 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]

23. 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

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

24. 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]

25. Lens type

Converging 1

Power calculation

Use of Power = 1/focal length **(1)**

= 1/0.05

= +20 dioptre (Allow e.c.f. from previous part) **(1)** 2

Distance of image from lens

Use of $1/\upsilon + 1/u = 1/f$ **(1)**

= 1/0.05 – 1/0.03 (Allow e.c.f. from previous part)

= 20 – 33.3

= –13.3 **(1)**

so $\upsilon = -1/13.3$

= – 0.075 m **(1)** 3

Image

Virtual, since υ is negative [or e.c.f.]

OR behind the object/lens 1

Ray diagram

2 correct rays drawn from top of object **(1)**

Rays projected back to crossing point **(1)**

Correct image arrow **(1)**

Arrows on rays and eye shown **(1)** Max.3

How image can be enlarged

Lens drawn further from object **(1)**

Rays converge to point further from lens **(1)** 2

[12]

26. 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]

27. 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

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

(= 497 nm) 1

Explanation

Thickness = $\lambda/4$ OR path difference = 180 nm **(1)**

Path difference = $\lambda/2$ **(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]

28. Material

e.g. porous material / made up of small fibres 1

Explanation

Any 1 point from the following:

- inelastic collisions between air molecules and fibres/materials
- fibres/materials absorb energy from the sound

fibres/materials deform plastically rather than transmitting vibrations Max 1

Physics of sound reduction

Any 4 from:

- Microphone is used to detect sound and feed to electronic device
- Signal treated to produce output identical in frequency
- but in antiphase with original OR inverted
- This output fed to loudspeaker

Interferes destructively with original sound Max 4

Resonance

Sound vibrations (forcing vibrator) have same frequency as another vibrator's natural frequency **(1)**

increasing amplitude/energy of other vibrator's vibrations **(1)** 2

Process

Damping 1

[9]

29. Simple harmonic

Acceleration (OR force) $\propto$ displacement **(1)**

and in opposite direction **(1)**

[OR $F = -kx$ **(1)** OR $x = A \cos \omega t$ **(1)** symbols defined **(1)**] 2

Graph

(i) E_k inverse of potential energy curve

(ii) T horizontal line at 2×10^{-6} J 2

Stiffness

Use of $E = ½ kx^2$ **(1)**

$2 \times 10^{-6} = ½ k\, 0.10^2$

$k = 4 \times 10^{-4}$ J m^{-2} **(1)**

[accept N m^{-1}] 2

Variation in potential energy

Any 3 points from the following:

- $I_{150} / I_{100} = 100^2 / 150^2 = 0.44$

So $E_{max} = 0.44 \times 2 \times 10^{-6} = 0.88 \times 10^{-6}$ (J) [no u.e]

Curve through (0,0), max 0.8 – 0.9

Curve the same

$I \propto$(amplitude)^2 Max 3

[9]

30. 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]

31. 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} ÷ 1.4×10^7m **(1)**
= 3.0×10^{-3} Hz **(1)** — 2

Meaning of digital

Stored as a series of numbers ones and zeros / ons and offs / binary **(1)** — 1

[12]

32. 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

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

$$= \frac{2 \times 300\,\text{m}}{1500\,\text{m}\,\text{s}^{-1}}$$ **(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]

33. Critical angle

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

Sin C= 1/1.5

C = 41.8° **(1)** 2

Angle of incidence

22.5° **(1)** 1

Explanation

Angle of incidence < critical angle **(1)**

Without silvering light, would pass out of prism **(1)**
/no total internal reflection 2

Focal length

$F = 1/P = 1/20 = 0.050$ m **(1)** 1

Image distance

Use of $1/u = 1/\upsilon = 1/f$ **(1)**

$1/2 + 1/\upsilon = 1/0.05$

= 0.051 m [ecf from previous part] **(1)** 2

Nature of image

Any two from:

- real
- inverted
- diminished **(1) (1)** 2

[10]

34. Calculation of speed of sound in wood

$c = \sqrt{(E/\rho)} = \sqrt{(16 \times 10^9 \text{ Pa} / 600 \text{ kg m}^{-3})}$ **(1)**

= 5160 in s^{-1} **(1)** 2

Time difference between sounds

Through air $t = s/c$ = 10 m/330 m s^{-1} = 0.030 s **(1)**

Through floor t = 10 m/5160 m s^{-1} = 0.002 s
so difference is 0.028 s not significant **(1)** 2

Comparison of intensities of sounds

Intensity α (amplitudes)^2 – stated or implied **(1)**

so intensity through wood is 3^2= 9 times greater **(1)** 2

How amplitude of echoes is reduced

Molecules in soft materials (walls/seats/bodies) transfer energy (from sound wave) **(1)** 1

[7]

35. Data for speaker and equation

Equation for shm: $x = A \cos \omega t$

A amplitude = 1.0 mm or 1.0×10^{-3} m

$\omega = 2\pi f = 6.28 \times 10^2$ (rad s^{-1}) – no unit penalty for ω **(1)** 2

Calculations

(i) $A = A\,\omega^2$

$= 1.0 \times 10^{-3} \text{ m} \times (6.28 \times 10^2 \text{ rad s}^{-1})^2 = 394 \text{ m s}^{-2}$**(1)**

(ii) $\upsilon = A\,\omega$ **(1)**

$= 1.0 \times 10^{-3} \text{ m} \times 6.28 \times 10^2 \text{ rad s}^{-1} = 0.63 \text{ m s}^{-1}$ **(1)** 3

Acceleration - time graph

Two cycles of sinusoidally shaped graph **(1)**

Period = 10 m s **(1)**

Amplitude = 394 m s^{-2} [e.c.f from (i)] **(1)** 3

Explanation

Resonance (stated or implied by explanation) **(1)**

Increased amplitude at resonant frequency **(1)** 2

[10]

36. Unit of power

Dioptre or D **(1)** 1

Power of cornea

42(.0) [No u.e.] **(1)** 1

Explanation of focal length

Distance from lens to focal point **(1)**

Focal point/which is point where **parallel** rays focused to point **(1)** 2

[Do not need the reference to 'focal point' for first mark if correctly described in the second point. A clearly labelled diagram gains both marks]

Effective focal length

$f = 1 \div P$ **(1)**

$= 1 \div 56.0$ D

= 0.018m [No u.e.] **(1)** 2

Ray diagram

One correct construction ray **(1)**

Another correct construction ray **(1)**

Rays cross over within 15 small squares of correct position (0. 12 m) **(1)**

Arrow object shown **(1)** 4

[10]

37. Path difference

$2 \times 1.11 \times 10^{-7}$ m $= 2.22 \times 10^{-7}$ 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]

38. 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]

39. Focal length of lens

Use of $1/u + 1/\upsilon = 1/f$ **(1)**

$1/1 + 1/0.050 = 1/f$

$1/f = 21$ **(1)**

$\therefore f = 0.048$ m [or 4.8 cm] [at least 2s.f.] **(1)** 3

Properties of image

Real **(1)**

Inverted **(1)**

Smaller **(1)** 3

Explanation of choice of transparent material

Different materials reflect/scatter/disperse/absorb/polarise different amounts of light **(1)**

The less this occurs the brighter the image **(1)** 2

[8]

40. Simple harmonic motion – conditions

Acceleration (or force) proportional to displacement [OR $a \propto -x$] **(1)**

Acceleration (or force) directed towards equilibrium position **(1)** 2

Graph

Horizontal line at $E_p = 19$ J **(1)** 1

Calculations

(i) Use of $E_K = E_r - E_p$ **(1)**
$= 19\text{J} - 5\text{J}$
$= 14$ J **(1)**

(ii) Use of $E\text{p} = \frac{1}{2}\ kx^2$ **(1)**
with readings from graph **(1)**
e.g. $k = 2 \times 5$ J / $(0.02\text{ m})^2 = 2.5 \times$ N m^{-1} **(1)**

[8]

41. Explanation

Any two from:

- signal attenuated through interaction with particles/asteroid
- signal diffracted on leaving transmitter
- not all of radio signal will be received by asteroid
- (reflected) signal spreads out (varying as $1/r^2$) **(2)** 2

Explanation of how reflected signal can be used to calculate speed

E.g.
frequency/wavelength of reflected signal changed **(1)**
Doppler Effect specified / Doppler equation given (with λ or f) **(1)**
all symbols in equation $\upsilon = c\ \Delta f / f_{\text{emitted}}$ explained **(1)** 3

Calculations

(i) Distance = speed × time

$= 3.0 \times 10^8 \times 120$

$= 3.6 \times 10^{10}$ m (for return journey)

Asteroid distance is 1.8×10^{10} m **(1)**

(ii) Time to reach Earth = distance ÷ speed

$= 1.8 \times 10^{10}/4000$ [Allow e.c.f from (i)]

$= 4.5 \times 10^6$ s

(= 52 days) **(1)**

Assuming that speed does not change (due to gravitational attraction of Earth) **(1)** 3

Explanation of why asteroid unlikely to collide with Earth

E.g. Earth will have moved around Sun
[Apply e.c.f from (ii)] **(1)** 1

[9]

42. <u>Phenomenon of resonance in the context outlined etc</u>

Any five from:

- spheres can oscillate
- resonance when forcing frequency = natural frequency
- sound provides forcing frequency
- low frequency due to mass/density of lead spheres

At resonance, there is:

- large amplitude of oscillation (of spheres)
- maximum energy transfer to spheres
- energy transfer to thermal in the rubber
- minimum energy transfer to neighbours 5

[5]

43. <u>Ray diagram</u>

Top/bottom ray bending towards (normal) at first interface **(1)**

Some appropriate bending at second interface **(1)**

To (focal) point on middle ray **(1)** 3

<u>Difference in power</u>

Less bending / less refraction / longer focal length **(1)**

As $P = 1/f$ – less power (need both statements) **(1)** 2

<u>Experiment</u>

"Far" object/ray box and parallel rays **(1)**

Focal length is distance from lens to <u>screen</u> **(1)**

Image on screen should be clear **(1)**

OR named illuminated object eg LED + u distance to lens **(1)**

Screen plus clear image + v distance **(1)**

Quote of lens formula to find f [Needs u and v identified] Max 3

<u>Explanation of liquid lens</u>

Distant object / parallel rays + thin lens + rays to F/by diagram **(1)**

Near object + fat lens/conventional ray diagram with object, 2 rays and image **(1)**

Divergent rays from object to lens/conventional ray diagram showing smaller f

Image formed at same distance from lens in near/far cases or "retina" labelled **(1)** 4

<u>Refractive index</u>

Oil would have higher refractive index **(1)**

so that light converged/bent towards normal as entering oil **(1)** 2

<u>Arrangement of oil and film</u>

Two charged /conducting plates/layers/capacitor symbol identified as salt water / recognisable copy of diagram **(1)**

Insulator is the oil (and polymer) **(1)** 2

Energy stored

Formula $CV^2/2$ / $QV/2$ + $Q = CV$ **(1)**

Substitution [does not require 10^{-12}] **(1)**

= 5.6×10^{-7} J **(1)** 3

[–1 for u.e. –1 a.e. off last 2 marks]

Definitions

Viscosity: measure of fluid's resistance/force/drag to a moving object through it/moving fluid past object or how fast fluid flows past object/object through fluid [Not runny or thick] **(1)**

Damping: conversion of energy/transfer of energy into heat/amplitude of oscillation decreasing **(1)** 2

Why not sensible to remove oscillations by increasing velocity

Take too long/difficult for lens to refocus **(1)** 1

[22]

44. Graph and conclusions about relationship between *P* and *V*

Initial power is 54D **(1)**

P does not increase until *V* is 25 – 50V **(1)**

P increases from 25 – 50 to 100 – 130 V **(1)**

P increases linearly with *V* from 100 V – 130 V **(1)**

Slope of this part = 0.4 [Units not required] **(2)** Max 3

Power variation

At *V*= 50 V *P* = 55 D **(1)**

At *V* = 150 V *P* = 82 D **(1)** 2

[If D missing penalise – 1 only if both values are given]

Time period of power oscillations

25 ms **(1)**

Taken from two oscillations (50/2) or checked twice/as indicated on diagram [Give this mark independently of correct answer] **(1)** 2

Table and graph

At least 3 correct values of time interval and power
80 – 87 ; 105 – 84 ; 130 – 83 **(1)**

Amplitude correctly evaluated
5 ; 2 ; 1 [Allow e.c.f. using 82] **(1)**

One further negative value **(1)**

In of amplitudes
1.61 ; 0.69 ; 0 OR 1.95 ; 1.39 ; 1.10 [min 2 dp except 0] **(1)**

Graph of ln values and *t*

Scales: points should occupy more than half grid in each direction + points correct **(1)**

Best fit straight line **(1)** 7

Prediction

Statement “a negative gradient shows it is an exponential reduction” **(1)** or implied by rearranged formula and comparison to $y = mx+c$ 1

[For amplitude vs t graph: first 4 marks as above, scales mark, best fit curve = 6 max + prediction if based on time to decrease by constant fraction stays constant]

Decay constant

Evidence of gradient **(1)**

To a value 0.034 - 0.04 **(1)**

Conversion of unit **(1)** 3

[For amplitude vs t graph
value of half life 14 – 20 ms **(1)**
to a value between 34 and 40] **(1)**

[18]

45. 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]

46. Standing waves

Waves reflected at support **(1)**

Upward and downward waves superpose **(1)**

where in phase constructive interference/antinode

OR

where antiphase destructive interference/node

OR

causes points of constructive and destructive interference

OR

causes nodes and antinodes **(1)** 3

Mark antinode

Correct **(1)** 1

Tension

0.17 N **(1)** 1

Mass per unit length

Mass per unit length = 0.00015 kg ÷ 0.24 m

= 0.00063 **(1)**
kg m^{-1} **(1)** 2

Speed

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

$= \sqrt{(0.17\text{N} \div 0.00063\,\text{kg m}^{-1})}$ **(1)**

= 16 m s^{-1} [No u.e.] **(1)** 2

Frequency of vibration

Wavespeed = frequency × wavelength **(1)**
Frequency = wavespeed ÷ wavelength
Frequency = 16.4 m s^{-1}
÷ 0.24 m [i.e. identify wavelength = 0.24 m] **(1)**
Frequency = 68 Hz **(1)** 3

[12]

47. Emitted pulse

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

Depth of rail

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

Properties

Any two from:

- durable
- elastic
- hard
- stiff
- strong
- tough **(1) (1)** 2

[10]

48. 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]

49. Polarisation

The (wave) oscillations **(1)**
occur only in one plane **(1)** 2
[OR shown with a suitable diagram]

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

The terms viscous and brittle

Viscous: a high resistance to flow **(1)**

Brittle: breaks/cracks/snaps without plastic deformation (when a load is applied) **(1)** 2

[12]

50. Oscillations

Correct ticks/cross **(1)**
Reasons **(1) (1) (1)** 4

Oscillations	SHM ✓ ✗	Reason
Mass on end of spring	✓	Force $\propto$ displacement [OR acceleration $\propto$ displacement] OR Force always towards the equilibrium position
Child jumping up and down	✗	Force constant when child in the air OR Period/frequency not independent of amplitute
Vibrating guitar string	✓	Force $\propto$ displacement [OR acceleration $\propto$ displace-ment] OR Frequency not dependent on amplitute

[4]

51. 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

Time taken for sound to reach observer

$v = \sqrt{(E/\rho)} = \sqrt{(5.0 \times 10^8 \text{ Pa} / 1.5 \times 10^3 \text{ kg m}^{-3})}$ **(1)**

$= 577 \text{ m s}^{-1}$ **(1)**

Hence time = $s/v = \frac{400}{577} = 0.69$ s **(1)** 3

[5]

52. Account of physics involved in provision of good acoustics

Any good relevant physics to be credited

1 mark for each separate point
+ 1 mark for amplification
Examples:

- Sound consists of longitudinal waves, compressions and rarefactions of air **(1)**
- Echoes caused by sound reflection from hard surfaces + cause sound to persist for longer **(1) (1)**
- Reverberation means that sound takes time to die away **(1)**
- Resonance involves driving frequency being the same as natural frequency of object + resulting in increased amplitude of vibration **(1) (1)**
- Absorption of sound by different materials + good absorber soft, **(1) (1)** flexible, low density, rough, foam, etc. **(1)**
- Damping is reduction in amplitude/intensity of sound
- Positions can occur where there is destructive interference + caused by direct and reflected paths being half wavelength out of phase **(1) (1)**
- Noise from outside reduced by insulating walls + made of porous material with large surface area **(1) (1)**
- Positioning of speakers and microphones to prevent feedback **(1) (1)**
- ANC (applied to unwanted noise) + explained **(1) (1)** Max 8

[Max 8]

53. 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 $\lambda = 21$ 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)**

$\lambda = 0.211$ m or 21.1 cm [no up] **(1)** 3

Use of π as a factor

Analogue **(1)**

Because the frequency can take any value **(1)** 2

[Accept π irrational/ not a whole number etc]

Use of a series of prime numbers

Digital **(1)**

Whole numbers only / effectively only on or off / 1s and 0s **(1)** 2

[12]

54. 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)**
= $1 \div 2.2 \times 10^{-3}$ s [Allow ecf]
= 454 Hz **(1)** 2

Statement of wavelength of fundamental oscillation

$\lambda = 2l$
= 2 × 1.23 m
= 2.46 m **(1)** 1

[10]

55. 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)**

μ **=** sin i / sin r = sin 53° / 39°

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

Critical angle

μ **=** 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]

56. 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]

57. Ultrasound

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

How ultrasound can be used

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

How reflected ultrasound provides information about heart

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]

58. Conditions for simple harmonic motion

Acceleration OR restoring force $\propto$ displacement **(1)**

in opposite direction / towards equilibrium position **(1)** 2

Why child's motion only approximately simple harmonic

Any one from:

- damped / friction opposes motion / air resistance
- swing's path is arc of circle, not straight line
- angle too large **(1)** 1

Calculations

(i) Period of the motion:

$T = 20\ \text{s}/6 = 3.3\ \text{s}$ **(1)**

$f = 1/T = 0.30\ \text{Hz}$ (allow e.c.f. for T) **(1)**

(ii) Value of ω

Use of $\omega = 2\pi f$

$= 2\pi \times 0.30$

$= 1.9\ \text{rad s}^{-1}$ (allow e.c.f. for f, no repeat unit error) **(1)**

(iii) Child's acceleration:

$a_{max} = -\omega^2 A$ **(1)**

$= -1.9^2 \times 1.2$ (allow e.c.f for ω) **(1)**

$= (-)\ 4.3\ \text{ms}^{-2}$

Swing an example of resonance

Push (driver) at same frequency as swing (driven) **(1)**

causes increase of amplitude / energy transfer **(1)** 2

[10]

59. Physics principles

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]

60. 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 2nd 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]

61. 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)**

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

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

[6]

62. Refraction of light

Change of direction / bends (towards the normal) **(1)** 1

[OR change of velocity]

Cause of refraction

Change of velocity / speed / density of medium / r.i. (bigger) **(1)** 1

[OR change of medium]

Power of cornea

Use of $P = 1/f$ **(1)**

$= 1/0.02$

$= 50$ D **(1)** 2

Effect

Any two from:

- normal lens provides focus for near (and far) objects/accommodation
- the lens changes shape to alter power/the plastic lens cannot change power / shape
- the plastic lens will result in one object distance being very clear / focussed
- limited / narrow focal range **(1)** **(1)** 2

Calculation

Use of $1/u + 1/\upsilon = 1/f$ **(1)**

$1/u + 1/0.02 = 54$

$= 54 - 50 = 4$ **(1)**

$u = ¼ = 0.25$ m [allow e.c.f.] **(1)** 3

Advantage

Any two from:

- f / power can be altered / changed
- more overlap of lenses = greater power/focus on closer objects
- as total power = $p_1 + p_2$ etc
- less overlap = less power/focus on far objects/accommodation **(1)** **(1)** 2

[11]

63. 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]

64. 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)**

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

65. 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]

66. Focal length

f = (−)0.3(3) m **(1)** 1

Position of image

Ray drawn through centre of lens from top of object **(1)**

Ray drawn from f (in 7^{th} box from lens) **(1)**

Correct positioning of image indicated (for diverging lens) **(1)** 3

Diagram

Rays of light diverging from (new lens) to front of eyeball **(1)**

Converging to a point on the retina **(1)** 2

Focussing on close objects

Rays from a close object have to be bent/converged more **(1)**

A more powerful/fatter/squashed lens is needed **(1)**

The eye muscles have to work on the lens **(1)** Max 2

Use of ultrasound

Any 3 from:

- reflection occurs on passing into the eyeball/when change of density **(1)**
- reflection occurs on passing out the back of the eyeball **(1)**
- as speed of sound known, distance can be calculated using d = v × t and then halved **(1)** 3

Effect on sight

More short-sighted/worse **(1)** 1

[12]

67. 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]

68. Evidence for Big Bang

2 independent points **(I)**
OR 2nd statement must follow logically from first **(1)** **(1)** 2

E.g.

- **(I)** red shifted light
- **(I)** (implies) expansion of Universe
- so extrapolating backwards, we can deduce Big Bang

- **(I)** microwave background radiation constant from all directions
- this is the glow of the Big Bang (as one looks back in time)

- **(I)** abundance of H and He are as predicted
- hence rapid period of nucleosynthesis in hot Big Bang

Fractional change in frequency of light from distant galaxy

Use of $z = H_0 d/c$ **(1)**

$= 100 \text{ km s}^{-1} \text{ Mpc}^{-1} \times 2 \times 10^3 \text{ Mpc} / 3 \times 10^8 \text{ m s}^{-1}$

$\times 10^3 \text{ m km}^{-1}$ **(1)**

= 0.7 [or ecf 0.0007] u.e. **(1)** 3

[OR, if no marks awarded, $v = H_0 d = 2 \times 10^5 \text{ km s}^{-1}$ **(1)**]

Meaning of “to the outer rim of everywhere”

E.g.: this is the edge of the Universe **(1)**
[do not accept end] 1

[6]

69. Velocity of jumper

$\omega = 2\pi/T = 2\pi/5.0$ s (= 1.26 s^{-1}) **(1)**

$\upsilon_{max} = A\omega$

= 4.0 m × 2π/5.0 s

=5.0(3) (m s^{-1}) **(1)** 2

-

Why tension in rope and jumper's weight must be balanced

When υ is maximum, acceleration = 0 **(1)**

so net force = 0 **(1)** 2

[OR: If forces not in equilibrium, he would accelerate/decel. **(1)**
So velocity cannot be maximum **(1)**]

Calculation of force constant for rope

Use of $T = 2\pi\sqrt{m/k}$ **(1)**

Hence $k = 4\pi^2 m/T^2 = 4\pi^2 \times 70$ kg/(5.0 s)^2

= 109 – 111 N m^{-1} [kg s^{-2}] **(1)** 2

Verification that rope is never slack during oscillations

$F = mg$ = 70 kg × 9.81 N kg^{-1} = 687 N **(1)**

At centre of oscillation, when forces in equilibrium,

$x = F/k$

= 687 N/110 N m^{-1} (allow e.c.f. from previous part) **(1)**

= 6.2 m which is larger than amplitude **(1)** 3

OR
Calculation of a_{max} (= $-\omega^2 A$) [6.32 m s^{-2}] **(1)**
Comparison with g 9.81 m s^{-1} **(1)**
Deduction **(1)**

Likewise for forces approach.

Motion of jumper

Any 1 from:
- motion is damped shm
- so amplitude decreases
- but period stays (approximately) the same **(1)** 1

[10]

70. 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]

71. Explanation of formation of standing wave

Waves reflected (at paper clip) **(1)**

Upward and downward waves superpose **(1)**

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

Mark antinode

Correct position **(1)** 1

Show that speed is about 10 m s^{-1}

$T = W = mg$

$= 4.8 \times 10^{-4} \text{ kg} \times 9.81 \text{ N kg}^{-1} = 4.7 \times 10^{-3} \text{ N}$ **(1)**

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

$= \sqrt{(4.7 \times 10^{-3} \text{ N} \div 3.1 \times 10^{-5} \text{ kg m}^{-1})}$ **(1)**

$= 12.3 \text{ m s}^{-1}$ **(1)** 3

Equation linking length of thread and wavelength

$l = \lambda$ **(1)** 1

Calculation of frequency

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

$f = \upsilon/\lambda$

$= 12.3 \text{ m s}^{-1} \div 0.45 \text{ m}$ [substitution] **(1)**

$= 27.3 \text{ Hz}$ **(1)** 3

[11]

72. 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]

73. 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]

74. 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]

75. 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]

76. 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]

77. Eye diagram:

Converging lens placed between O and eye [Allow drawing of lens or labelled line] **(1)**
Rays converge at lens **and** at eye to meet on the retina **(1)** 2

What is meant by **polymer**:

(long) **chain** molecule / **chain** of atoms / **chain** of monomers **(1)** 1
[chain of molecules = 0]

Object distance:

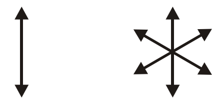
$1/f = 150$ **(1)**
Correct substitution of v into lens formula [Accept 2(cm) or 0.02(m)] **(1)**
Correct answer [0.01 m or 1.0 cm] [allow 0.0098 m] **(1)** 3

e.g.
$150 = 1/u + 1/0.02$
$150 – 50 = 100 = 1/u$
$u = 1/100 = 0.01$ m (1.0 cm)

[6]

78. 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]

79. Energy changes in the string:
Idea that there is an interchange of energy(**1**)
[e.g. X → Y, (elastic) P.E. (stored in string) → K.E. of string / Y → X, K.E. of string → (elastic) P.E.(stored in string) / the total energy in the string remains constant] [Do not accept gpe, do not accept elastics unqualified by PE]

1 mark for correct row or column of table [table not expected]

	X	Y
KE	0	max
PE	max	0

(1)

[accept minimum instead of zero] [ignore **g**pe for this mark] 2

Acceleration of the string:

2 points from:

- at Y acceleration is **zero (1)**
- at X acceleration is a **maximum (1)**
- acceleration towards Y **only (1)** max 2

Meaning of resonate:
Body vibrates with increasing amplitude / large amplitude **(1)**
[accept max energy transfer]
(When forcing frequency from vibrating string) equals natural frequency of body [accept near to] **(1)** 2

Why resonance is desirable:
Idea that the sound produced is louder than it would otherwise be **(1)** 1
[e.g. increases intensity of sound / amplifies sound / produces a loud sound]

Velocity of sound:
Use of $c^2 = E/\rho$ **(1)**
Correct answer [3950(ms^{-1})] to at least 2 sig figs [no u.e.] ☐**(1)** 2
[Bald answer scores 0, reverse calculation can score 2/2]

Example of calculation:
$c^2 = 10.0 \times 10^9$ N m^{-2} / 640 kg m^{-3}
$= 1.6 \times 10^7$ m^2 s^{-2}
So c = 3950 m s^{-1}

Lowest frequency:
Recall $c = f.\lambda$ **(1)**
Correct answer [5600 Hz or 5714 Hz if 4000 ms^{-1} used] **(1)** 2

Suggest how intensity of sound is affected:
(Intensity is proportional to A^2 Hence) intensity is 25 times greater **(1)** 1

[12]

80. Doppler effect:
2 points from

- As ambulance approaches, frequency is higher (than normal) **(1)**
- As ambulance recedes, frequency is lower (than normal) **(1)**
- At moment of passing observed frequency = siren frequency **(1)** max 2

Diagram and explanation:

Diagram shows planet, star and Earth in line, with planet on far side of star **(1)**
Diagram shows planet, star and Earth in line, with planet between star and Earth **(1)**
Idea that planet attracts star towards itself **(1)**
Hence star experiences a change in velocity towards planet **(1)**
Max f / min λ / blue shift when planet is nearest Earth **or** min f / max λ / red shift when planet is furthest away from Earth [must be referring to radiation from the **star**] [must not refer to sound] **(1)** max 4
[A good diagram can score all 4 marks. Information on the diagram overrules written]

Time for orbit:
Idea of measuring/identifying the time taken for planet to return to the **same** position in its orbit or half an orbit **(1)** 1
[e.g. the time between successive minima or maxima / the time between the start of red shift and the start of blue shift is half an orbit]

Explanation:

$F = GMm/r^2$ quoted [watch out for F change to g] **(1)**
(For the Earth) m is very small [accept size is very small] **(1)**
Hence the force exerted on the star is smaller(despite a smaller r) **(1)**
Change in velocity / wobble produced is too small to give an observable Doppler shift [frequency shift, red/blue shift accepted in place of Doppler shift] **(1)** 4

[11]

81. $E = hf$ /photon energy is proportional to frequency **(1)**
Photon energy must be greater than work function/minimum required to liberate electron **(1)** 2

$hf = \phi + ½\, m\upsilon^2$ max $E_k = ½\, m\upsilon^2$ max $= hf - \phi$

$E_k = (6.63 \times 10^{-34}$ J s $\times 1.70 \times 10^{18}$ Hz) $- 9.61 \times 10^{-16}$ J **(1)**

$= 1.127 \times 10^{-15}$ J $- 9.61 \times 10^{-16}$ J **(1)**

$= 1.66 \times 10^{-16}$ J **(1)** 3

[5]

82. Explanation of line spectra:

Specific frequencies or wavelengths **(1)**

Detail, e.g. absorption/emission **(1)**

OR within narrow band of wavelengths 2

Explanation how line spectra provide evidence for existence or energy levels in atoms:

Photons **(1)**

Associated with particular energies **(1)**

Electron transitions **(1)**

Discrete levels (to provide line spectra) **(1)** 3

[5]

83. How electrons are provided with energy:

Energy from radioactivity in the rocks **(1)** 1

Diagram:

Arrow from top defect level to somewhere in valence band **(1)** 1

Calculation:

Frequency $= E/h = 4.2 \times 10^{-19}$ J/6.63×10^{-34} J s $= 6.34 \times 10^{14}$ Hz **(1)**

Wavelength $= c/f$ **(1)**

$= 3.0 \times 10^8$ m s^{-1} / 6.34×10^{14} Hz

$= 4.7 \times 10^{-7}$ m **(1)** 3

Explanation:

There are several possible levels to which electron can be raised from valence band **(1)**

so several possible jumps down and several photon energies **(1)**

[OR reference to valence band being broad] 2

What must be done for radiation to be emitted:

Artefact must be heated **(1)**

Estimate:

It is twice as old (100 000 years old) **(1)**

Assumption:

For example: radioactive background constant **(1)**

OR defect levels not all occupied 3

[10]

84. Threshold wave:

Electron requires certain amount of energy to escape from surface **(1)**

This energy comes from one photon **(1)**

Use of $E = hf$ **(1)**

(So photon needs) minimum frequency **(1)**

Hence maximum wavelength

OR use of $E = hc/\lambda$ **(1)** Max 4

Work function:

$f = c/\lambda = 3.0 \times 10^8 / 700 \times 10^{-9}$ m **(1)**

$= 4.28 \times 10^{14}$ Hz **(1)**

$E = hf = 6.63 \times 10^{-34}$ J s $\times 4.28 \times 10^{14}$ Hz $= 2.84 \times 10^{-19}$ (J) [Allow e.c.f.] **(1)** 3

Circuit :

Circuit showing resistors only in series **(1)**

Potentials labelled **(1)**
[Use of potential divider – allowed]
Resistor values 1: 1: 1 OR 1:2 **(1)** Max 2

Suggestion:

Cosmic rays travel more slowly than light **(1)** 1

[10]

85. Atomic processes:

Electrons only allowed in specific / discrete levels (lines only) **(1)**

(Electrons become excited), move up an energy level **(1)**

(When atom relaxes) the electrons return to lower energy levels **(1)**

With the emission of a photon/light **(1)**

Of frequency given by energy level difference / Planck constant

OR

Longer energy level transition the smaller the λ / greater the *f* **(1)** 5

Type of force:

Gravitational/centripetal **(1)** 1

Explanation of varying wavelength:

Doppler shift **(1)**

Due to relative movement (between source and observer)/moving towards **(1)**

(or away from) us

receding leads to longer λ / red shift or vice versa **(1)** Max 2

Calculation of orbital speed:

From graph $\Delta\lambda$ ×= 2 nm **(1)**

$\upsilon = 2 \times 3 \times 10^8 / 260.0 = 2300$ km s^{-1} OR $w = 5.6 \times 10^{-6}$ rad s^{-1} **(1)** 2

[Allow radial speed]

Calculation of radius of orbit:

Use of $\upsilon = 27\pi r / T$ **(1)**

$T = 12.9 \times 24 \times 3600$ s **(1)**

Radius= 4.1×10^8 km **(1)** 3

[13]

86. Energy of photon of light

$E = hf = 6.63 \times 10^{-34}$ J s × 6.0×10^{14} Hz = 3.98×10^{-19} (J) 1

Graph

Points correct (± ½ square) **(2)**

Single straight line of best fit (NOT giving intercept below 4.5×10^{14}) **(1)**

Line drawn as far as *f* axis **(1)** 4

Value for *h*

Large triangle [at least 7 cm on K.E. axis] **(1)**

Gradient = e.g. $(6.05 - 4.55) \times 10^{14} / 1.0 \times 10^{-19} = 1.5 \times 10^{33}$ **(1)**

h = 1/gradient = 6.67×10^{-34} J s **(1)** 3

Value of ϕ

Reading co-ordinates of a fixed point on graph (e.g. 0, 4.55×10^{14}) **(1)**

ϕ from equation, e.g.

so ϕ = frequency intercept × h

= e.g. $4.55 \times 10^{14} \times 6.67 \times 10^{-34}$

= 3.03×10^{-19} J **(1)** 2

Explanation

Not enough energy [OR frequency too low]

For 2nd mark, numerical/added detail required,

e.g calculation: $E = 6.63 \times 10^{-34} \times 4.5 \times 10^{14}$ Hz $= 2.98 \times 10^{-19} < \phi$

OR threshold frequency read from graph 2

[12]

87. Description

Electron (near surface of cathode) absorbs photon and gains energy **(1)**

Work function is energy needed for electron to escape from surface **(1)**

Electrons released in this way are called photoelectrons **(1)** 3

Lowest frequency of radiation

$f_0 = E/h$ **(1)**

$= 2.90 \times 10^{-19}$ J/6.63×10^{-34} J s **(1)**

$= 4.37 \times 10^{14}$ Hz **(1)** 3

Suitability of potassium

$\lambda = 3 \times 10^{8}$ m s^{-1} / 4.37×10^{14} Hz [use of lowest frequency] **(1)**
6.86×10^{-7} m [**with** suitable comment] **(1)**

OR

$f = 3 \times 10^{8}$ m s^{-1} / 4.0×10^{-7} **and** $f = 3 \times 10^{8}$ m s^{-1} / 7.0×10^{-7} [uses range of λ] **(1)**
$f = 7.5 \times 10^{14}$ Hz to 4.3×10^{14} Hz [**with** suitable comment] **(1)** 2

[Suitable comment – e.g. this is within range of visible light/almost all of the visible light photons will emit photoelectrons]

Maximum kinetic energy

Use of $E = hc/\lambda$ AND minimum wavelength **(1)**

Max photon energy = $hc/\lambda = 6.63 \times 10^{-34}$ J s × 3×10^{8} m s^{-1}/(400 × 10^{-9}m)

$= 4.97 \times 10^{-19}$ J [no u.e]

Max k.e. = max photon energy – work function [or use equation]

$= 4.97 \times 10^{-19}$ J – 2.90×10^{-19} J

$= 2.07 \times 10^{-19}$ J [allow ecf if wrong wavelength used] [no u.e] **(1)** 3

Why some photoelectrons will have less than this k.e.

One point from:

- photon energy might be transferred to electron below surface
- so some energy transferred to atoms on the way to surface
- hence electron leaves surface with less energy than max
- max is for electron from the surface
- lower energy photon responsible for emission **(1)** 1

[12]

88. Error in circuit diagram

Cell needs to be reversed **(1)**
Any one point from:

- electrons released from the magnesium
- copper wire needs to be positive to attract electrons **(1)** 2

Completion of sentence

UV is made up of particles called photons **(1)** 1

UV and visible light

(i) UV has shorter wavelength/higher frequency/higher photon energy **(1)**

(ii) Both electromagnetic radiation/both transverse waves/same speed (in vacuum) **(1)** 2

Explanation of why low intensity UV light produces a current

Any three points from:

- reference to photons or $E = hf$
- frequency > threshold frequency
- electron must have sufficient energy to be released
- UV photons have more energy
- electron is released by ONE photon
- brighter light just means more photons **(1) (1) (1)** Max 3

Why current stopped

Glass prevents UV reaching magnesium **(1)** 1

[9]

89. <u>Wavelength of the photon</u>

$F = m\upsilon^2 / r$ OR $a = \dfrac{\upsilon^2}{r}$ <u>and</u> $F = ma$ **(1)**

$F = kq_1\, q_2 / r^2$ **(1)**

$\Rightarrow m\upsilon^2 = kq_1\, q_2 / r$

$\Rightarrow \frac{1}{2} m\upsilon^2 = kq_1\, q_2 / 2r$ [$=2.13 \times 10^{-18}$ J if evaluated] **(1)**

Use of $E = hc/\lambda$ OR $E = hf$ <u>and</u> $\lambda = \dfrac{c}{f}$ **(1)**

$\Rightarrow \lambda = hc/E = 2hcr/ke^2$

$\Rightarrow 9.3 \times 10^{-8}$ m **(1)** 5

90. <u>Polymer</u>

Long chain **(1)**

molecules / of atoms / monomers / units **(1)** 2

<u>Energy of photon of ultraviolet light</u>

$f = c/2.5 \times 10^{-7}$ **(1)**

$= 1.2 \times 10^{15}$

Use of $E = hf$ **(1)**

$6.63 \times 10^{-34} \times 1.2 \times 10^{15} = 8.0 \times 10^{-19}$ J **(1)** 3

<u>Process of ultraviolet absorption</u>

Energy level diagram with three or more lines used **(1)**

Words: electron and photon in context **(1)**

Arrow up/electron excitation when absorbing ultraviolet light **(1)**

Arrow down to intermediate level or from intermediate level emits blue **(1)** 4

<u>Energy level diagram</u>

Energy level *bands* **(1)** 1

<u>Brightness of posters</u>

(Invisible) ultraviolet absorbed **(1)**

(Re–)emitted as (visible blue) light **(1)** 2

[12]

91. Description of photon

Packet/quantum/particle of energy [accept $E = hf$ for energy] **(1) (1)**

[allow {packet/quantum/particle} of {light/e-m radiation/e-m wave} etc for **(1) X**] 2
[zero marks if error of physics such as particle of light with negative charge]

Show that energy to move electron is about 8×10^{-20} J

$W = QV$ **(1)**

$= 1.6 \times 10^{-19}$ C $\times$ 0.48 V

$= 7.7 \times 10^{-20}$ J [no ue] **(1)** 2

Calculate efficiency of photon energy conversion

Efficiency = (7.7×10^{-20} J ÷ 4.0×10^{-19} J) [ecf] **(1)**

= 0.19 or 19 % **(1)** 2

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92. Explanation of 'excited'

Electrons/atoms gain energy **(1)**

and electrons move to higher (energy) levels **(1)** 2

[Credit may be gained for diagrams in this and the next 3 parts]

Explanation of how radiation emitted by mercury atoms

Electrons (lose energy as they) drop to lower levels **(1)**

Emit photons / electromagnetic radiation **(1)** 2

Explanation of why only certain wavelengths are emitted

Wavelength (of photon) depends one energy **(1)**

Photon energy depends on difference in energy levels **(1)**

Levels discrete / only certain differences / photon energies possible **(1)** 3
(and therefore certain wavelengths)

Why phosphor emits different wavelengths to mercury

Different energy levels / different differences in energy levels **(1)** 1

Calculation of charge

$Q = It$ **(1)**

= 0.15 A × 20 × 60s

= 180 C **(1)** 2

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93. Example of light behaving as a wave

Any one of:

- diffraction
- refraction
- interference
- polarisation **(1)** 1

What is meant by monochromatic

Single colour / wavelength / frequency **(1)** 1

Completion of graph

Points plotted correctly [–1 for each incorrect point] **(1) (1)**

Line of best fit added across graph grid **(1)** 3

What eV_s tells us

Maximum **(1)**

Kinetic energy of the electrons / ½ mv^2 of electrons **(1)** 2

Threshold frequency for sodium

Correct reading from graph: 4.3×10^{14} Hz **(1)** 1

[Accept $4.1 \times 10^{14} – 4.7 \times 10^{14}$Hz]

Work function

$f = hf_0 = 6.63 \times 10^{-34}$ J s × 4.3×10^{14} Hz **(1)**

$= 2.9 \times 10^{-19}$J [Allow ecf] **(1)** 2

Why threshold frequency is needed

- Electron requires certain amount of energy to escape from surface **(1)**
- This energy comes from one photon of light **(1)**
- $E = hf$ **(1)** Max 2

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94. Meaning of energy level

Specific allowed energy/energies (of electron in an atom)**(1)** 1

Meaning of photon

Quantum/packet/particle of energy/radiation/light/electromagnetic wave **(1)** 1

Formula for photon energy

$E_2 – E_1$ **(1)** 1
[Allow $E_1 + E_{photon} = E_2$]

Explanation of photon wavelengths

Same energy change / same energy difference / energy the same **(1)** 1

Meaning of coherent

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