T4-1 *[180 marks]*

1\.

[1 mark]

Markscheme

A

Examiners report

[N/A]

2\.

[1 mark]

Markscheme

A

Examiners report

[N/A]

3\.

[1 mark]

Markscheme

B

Examiners report

[N/A]

4\.

[1 mark]

Markscheme

B

Examiners report

[N/A]

5\.

[1 mark]

Markscheme

D

Examiners report

[N/A]

6.

[1 mark]

Markscheme

A

Examiners report

[N/A]

7.

[1 mark]

Markscheme

A

Examiners report

[N/A]

8.

[1 mark]

Markscheme

A

Examiners report

[N/A]

9.

[1 mark]

Markscheme

A

Examiners report

[N/A]

10.

[1 mark]

Markscheme

D

Examiners report

[N/A]

11.

[1 mark]

Markscheme

B

Examiners report

[N/A]

12.

[1 mark]

Markscheme

B

Examiners report

[N/A]

13a.

[2 marks]

Markscheme

(i) the work done per unit charge in moving a quantity of charge completely around a circuit / the power delivered per unit current / work done per unit charge made available by a source;

(ii) place voltmeter across battery;

Examiners report

[N/A]

13b.

[2 marks]

Markscheme

(periodic) motion in which acceleration/restoring force is proportional to the displacement from a fixed point;

directed towards the fixed point / in the opposite direction to the displacement;

Examiners report

[N/A]

13c.

[4 marks]

Markscheme

(i) $\omega = (2\pi f = 2\pi \times 1250)\, 7854$ rad s^{-1};

$a_0 = (-\omega^2 x_0 = -7854^2 \times 0.85 \times 10^{-3} =)\ (-)5.2 \times 10^4\ ms^{-2}$;

(ii) correct substitution into
$E_T = \frac{1}{2} m \omega^2 {x_0}^2$ irrespective of powers of 10;

0.14 to 0.15 J;

Examiners report

[N/A]

13d.

[2 marks]

Examiners report

[N/A]

13e. *[6 marks]*

Markscheme

(i) S leads L / idea that the phase of L is the phase of S minus an angle;

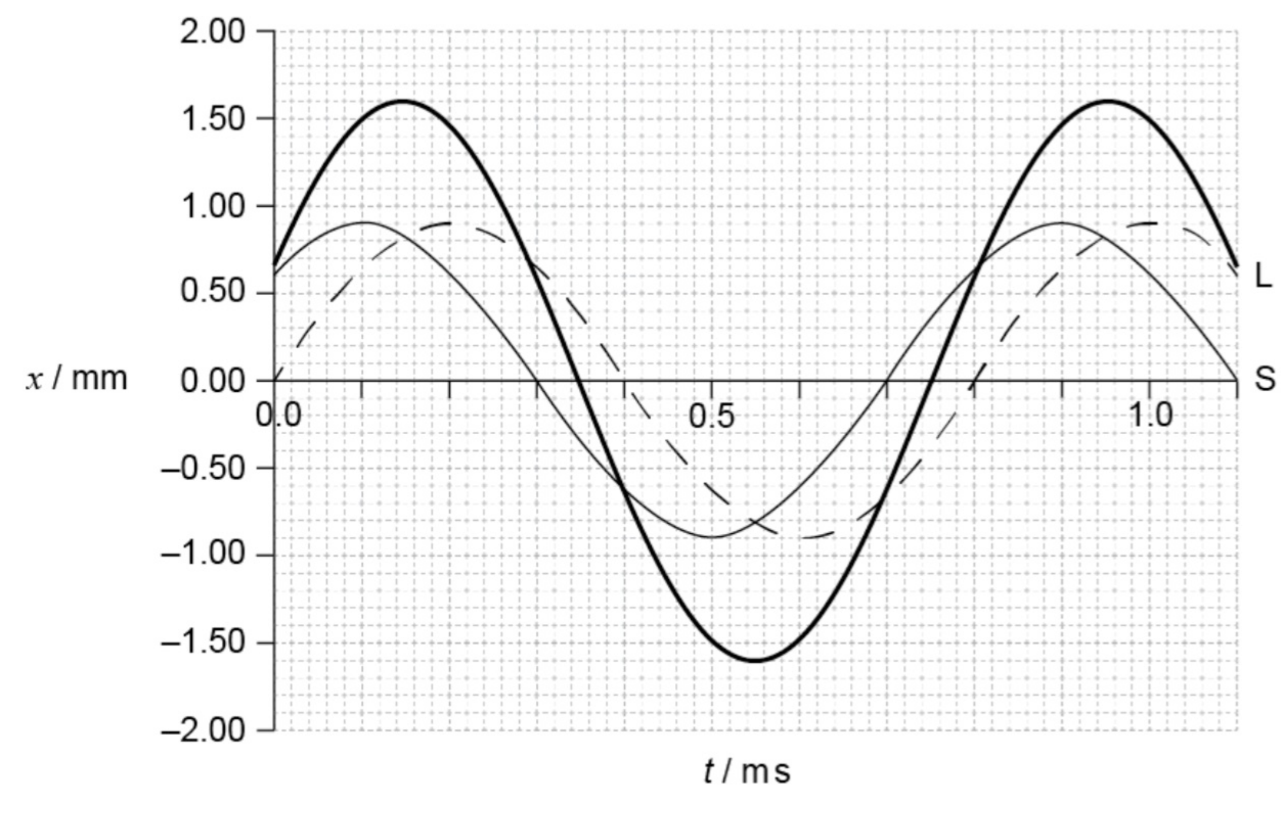
$\frac{1}{8}$ period / 1×10^{-4} s / 0.1 ms;

$\frac{\pi}{4}$ / 0.79 rad / 45 degrees;

(ii) agreement at all zero displacements;

maxima and minimum at correct times;

constant amplitude of 1.60 mm;



Examiners report

[N/A]

14a. *[3 marks]*

Markscheme

mention of interference;
interference is between reflected waves from both reflectors;
minimum caused (by destructive interference) when crest meets trough/when path difference is
$\frac{\lambda}{2}$ / (completely) out of phase / phase difference of
π/180º / *OWTTE*;
minimum occurs when twice the distance between plates is
$\left(n+\frac{1}{2}\right)\lambda$;

Ignore references to standing waves.

Examiners report

[N/A]

14b. *[3 marks]*

Markscheme

(i) spreading out of a wave; *(do not allow "bending" even if context is obstacle)*
when it meets an aperture/gap/slit/obstacle;
Allow credit for answers appearing on clear labelled diagram for both marks.

(ii)
$\left(\theta = \frac{32}{60} =\right) 0.533\ (\text{rad})$ ***or*** 30.6(º);
*Award **[0]** for calculation that uses 1.22 (0.65 rad).*
*Award **[0]** for 0.533º or 30.6 rad.*
At least one centre is using the abbreviation ᶜ for rad. Please allow this.

Examiners report

[N/A]

14c. *[2 marks]*

Markscheme

sound waves (in air) are longitudinal;
longitudinal waves cannot be polarized / only transverse waves can be polarized;

*Award **[0]** for any suggestion that ultrasound is an electromagnetic wave.*

Examiners report

[N/A]

15a. *[1 mark]*

Markscheme

node;

Examiners report

[N/A]

15b. *[3 marks]*

Markscheme

(i) wavelength
$= \frac{2.4}{2.5} = (0.96\text{m});$
$c = f\lambda = 144\ (\text{ms}^{-1});$

(ii) 60 (Hz);

Examiners report

[N/A]

16a. *[2 marks]*

Markscheme

by crossing the analyser with the polarized light;
the angle of polarization/electric field vector can be determined;

Examiners report

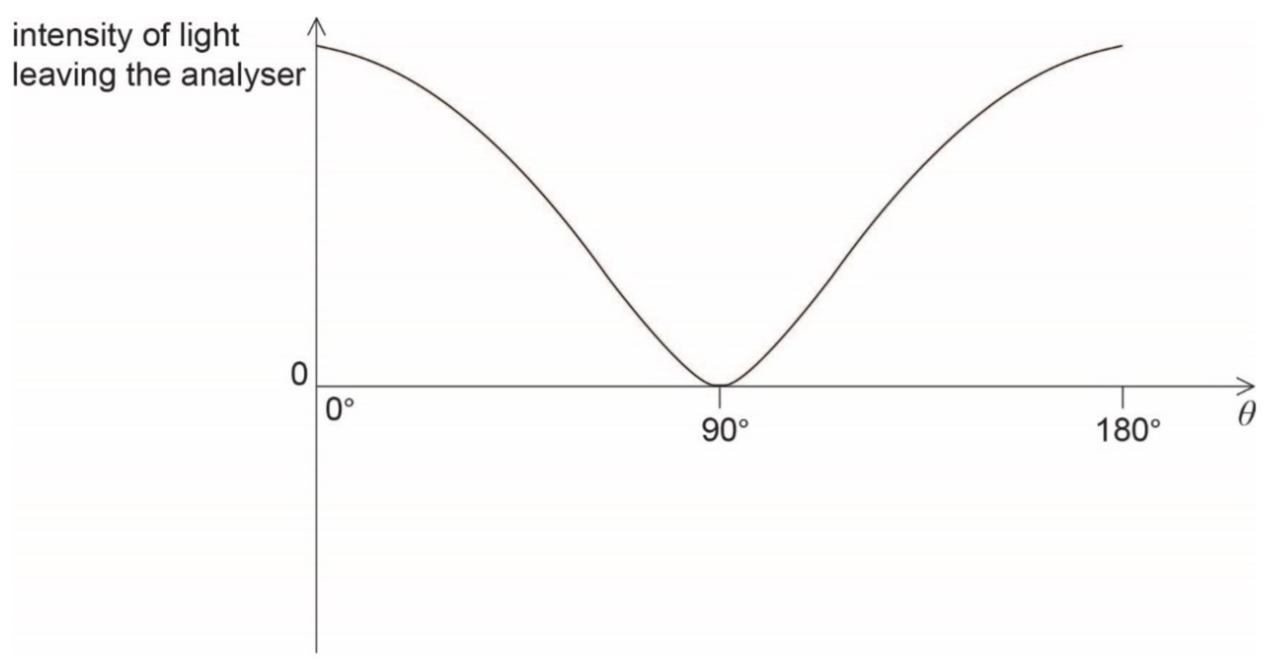
[N/A]

16b. *[3 marks]*

Markscheme

(i) ($I = I_0 \cos^2 25º =$) $0.82 I_0$;

(ii) $\cos^2$ shape; *(allow negative intensities for this mark)*
max at 0º and 180º, zero at 90º; *(allow non-$\cos^2$ line for this mark)*



Examiners report

[N/A]

17a. *[4 marks]*

Markscheme

(i) travelling waves move down the tube;
which then interfere with the reflected waves (from the closed end of the tube/surface of the water);
Accept superposition as an alternative to interference.

(ii)
$\lambda = (4L = 4 \times 0.33 =) 1.32 \, (\mathrm{m})$;
$v = (f\lambda = 256 \times 1.32 =) 338 \, (\mathrm{ms}^{-1})$;

Examiners report

Part (a) was answered well by many, but the idea of superposition of incident and reflected waves was often expressed poorly. Candidates seemed to have memorised the definition of how a standing wave is formed but often struggled to see how it applied to this situation. Part (ii) was easy if the candidate knew that the wavelength was 4L. Many just used L or other multiples of L.

17b. *[2 marks]*

Markscheme

(i) vertical;

(ii) X;

Examiners report

Part (b) was also an easy 2 marks as long as it was remembered that the waves were longitudinal.

18. *[1 mark]*

Markscheme

light in which the electric vector oscillates on one plane/direction;

Examiners report

In part (a) the definition was often not specific enough, the idea that the electric field vector is oscillating rather than just light was often omitted.

19. *[1 mark]*

Markscheme

C

Examiners report

This was an unusual question, and it was disappointing that candidates did not naturally calculate 'average speed' as total distance divided by time taken.

20. *[1 mark]*

Markscheme

A

Examiners report

Sinusoidal graphs are only generated in SHM when time is on the x-axis. Hence B and C are incorrect. D should be well-known to the candidates as the definition of SHM, but can be ruled out as it shows zero v when x = 0. Hence, by elimination, it must be A.

21. *[1 mark]*

Markscheme

B

22. *[1 mark]*

Markscheme

B

Examiners report

23. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

24. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

25. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

26. *[1 mark]*

Markscheme

D

Examiners report

70% of the candidates assumed the peak intensity does not change and opted for either A or B. But if the slit width is reduced then the energy transmitted (and hence peak intensity) will be reduced.

27. *[1 mark]*

Examiners report

It would seem that candidates had not read this question carefully and were trying to remember similar past questions. The incoming light is unpolarized, hence B and C must be incorrect. As the polarizer will reduce the intensity, A must also be incorrect.

28.

[1 mark]

Markscheme

B

Examiners report

[N/A]

29.

[1 mark]

Markscheme

B

Examiners report

[N/A]

30.

[1 mark]

Markscheme

D

Examiners report

This was very poorly done with over half of the candidates opting for A. Simple recall of the Brewster angle, which involves tan of an angle, should cause candidates to eliminate B and C (which most of them did). To choose between A and D, though, it is required to look at the situation as depicted (rather than jumping to conclusions based upon familiar diagrams). θ is the angle to the surface – not the angle of incidence. So A must be incorrect.

31a.

[2 marks]

Markscheme

power/energy per second emitted proportional to surface area;
and proportional to fourth power of absolute temperature / temperature in K;
Accept equation with symbols defined.

Examiners report

The Stefan-Boltzmann law was poorly understood with few candidates stating that the absolute temperature is raised to the fourth power.

31b. *[2 marks]*

Markscheme

solar power given by $4\pi R^2\sigma T^4$;

spreads out over sphere of surface area $4\pi d^2$;

Hence equation given.

Examiners report

This question was poorly done with few candidates substituting the surface area of the sun or the surface area of a sphere at the Earth's radius of orbit.

31c. *[2 marks]*

Markscheme

$$\left(\frac{\sigma R^2 T^4}{d^2} =\right) \frac{5.7\times10^{-8}\times\left[7.0\times10^{8}\right]^2\times\left[5.8\times10^{3}\right]^4}{\left[1.5\times10^{11}\right]^2};$$

$=1.4\times10^3 (Wm^{-2})$;

*Award **[2]** for a bald correct answer.*

Examiners report

Despite not being able to state or manipulate the Stefan-Boltzmann law most candidates could substitute values into the expression and calculate a result.

31d. *[2 marks]*

Markscheme

some energy reflected;

some energy absorbed/scattered by atmosphere; depends on latitude;

depends on time of day;

depends on time of year;

depends on weather (*eg* cloud cover) at location; power output of Sun varies;

Earth-Sun distance varies;

Examiners report

This question was well answered at higher level.

31e. *[2 marks]*

Markscheme

power radiated = power absorbed;

$$T = \sqrt[4]{\frac{240}{5.7\times10^{-8}}} = (250\text{K});$$

Accept answers given as 260 (K).

Examiners report

To show the given value there is the requirement for an explanation of why the incident power absorbed by the Earth's surface is equal to the power radiated by the Earth, few candidates were successful in this aspect. Although most could substitute into the Stefan-Boltzmann equation they needed to either show that the fourth root was used or to find the temperature to more significant figures than the value given.

31f.

[3 marks]

Markscheme

radiation from Sun is re-emitted from Earth at longer wavelengths; greenhouse gases in the atmosphere absorb some of this energy; and radiate some of it back to the surface of the Earth;

Examiners report

A surprising number of candidates could not explain the greenhouse effect. A common misunderstanding was that the Earth reflected radiation into the atmosphere and that the atmosphere reflected the radiation back to the Earth.

31g.

[2 marks]

Markscheme

the force (of the spring on the object)/acceleration (of the object/point O) must be proportional to the displacement (from the equilibrium position/centre/point O);
and in the opposite direction to the displacement / always directed towards the equilibrium position/centre/point O;

Examiners report

The conditions for simple harmonic motion were poorly outlined by most candidates. Few identified a relationship between force/acceleration and displacement, with most talking about it going backwards and forwards without slowing down.

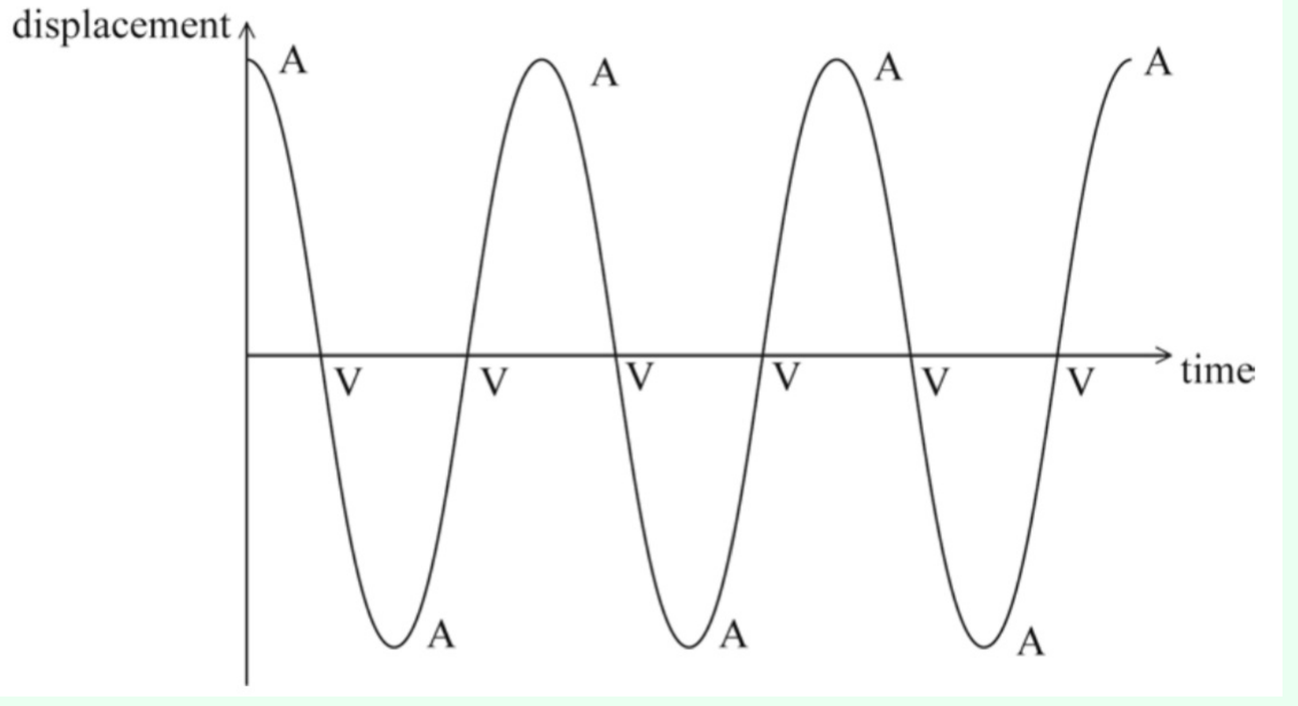
31h.

[4 marks]

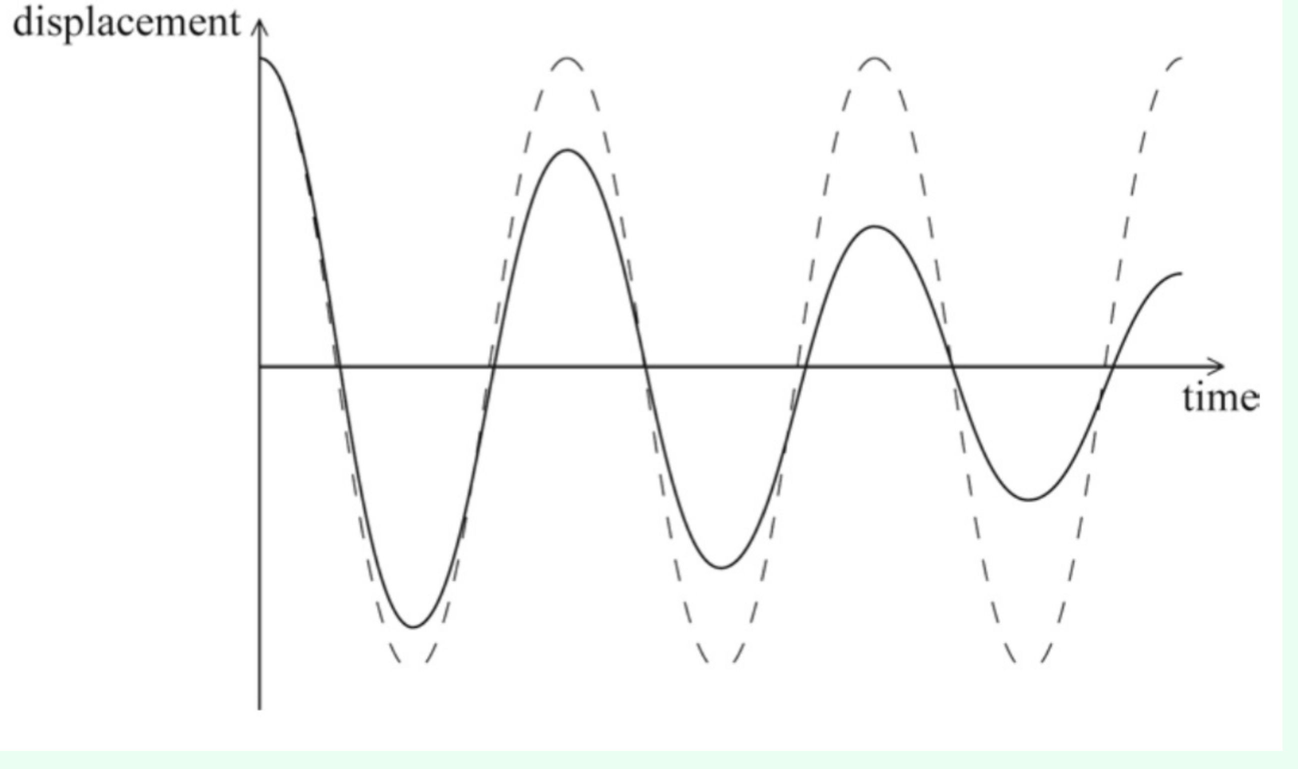
Markscheme

(i) one A correctly shown;

(ii) one V correctly shown;



(iii) same period; *(judge by eye)*
amplitude decreasing with time;



Examiners report

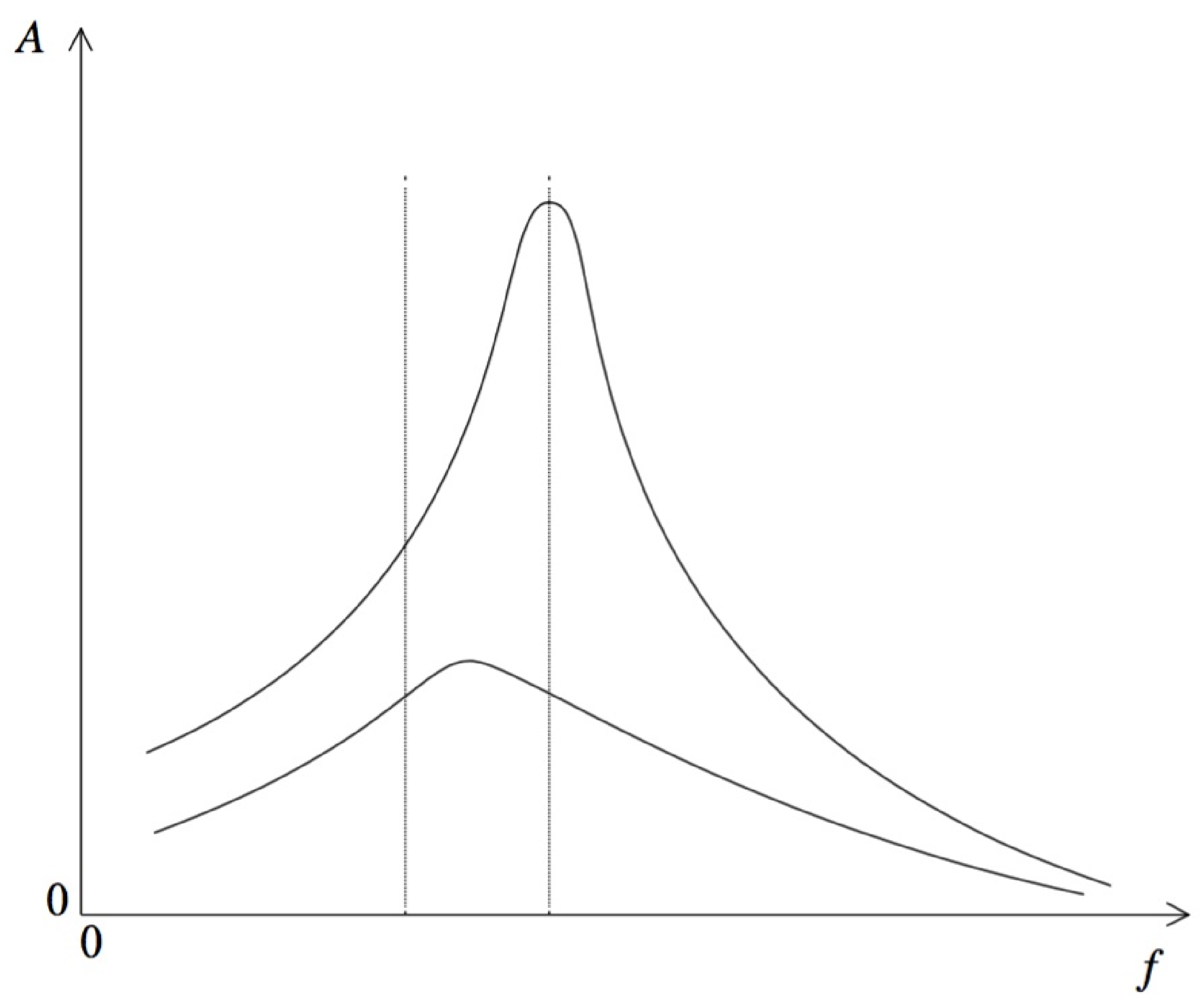
This question was well answered by many. The only notable mistake was with reducing the time period of the damped oscillation.

31i. *[4 marks]*

Markscheme

(i) resonance is where driving frequency equals/is close to natural/resonant frequency;
the natural/resonant frequency is at/near the maximum amplitude of the graph;

(ii) lower amplitude everywhere on graph, bit still positive;
maximum in same place/moved slightly *(that is, between the lines)* to left on graph;



Examiners report

i) Identifying the peak of the graph with the resonant frequency was broadly successfully done but not many candidates stated that this occurs when the driving frequency is equal to the natural frequency.

ii) This sketch was generally well done.

32a. *[5 marks]*

Markscheme

(i) diagram showing (circular) wavefronts around source, so that wavefronts are closer together on side of observer;
speed of sound waves for observer is the same (as for stationary case) but observed wavelength is smaller;

since $f' = \frac{v}{\lambda'}$, (observed frequency is larger);

(ii) $f'\left(= f\left[\frac{v}{v-u_s}\right]\right) = 275\left[\frac{330}{330-20}\right]$;
=293(Hz);

*Award **[0]** for use of moving observer formula.*
*Award **[1]** for use of v+u_s to give 259 (Hz).*
*Award **[2]** for a bald correct answer.*

Examiners report

ai) Many candidates scored the first mark for the diagram showing the wavefronts closer on the side of the observer but most of the written explanations just repeated this and didn't expand further.

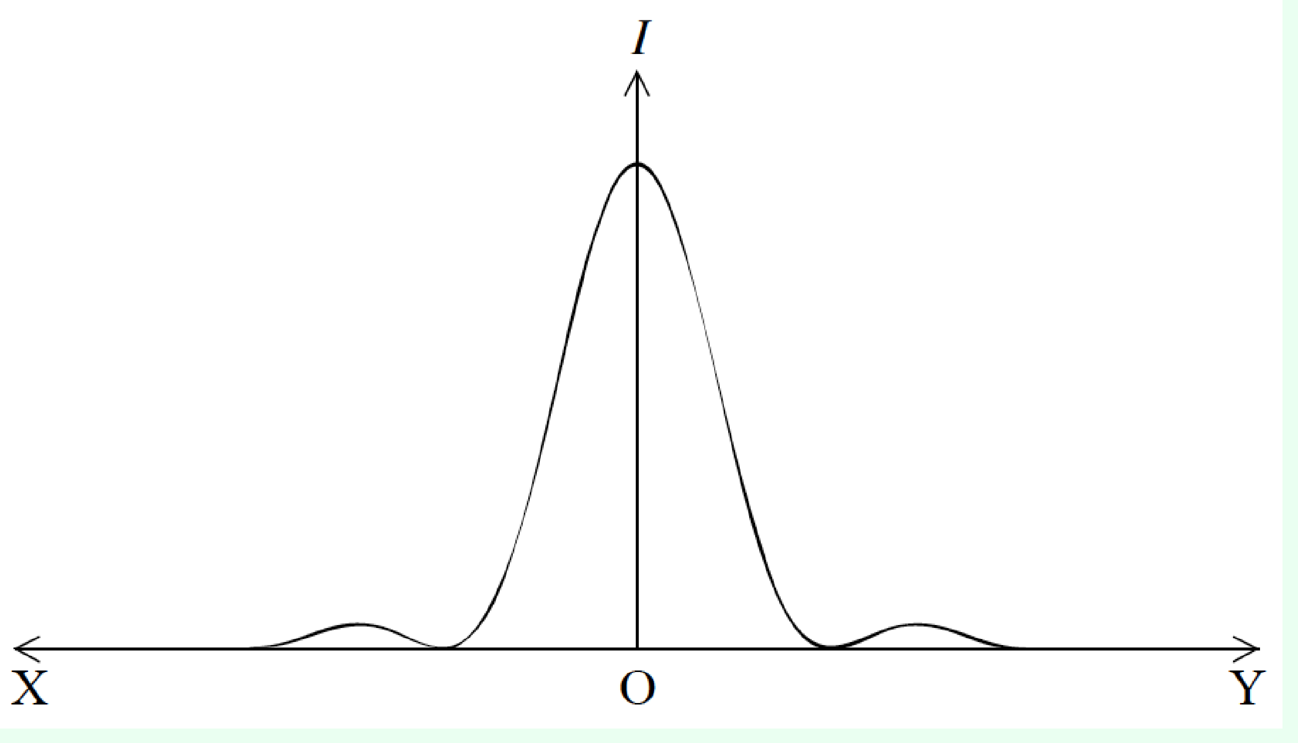
aii) This question was very well answered with the majority of candidates choosing the appropriate formula and evaluating correctly.

32b. *[4 marks]*

Markscheme

(i) central symmetrical maximum;
at least one secondary maximum on each side, no more than one third the height of the central maximum; { *(judge by eye)*

minima drawn to zero, *ie* touching axis;
width of the secondary maximum half the width of the primary maximum; { *(judge by eye)*



(ii) greater distance between maxima/minima / pattern more spread out;

Examiners report

bi) Most candidates were able to score full marks on this question.

bii) Again this was answered successfully.

32c. *[3 marks]*

Markscheme

(i) in a polarized wave, the oscillations/vibrations are in one direction/plane only;
in an unpolarized wave, the oscillations/vibrations are in all directions/ planes (perpendicular to the direction of energy transfer);
Must see mention of oscillations or vibrations in first or second marking point.

(ii) sound waves are longitudinal / the oscillations/vibrations are always parallel to direction of energy transfer;

Examiners report

ci) Few candidates included the words oscillations or vibrations in their answers and consequently scored zero marks.

cii) Many recognized that sound waves are longitudinal and that is why they cannot be polarized.

33a.

[5 marks]

Markscheme

(i) $f_1 = \frac{v}{4L}$, $f_2 = 3f_1 = \frac{3v}{4L}$;
$f_2 - f_1 = \frac{v}{2L} = 820\,(\text{Hz})$;
$L = \frac{330}{2\times820}$;
(L=0.20m)

(ii) $\lambda = 4L = 0.80\,(\text{m})$;
$f = \left(\frac{330}{0.8}\right) = 413\text{Hz}$;

This is a question testing units for this option. Do not award second marking point for an incorrect or missing unit.

Examiners report

[N/A]

33b.

[4 marks]

Markscheme

(i) a change in the observed frequency/wavelength of a wave;
when there is relative motion of observer and source;

(ii) $f'\left(= f\frac{v}{v-u_s}\right) = 410 \times \frac{330}{330-50}$;
$f' = 480\,(\text{Hz})$;
Allow ECF from (a)(ii).

Examiners report

[N/A]

34a.

[2 marks]

Markscheme

waves of different wavelength/frequency;
travel at different velocities;
the index of refraction of the medium depends on the wavelength/frequency;

Examiners report

Too many candidates showed that they do not know the terminology and vaguely described other phenomena instead of dispersion, quite often scattering. Breaking into component colours was sometimes mentioned by the candidates but this was not accepted as correct as the question was about electromagnetic waves, not only about light. A reasonable number of correct answers were seen with reference of both different speed and index of refraction.

34b.

[2 marks]

Markscheme

during simple harmonic motion the charge oscillates/accelerates;
(oscillating/accelerating) charges radiate/produce (varying) electric/magnetic fields / produce electromagnetic waves;

Examiners report

In (b) only the stronger HL candidates clearly connected accelerated charge with the production of electromagnetic radiation. Most SL answers simply repeated the production of electromagnetic waves, missing the importance of the acceleration of the electron and not relating it to electric and magnetic fields.

35a. *[5 marks]*

Markscheme

(i) intensity at P is zero hence complete destructive interference occurs;
point P is at the same distance from A and B / path difference is zero;
destructive interference comes from a 180º phase difference in the signals;

(ii) separation between minima s=3(km);
$\frac{D}{d}\left(=\frac{s}{\lambda}=\frac{3000}{40}\right)=75;$

Examiners report

This question discriminated very well and a full range was seen in the quality of answers. Well prepared candidates showed a good understanding and ability to apply the concept of interference. Lesser prepared candidates were not able to analyse the intensity-position graph. In (a)(i), candidates repeated the question without additional information and did not gain marks in (a)(ii) because they did not have enough information.

35b. *[2 marks]*

Markscheme

R is always equidistant to stations A and B / signals from A and B are always out of phase;
intensity is always zero;

Examiners report

(b) discriminated well between, as evidenced by candidates, those that analysed the situation and those that attempted to remember some information from problems with similar context. Well prepared HL candidates realized that point P has no special position on the line M. (b) was very poorly answered at SL. The explanation of why the intensity is always zero was generally unclear and did not signify thought.

36. *[1 mark]*

Markscheme

D

Examiners report

Many candidates opted for B and this may be down to not taking the time to read the question carefully. Typically, questions on simple harmonic motion ask for the relationship between acceleration and displacement, but in this case, the question asks for the relationship between acceleration and velocity. Candidates will benefit from checking that the other options are wrong before quickly deciding upon their initial thoughts.

37. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

38. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

39. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

40. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

41. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

42. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

43. *[1 mark]*

Examiners report

It was clear from paper 2 that candidates had no real grasp of the physical meaning of the different ways of representing a wave. They are comprised of oscillating particles, but can be represented either as ray, or as a series of wave fronts or graphically. It appears that this area of the syllabus is not being rigorously taught.

44a. *[2 marks]*

Markscheme

the acceleration (of a particle/P) is (directly) proportional to displacement;
and is directed towards equilibrium/in the opposite direction to displacement;
Do not accept "directed towards the centre".

Examiners report

[N/A]

44b. *[5 marks]*

Markscheme

(i) the direction of energy propagation is at right angles to the motion of the particles/atoms/molecules in the medium;

(ii) $\lambda = \frac{v}{f} = vT$;
$= (0.40 \times 0.3 =)\, 0.12\text{m}$;

(iii) $n/1.8 = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$;
to give λ_2=0.067m;

Examiners report

[N/A]

44c. *[3 marks]*

Markscheme

X: graph is a straight line and through the origin / resistance is constant;
so because $V \propto I$ it is ohmic;

Y: not ohmic because graph is not straight/is curved / resistance is not constant;
Award ***[3]*** *for an answer where resistance values are calculated to show constancy or otherwise.*

Examiners report

[N/A]

44d.

[8 marks]

Markscheme

(i) read-off of intersection of lines X and Y [4.0,6.0] / reference to 4.0V **and** 6.0mA; { *(allow power of 10 error)*

$R_X = R_Y = \frac{6.0}{4.0 \times 10^{-3}} = 1.5 \times 10^3 \Omega;$

resistance of combination=750Ω;

(ii) use the idea of potential divider $\frac{R}{750} = \frac{2.0}{6.0}$;

R=250Ω;

or

current=8mA;

$R = \frac{2.0}{0.008} = 250\,(\Omega);$

(iii) total resistance=1000Ω;

total current=8.0×10^{-3}A ***or*** pd=8.0V;

total power=($8.0\times8.0\times10^{-3}$=)64mW;

Examiners report

[N/A]

45a.

[3 marks]

Markscheme

(i) the acceleration (of a particle/P) is (directly) proportional to displacement;

and is directed towards equilibrium/in the opposite direction to displacement;

Do not accept "directed towards the centre".

(ii) $\frac{\pi}{2}$/90°/quarter of a period;

Examiners report

[N/A]

45b.

[6 marks]

Markscheme

(i) light from a hydrogen discharge tube/hot hydrogen gas/ hydrogen tube with potential difference across it;

is passed onto a prism/diffraction grating;

and then is observed on a screen/through a telescope;

Accept good labelled diagram for explanation of any marking point.

(ii) each wavelength corresponds to the energy of the photon emitted;

when an electron makes a transition from a higher to lower energy level;

since only discrete wavelengths/finite number of wavelengths are present, then only discrete energy levels are present / *OWTTE*;

Examiners report

[N/A]

45c. *[4 marks]*

Markscheme

(i) −3.40 eV;

*Award **[0]** for omitted negative sign.*

(ii) energy difference between levels$= \frac{hc}{\lambda e} = \frac{6.63\times10^{-34}\times3\times10^{8}}{4.85\times10^{-7}\times1.6\times10^{-19}}$;

=2.55eV;

$[3.40 - 2.55] = 0.85 = \frac{13.6}{n^2}$ to give n^2=16;

n=4;

*Award **[3]** for reversed argument.*

Examiners report

[N/A]

45d. *[2 marks]*

Markscheme

the total emitted energy is shared between the electron and the antineutrino;

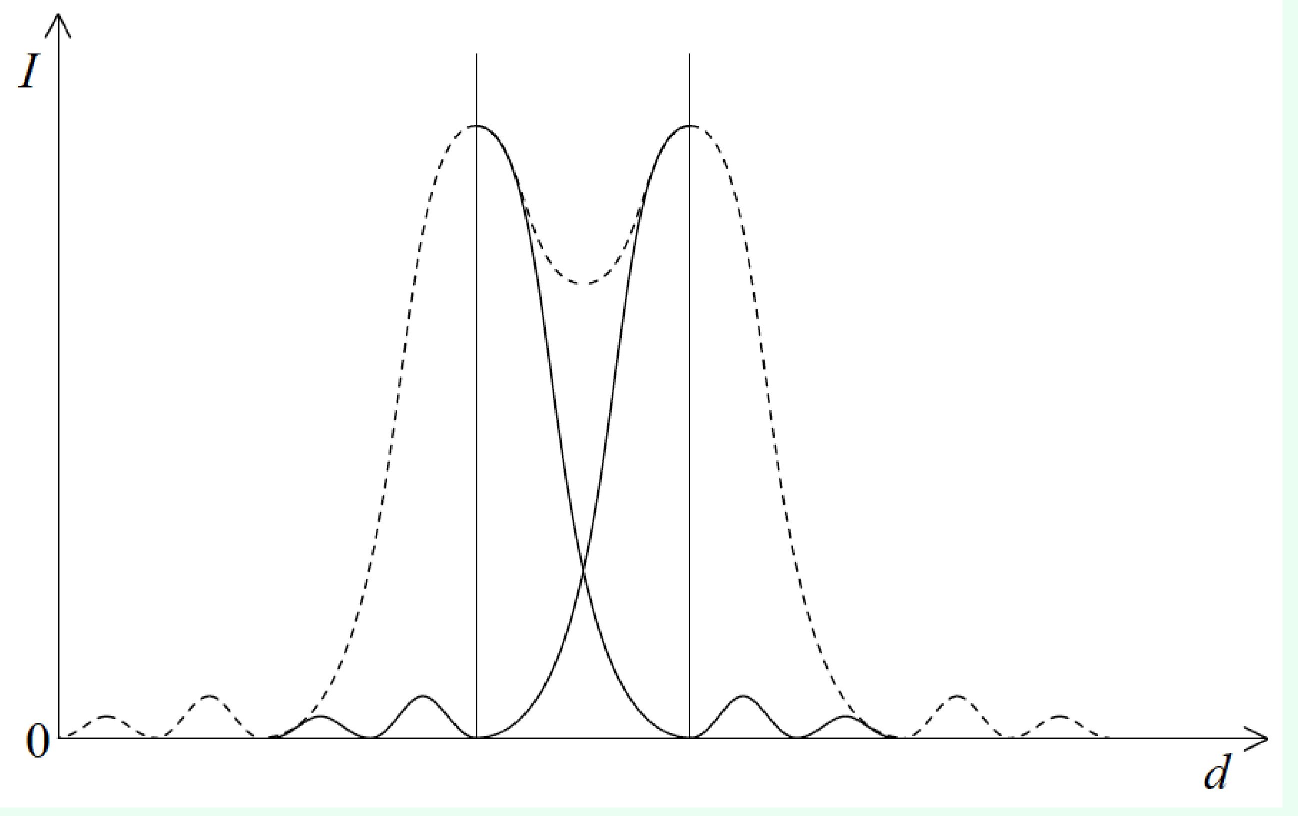
the energy/velocity can be shared/distributed in an infinite number of ways / *OWTTE*;

Examiners report

[N/A]

46a. *[3 marks]*

Markscheme



correct shape of two diffraction patterns showing central maximum and at least one secondary maximum each side of central maximum;
intensity of secondary maxima no greater than one third intensity of central maxima; } *(judge by eye)*
first minimum of one pattern coincident with central maximum of other pattern;

or

Allow just the approximate dotted resultant intensity patterns:
correct pattern of two symmetrical principal maxima;
with local minimum between them;
at least one secondary maximum on each side which are no more than $\frac{1}{3}$ of the intensity of the principal maxima;

Examiners report

[N/A]

46b. *[3 marks]*

Markscheme

angular separation for resolution$=1.22\frac{\lambda}{b}=1.22\times\frac{5.0\times10^{-7}}{1.9\times10^{-3}}=\left(3.21\times10^{-4}\right)(\text{rad})$;
$=\frac{1.4}{d}$;
d=4.4(km);
*Award **[2 max]** if 1.22 not used and answer is 5.3 km.*
*Award **[3]** for a bald correct answer.*

Examiners report

[N/A]

46c. *[1 mark]*

Markscheme

light in which the electric/magnetic field (vector) vibrates only in one plane/direction;

Examiners report

[N/A]

47a. *[2 marks]*

Markscheme

net displacement of the medium;
equals the resultant/sum of individual displacements;
*Award **[1 max]** for reference to amplitude rather than displacement.*
*Award **[0]** for reference only to troughs and crests.*

Examiners report

[N/A]

47b. *[7 marks]*

Markscheme

(i) division of wavefront so constant phase;

(ii) interference/superposition occurs at A;
between waves from each opening;
waves arrive in phase / path difference is one wavelength;
producing a (1st order) maximum;
*Award **[3 max]** for clear points that appear on diagram.*

(iii) maxima occur when the path difference is an integral number of wavelengths;
because wavelength doubles, larger distances/angles required to achieve same path difference;
successive maxima fringes are twice as far/further apart;

or

quotes double slit/grating formula;
substitute 2λ into equation and states all other terms stay constant;
successive maxima fringes are twice as far/further apart;

Examiners report

[N/A]

47c. *[2 marks]*

Markscheme

Assuming spacing of openings stays the same.
same separation of maxima;
maxima increase in amplitude/intensity;
maxima narrower/sharper;
formation of secondary maxima;
*Award **[2 max]** for other reasonable responses if the response clearly states an assumption that the openings are closer or further apart than before.*

Examiners report

[N/A]

48.

[1 mark]

Markscheme

C

Examiners report

[N/A]

49.

[1 mark]

Markscheme

D

Examiners report

[N/A]