T4-2 *[251 marks]*

1. *[1 mark]*

Markscheme

C

Examiners report

Candidates needed to recognise that the path difference needs to be equal to an odd number of half-wavelengths for destructive interference to happen. With a path difference of 0.60m this is true only for wavelength of 0.40m giving a half- wavelength of 0.20m and thus three half-wavelengths occurring.

2. *[1 mark]*

Markscheme

C

Examiners report

This was a slightly unusual question in that the inverse square law is usually used by starting close to an object and then moving away; here it was used in reverse. Nevertheless, one distance was four times further than the other and so the intensity ratio would be 1:16 with it therefore being 16 times greater for the planet closer to the star.

3. *[1 mark]*

Markscheme

D

Examiners report

Not enough candidates recognized that intensity depends upon the square of the amplitude. Option C was nearly as popular as the key D.

4. *[1 mark]*

Markscheme

B

Examiners report

Candidates often find this to be difficult. In a standing wave each particle has its own amplitude with that at the nodes being zero and that at the antinodes being a maximum. For a progressive wave all particles follow on from their neighbours and have the same amplitude.

5. *[1 mark]*

Markscheme

B

Examiners report

Candidates found this question to be the most challenging on the paper. At the Brewster angle the reflected light is plane polarized but that does not mean that the transmitted (refracted) light is plane polarized. There will still be some light in the same plane of vibration as the reflected light but there will now be less of it. The transmitted light is therefore partially plane polarized.

6.

[1 mark]

Markscheme

D

Examiners report

[N/A]

7.

[1 mark]

Markscheme

C

Examiners report

When unpolarized light passes through a polarising filter its intensity halves. Clearly all angles of the polarising filter are logically equivalent and therefore immaterial. However, when polarized light passes through a polarizing filter its intensity is reduced depending upon the angle of the filter to the plane of polarization. Hence C is the only logically possible answer. The most popular response, however, was D, presumably since the candidates referred to their formula booklets before thinking through the situation illustrated.

8.

[1 mark]

Markscheme

D

Examiners report

In this question the majority of candidates thought, incorrectly, that the ball would be in equilibrium at the central position when the string is vertical. The ball is obviously not in equilibrium since it is moving on a circular arc and so at the vertical position there must be a net force directed towards the center of the arc and so there cannot be equilibrium.

9.

[1 mark]

Markscheme

A

Examiners report

[N/A]

10a. *[1 mark]*

Markscheme

(when two similar waves meet) the resultant displacement is the (vector) sum of the individual displacements;

*Allow **[0]** for description in terms of amplitude.*

Examiners report

Few candidates stated the principle of superposition clearly enough to gain a mark – most talked about the sum of the amplitudes rather than of the displacements.

10b. *[5 marks]*

Markscheme

(i) (constructive interference gives) amplitude $2A$; intensity is proportional to square of total amplitude ($=4A^2$);

(ii) attempted use of Pythagoras to measure path difference;

path difference =0.55 (m);

path difference = $\frac{\lambda}{2}$ (so out of phase / destructive interference);

Attempted use of Pythagoras may appear on diagram for (b)(i).

Examiners report

(i) With hindsight having a distance of 4.0m as well as the $4A^2$ was unfortunate and weaker candidates felt obliged to include the distance in their explanation. Of course this did make it clear to examiners that such candidates had very insecure knowledge of this topic. Most answers were unconvincing and highlighted the lack of understanding of this principle.

(ii) A minority of candidates used Pythagoras's theorem to show that the path difference was half a wavelength leading to destructive interference. Weaker candidates tried to argue the case without performing any calculation.

11a. *[3 marks]*

Markscheme

(i) 32 (mm);

(ii) period = 160 (ms);

frequency = 6.2/6.3 (Hz);

Allow ECF for incorrect period.

Examiners report

(i) Nearly all candidates correctly stated the amplitude as being 32 mm.

(ii) Most were able to measure the period and many then went on to calculate the frequency with the occasional hiccup with conversion of ms into kHz etc.

11b. *[4 marks]*

Markscheme

(i) $\omega=2\pi\times6.25$;
$v(=39.3\times32\times10^{-3})=1.3(ms^{-1})$; *(allow ECF from (a))*

or

tangent drawn to graph at a point of zero displacement;

gradient calculated between 1.2 and 1.4;

(ii) displacement = 23–26 (mm);

35–40 (ms^{-2});

23 mm found by calculating displacement

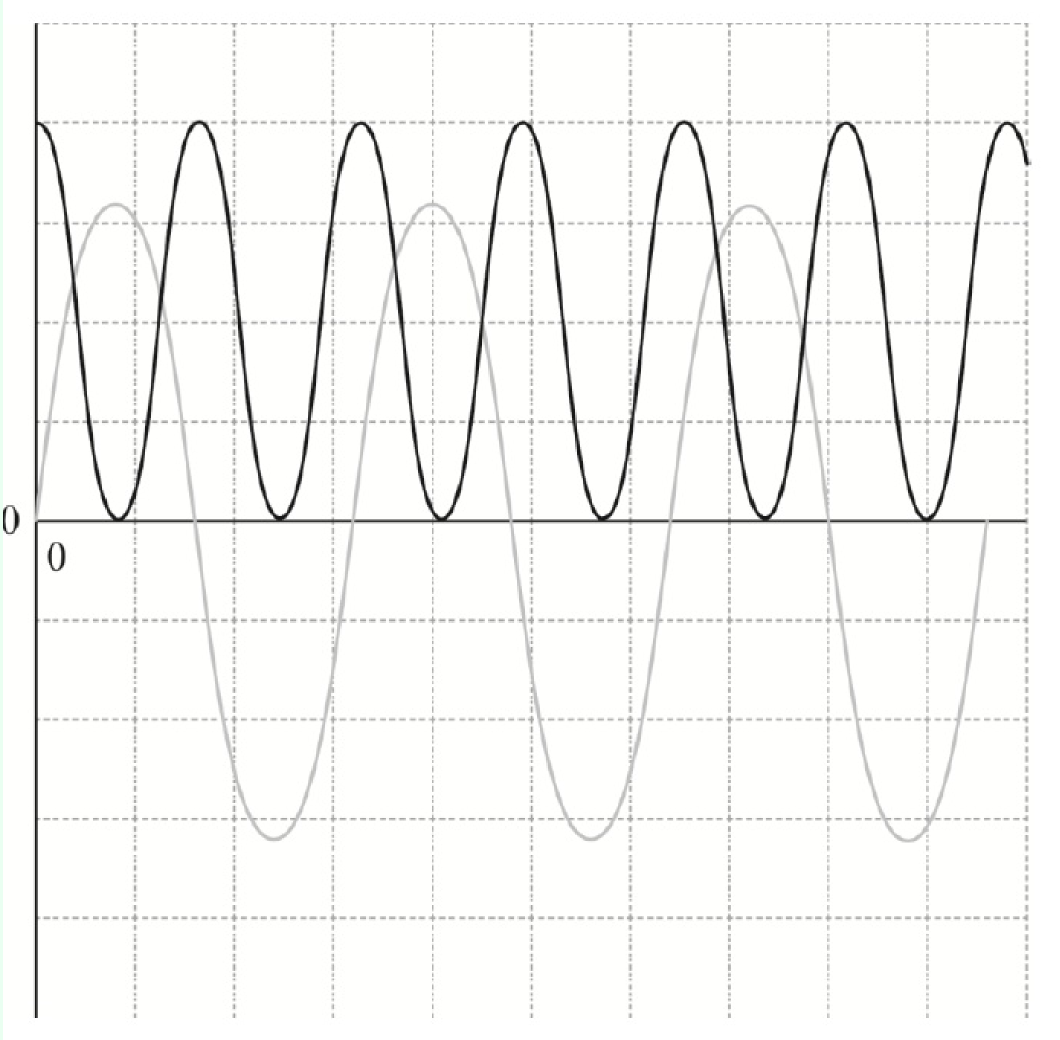
Examiners report

(i) A large proportion of candidates correctly determined the maximum speed of the object by correctly calculating the angular speed and multiplying it by the amplitude. Full marks were awarded to those calculating the gradient of the tangent to the displacement-time graph at zero displacement.

(ii) In the simplest route to the answer candidates were usually successful in measuring the displacement at 140 ms and then using the defining equation for SHM to calculate the acceleration. Other routes were allowed as alternatives but success was infrequent.

11c. *[3 marks]*

Markscheme



double frequency;

always positive and constant amplitude;

correct phase *ie* cosine squared;

Ignore amplitude value.

*A minimum of one complete, original oscillation needed to award **[3].***

Examiners report

Given the relative difficulty of transposing the displacement into a velocity and then squaring it to find the shape of the kinetic energy function, this part was done very well. Most candidates recognised that the energy was always positive, of twice the frequency of the displacement graph and took a cosine squared shape. Sketches were of variable quality but often better than others on the paper.

12. *[1 mark]*

Markscheme

D

Examiners report

This was indeed an unusual question, although perfectly fair as a test of 4.5.1. Most candidates did not realize that a wave, in reflecting off the boundary of a less dense medium, will not undergo any phase change. Hence the pulse will not be inverted – the opposite of what happens if the reflection is off a denser medium.

13.

[1 mark]

Markscheme

C

Examiners report

14.

[1 mark]

Markscheme

B

Examiners report

The majority of candidates answered this question correctly. Candidates are expected to recall the orders of magnitude of the wavelengths of the principal radiations in the electromagnetic spectrum, as stipulated by the Guide. It can be argued that a more distinct wavelength could have been chosen so as to avoid possible confusion with the area between “soft” X-rays and UV but the statistics of the question do not indicate that candidates were upset by this choice.

15.

[1 mark]

Markscheme

A

Examiners report

[N/A]

16.

[1 mark]

Markscheme

B

Examiners report

This question concerned itself with phase difference in a standing wave. It appears not to be well known that particles within any one loop are in phase with each other and that two particles in *adjacent* loops differ in phase by 180°.

17.

[1 mark]

Markscheme

B

Examiners report

The majority of the candidates got the answer to this question but an almost equal number thought that the refractive index was given by the ratio of sines in option C. This shows clearly that candidates thought they were dealing with Snell's law and not Brewster's law.

18.

[1 mark]

Markscheme

A

Examiners report

19a.

[2 marks]

Markscheme

wave travels down string and is reflected / *OWTTE;*

incident and reflected waves interfere/add/superpose to give a standing wave;

Examiners report

(a) and (b) were well done in general, though many forgot to multiply the length by 2 to obtain the wavelength in (b).

19b.

[2 marks]

Markscheme

$\lambda = 2L = 1.28$ (m);

$v = \lambda f = 420$ (ms^{-1});

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

Examiners report

(a) and (b) were well done in general, though many forgot to multiply the length by 2 to obtain the wavelength in (b).

20a.

[2 marks]

Markscheme

the acceleration of piston/P is proportional to its displacement from equilibrium;
and directed towards equilibrium;
*There must be a clear indication what is accelerating otherwise award **[1 max]**.*

Examiners report

Candidates were asked to define SHM as applied to the situation in the question. Many failed to do this and wrote in general terms about SHM.

20b. *[7 marks]*

Markscheme

(i) 12(cm); (*accept* –12)

(ii) any maximum or minimum of the graph;

(iii) period= 0.04 (s); *(allow clear substitution of this value)*
$\omega = \left(\frac{2\pi}{T} =\right) \frac{2\times3.14}{0.04} = 157\left(\text{rads}^{-1}\right)$

maximum acceleration=($A\omega^2$=)0.12×157^2=3.0×10^3(ms^{-2}); *(watch for ECF from wrong period)*

(iv) at t=0.052sx=(-)4(±1)cm;
$\text{KE} = \left(\frac{1}{2}m\omega^2\left[A^2 - x^2\right] =\right) 0.5\times0.32\times157^2\left[0.12^2 - 0.04^2\right] = 50\,(\pm7)\,(\text{J});$

Watch for incorrect use of cm.
Allow ECF from calculations in (b)(iii).
Do not retrospectively credit a mark for ω to (b)(iii) if it was not gained there on original marking.
Allow use of sin ωt to obtain v.
Award ***[2]*** *for a bald correct answer.*

Examiners report

(i) This was well done.

(ii) Almost all candidates were able to identify a correct point for the maximum acceleration.

(iii) and (iv) Solutions for these were confused. Some attempted to use kinematic equations. Others mixed metres and centimetres in their answers. Other algebraic errors were present too (e.g. confusing 12^2 – 4^2 for $(12 - 4)^2$). This is an area that candidates could practice more.

20c. *[4 marks]*

Markscheme

(i) the direction of the oscillations/vibrations/movements of the particles (in the medium/gas);

for a longitudinal wave are parallel to the direction of the propagation of the energy of the wave;

(ii) $f = \left(\frac{1}{T} =\right) \frac{1}{0.04} = 25\,(\text{Hz});$
$\lambda = \left(\frac{v}{f} =\right) \frac{340}{25} = 14\,(\text{m});$

Award ***[1 max]*** *if frequency is not clearly stated.*
Allow ECF from calculations in (b)(iii).

Examiners report

(i) There were three marks for this question: for distinctions between longitudinal and transverse and for a clear description of the point of comparison. The latter was the mark most frequently lost. Many candidates have the vague idea that something about transverse is perpendicular and that the same parameter is parallel for longitudinal, but what “that something” is was frequently confused.

(ii) Candidates are now taking more care over the clear declaration of the frequency leading to the wavelength.

21. *[1 mark]*

Markscheme

A

Examiners report

Around the same number of candidates opted for A, B and C. The better candidates clearly favored the correct response, A. A quick and simple sketch reveals the answer immediately – this should be the candidates’ natural reaction given a resonance problem of this nature.

22.

[1 mark]

Markscheme

A

Examiners report

This was another question that elicited a number of critical comments from teachers, although the statistics showed two-thirds of the candidates choosing the response A. The amount of light reflected from a glass surface is negligible (and unquantifiable within the parameters of the question), so clearly A was the best response.

23a.

[3 marks]

Markscheme

ray: direction of wave travel / energy propagation;
wavefront: line that joins points with same phase/of same crest/trough;
ray normal/at right angles/perpendicular to wavefront;

Examiners report

[N/A]

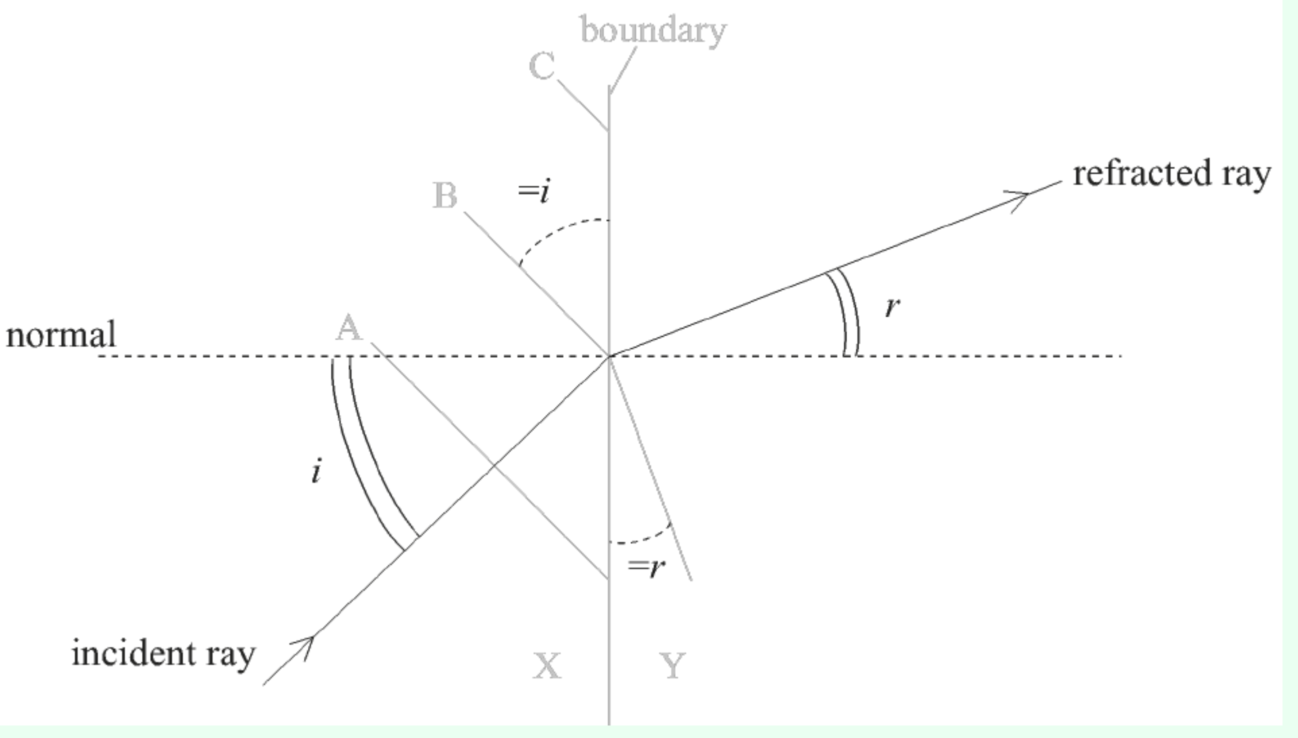
23b. *[4 marks]*

Markscheme

(i) line parallel to existing line in Y and continuous at boundary; *(both needed)*

(ii) measures “wavelength” correctly in media X and Y; } *(by eye)*
(look for ratio of 0.5: 1 in responses)
$\frac{n_X}{n_Y} = \frac{\lambda_Y}{\lambda_X}$;
0.5:1; *(accept answers in the range of 0.47 to 0.53)*

or



justification that angles needed for calculation are either pair of *i* and *r* as shown and angles measured correctly;
$\frac{n_X}{n_Y} = \frac{\sin r}{\sin i}$;
0.5:1;

Examiners report

[N/A]

23c. *[2 marks]*

Markscheme

mention of perpendicular/right angle/90° angle for transverse and parallel for longitudinal;
clear comparison between direction of energy propagation and direction of vibration/oscillation of particles for both waves;

Examiners report

[N/A]

23d. *[3 marks]*

Markscheme

(i) time period=6.0ms;
167Hz;

(ii) M where line crosses *x*-axis;

(iii) counts rectangles (14±2) to first peak;
one rectangle equivalent to 0.5 mm;
7.2 mm;

or

$\omega = (2\pi f =) \, 330\pi$;
$a = \left(\frac{v}{w} =\right) \frac{7.5}{330\pi}$;
7.2 mm;
Allow any valid algebraic method, eg $v = \omega\sqrt{({x_0}^2 - x^2)}$.

Examiners report

[N/A]

24. *[1 mark]*

Markscheme

the electric field vector oscillates in one plane/direction only;

Examiners report

[N/A]

25. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

26. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

27. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

28.

[1 mark]

Markscheme

C

Examiners report

[N/A]

29.

[1 mark]

Markscheme

C

Examiners report

B was a popular distractor indicating that some candidates thought that being „in phase‟ represented a phase difference of π rather than 2π.

30.

[1 mark]

Markscheme

D

Examiners report

[N/A]

31.

[1 mark]

Markscheme

D

Examiners report

[N/A]

32.

[1 mark]

Markscheme

D

Examiners report

It is reasonable to expect higher level physics candidates to know the value of cos30°, and if they do not, they can always sketch the relevant triangle. The evidence from the statistics, though, would suggest that the majority of candidates either omitted to factor in the effect of the light passing through the first polarizer, or that they thought the intensity was reduced by the factor cos60º (rather than $\cos^2 60º$) on passing through the second polarizer.

33a. *[8 marks]*

Markscheme

(i) the acceleration of (force acting on) W is proportional to its displacement from equilibrium;
and directed towards equilibrium;

(ii) F=(18×0.04=) 0.72N;
acceleration=$\frac{0.72}{0.15}$=4.8 ms^{-2};

(iii) $\omega = \sqrt{\frac{a}{x}}$;
=10.95rads^{-2};
$T = \left(\frac{2\pi}{\omega} =\right) \frac{6.28}{10.95} = 0.57\text{s}$;

(iv) =1.4×10^{-2}(J);

Examiners report

There were a few G2 comments suggesting that this question was off-syllabus as it involved (the G2s claimed) the use of Hooke"s law. In fact, k was defined as force per unit extension rather than as the spring constant and the whole question was accessible through knowledge based purely on SHM theory.

(i) Many realized that for two marks they were required to state the relationship between acceleration and displacement and give the direction of acceleration.

(ii) and (iii) The determination of the maximum acceleration and the period of oscillation were well done by many at HL. A number of routes were possible for part (iii) and all gained equal credit. Answers were patchier from SL candidates who struggled more than the HL with these tasks.

(iv) **SL only** Performance was again patchy. Some of the candidates at SL do not seem at ease with the ideas and equations that lie behind SHM theory.

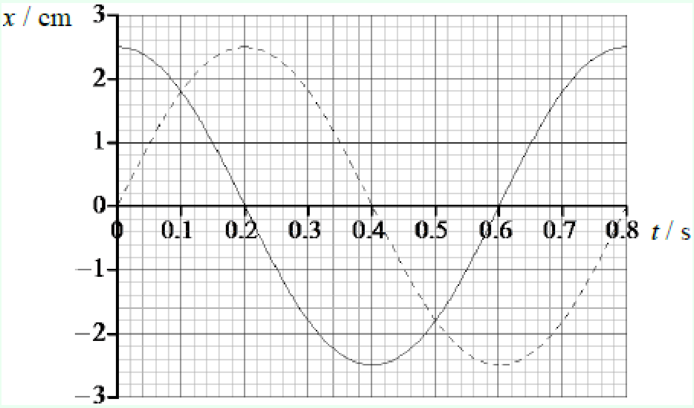
33b. *[6 marks]*

Markscheme

(i) the direction of oscillation of the particles of the medium;
(*must see "particles"*)
is in the direction of energy propagation;
Accept answer in terms of coils of spring in place of particles of medium.

(ii) frequency=$\left(\frac{1}{T} = \frac{1}{0.80} =\right) 1.25\text{Hz}$;
wavelength=$\frac{v}{f} = \frac{3.0}{1.25} = 2.4\text{cm}$ ***or*** 2.4×10^{-2}m;

(iii)



graph: positive cosine; *(line must cross axis at 0.2 and 0.6 as shown)*
explanation: 1.8 cm is ¾ of a wavelength;

Examiners report

(i) Examiners were disappointed to see that candidates could only rarely give a complete description of a longitudinal travelling wave. Descriptions were vague and rarely made the relative directions of energy propagation and particle displacement clear in an unambiguous way.

(ii) Although many obtained the correct answer, the method used was often unexplained with no obvious link to the graph via a statement of frequency or period. Such non-clarity was penalized.

(iii) Most candidates were unable to make progress with this question and it was frequently left blank. The problem required a recognition that a distance of 1.8 cm corresponded to a ¾λ shift and hence a corresponding shift on the graph.

34a.

[2 marks]

Markscheme

the force/acceleration is proportional to the displacement from the equilibrium position/centre;
the force/acceleration is directed towards the equilibrium position/centre / the force/acceleration is in the opposite direction to the displacement;

Examiners report

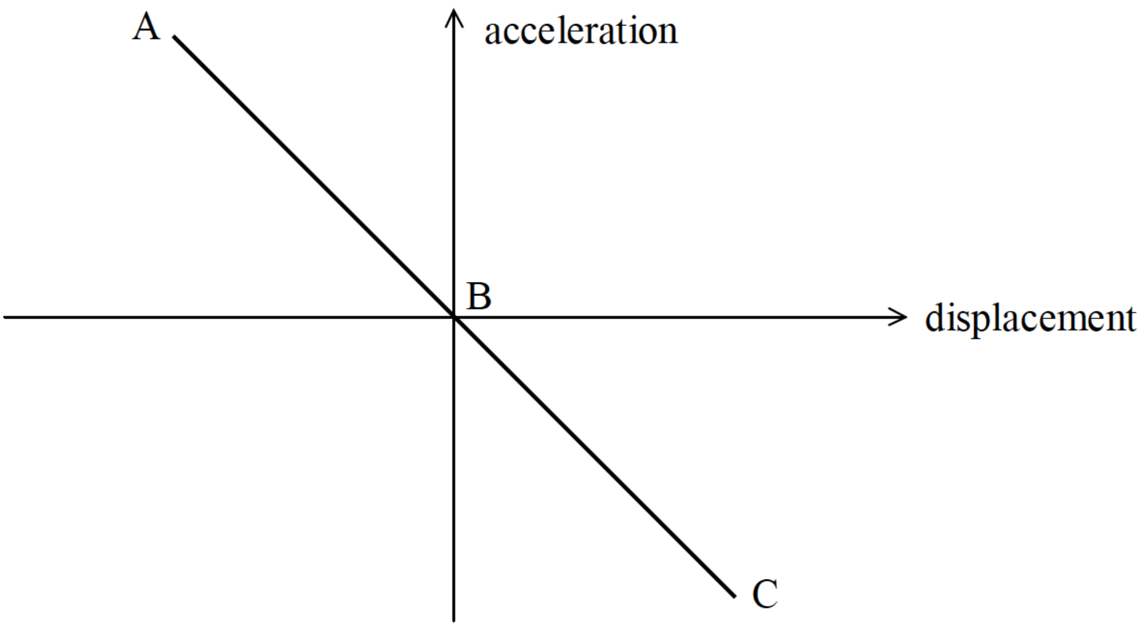
[N/A]

34b.

[3 marks]

Markscheme

(i) straight line through the origin;
with negative gradient;



(ii) all three labels correct;

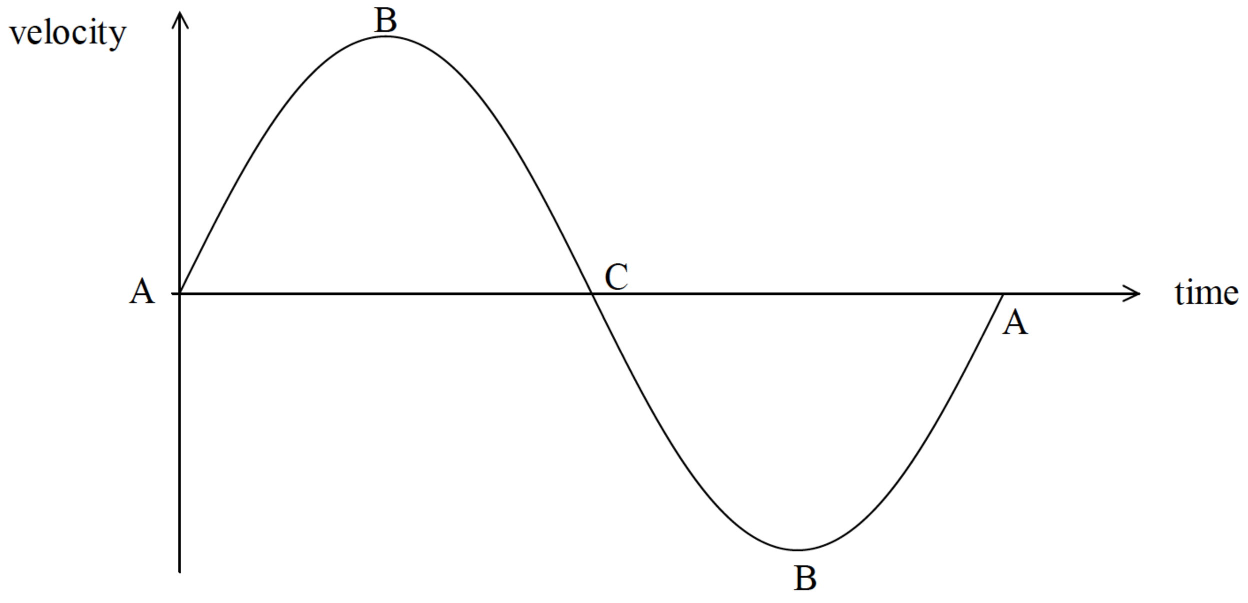
Examiners report

[N/A]

34c. *[3 marks]*

Markscheme

(i) positive sine graph;
drawn correctly for one period;



(ii) all three labels correct;
Accept either of the As and either of the Bs.
Accept either B if shown on the time axis in the correct position.

Examiners report

[N/A]

34d. *[3 marks]*

Markscheme

$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.20} = 31.42 \approx 31\text{rads}^{-1}$;
$v_{\text{max}} = \omega x_0 = 31.42 \times 0.040$;
$v_{\text{max}} = 1.257 \approx 1.3\text{ms}^{-1}$;

Examiners report

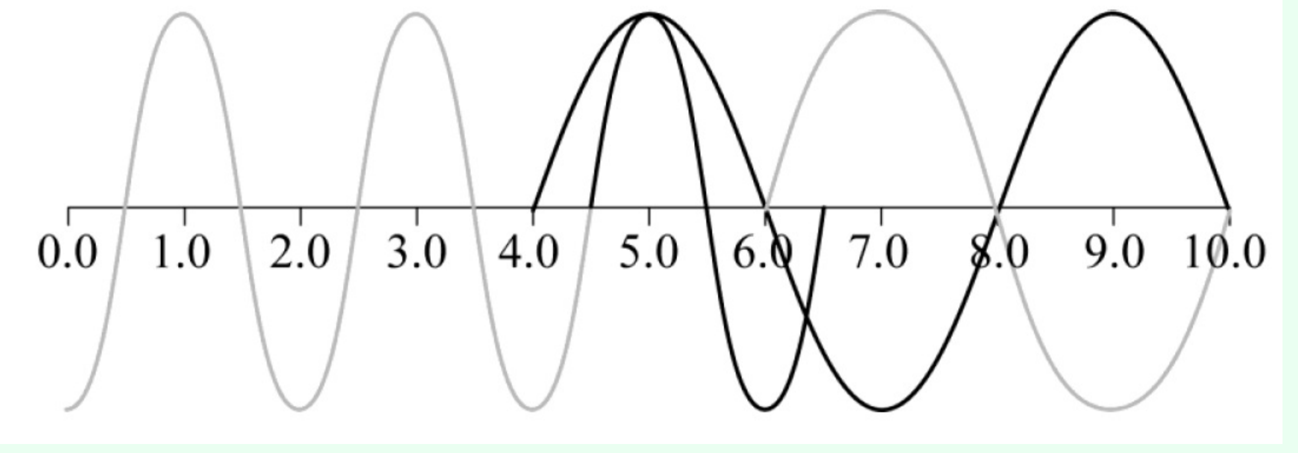
[N/A]

34e. *[4 marks]*

Markscheme

(i) if two or more waves overlap/meet/pass through the same point;
the resultant displacement at any point is found by adding the displacements produced by each individual wave;

(ii) 0.20 s later, wave X will have crests at 5.0, 3.0 and 1.0 m, wave Y will have crests at 5.0 and 9.0 m / each wave will have moved forward by 2.0 m in 0.20 s / wave profiles for 0.20 s later drawn on diagram;



maximum displacement where two crests meet, *i.e.* at 5.0 m;

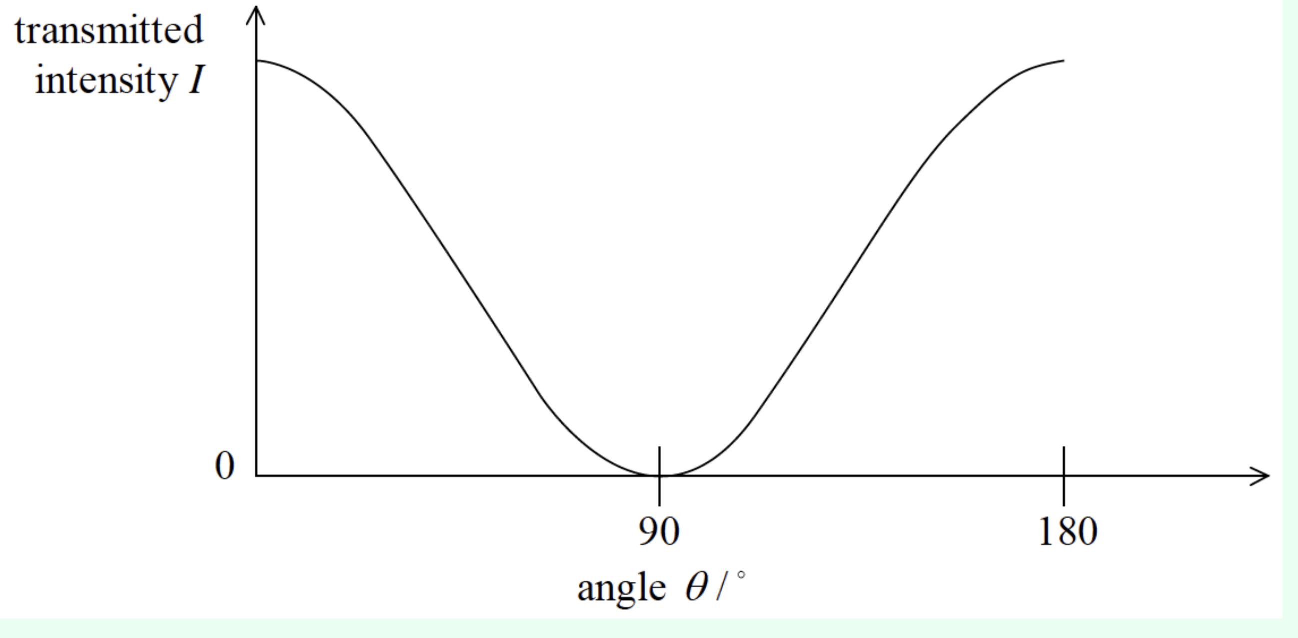
Examiners report

[N/A]

35. *[2 marks]*

Markscheme

general $\cos^2$ shape;
zero intensity at 90° and maximum at both 0° and 180°;



Examiners report

[N/A]

36a.

[3 marks]

Markscheme

at certain fixed frequencies;
incident wave and reflected wave;
superpose (or interfere);

Examiners report

[N/A]

36b.

[5 marks]

Markscheme

(i) antinode clearly labelled in centre;

(ii) wavelength=1.7 m;
speed=1.2×10^{2} ms^{-1};

(iii)

(iv) 1.2×10^{2} ms^{-1};

Examiners report

[N/A]

37a.

[2 marks]

Markscheme

(i) downward arrow at P;

(ii) clear single wavelength marked;

Examiners report

[N/A]

37b. [2 marks]

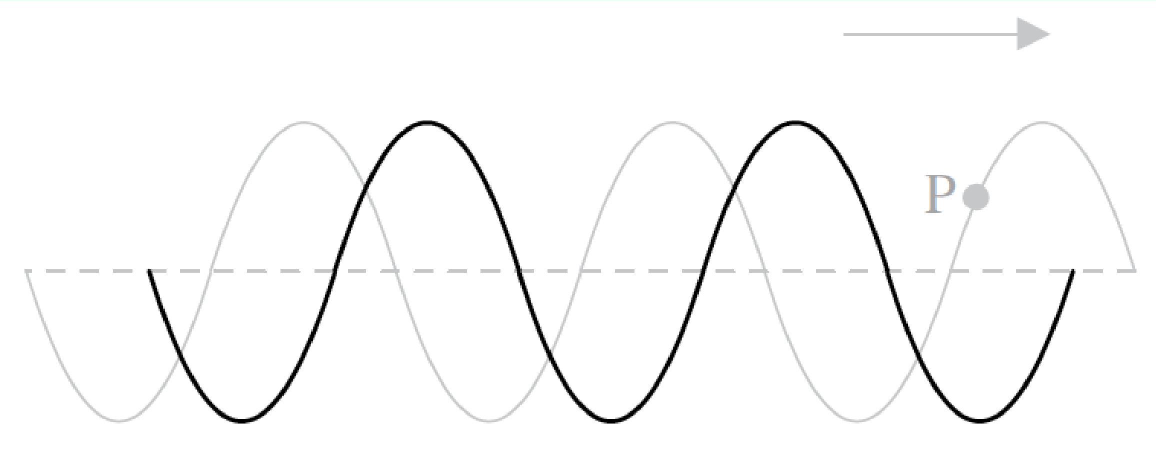
Markscheme

(i) frequency=$\frac{18}{25}$(Hz)=0.72(Hz);

period=$\left(\frac{1}{0.72}=\right)$ 1.4s;

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

(ii) wave moved to right by one-third of a cycle by eye;



Examiners report

[N/A]

37c. [5 marks]

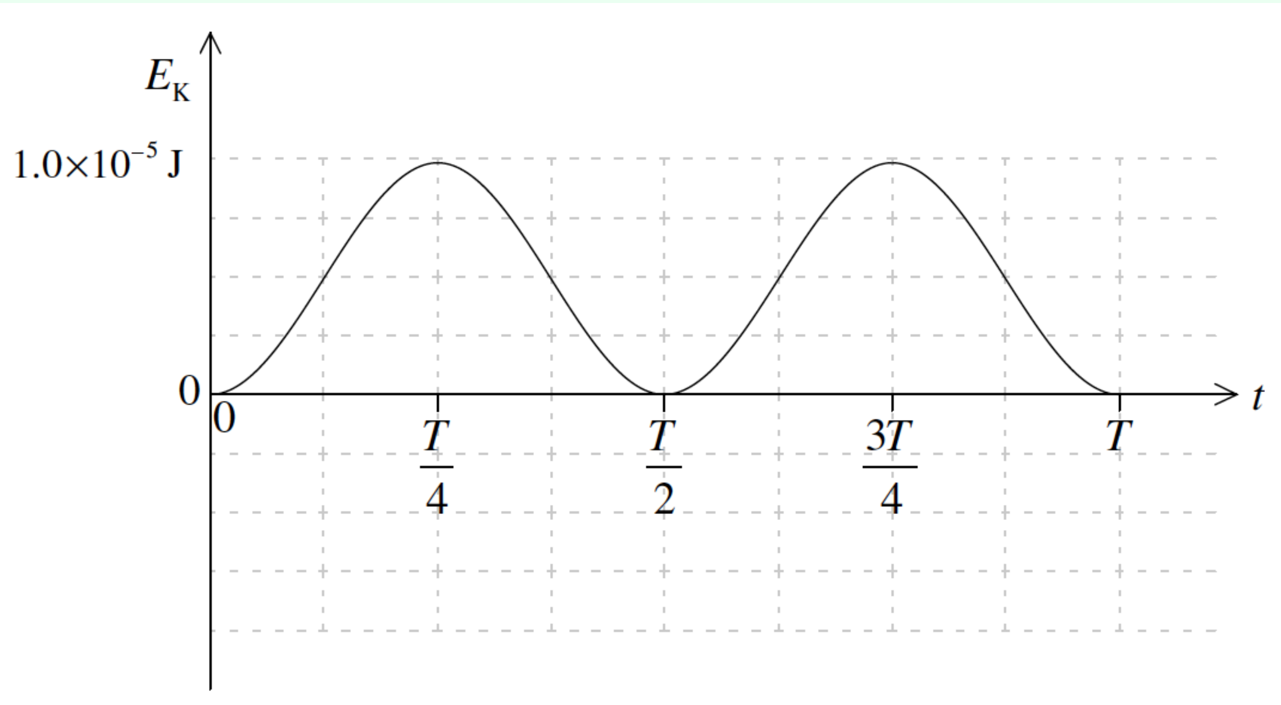
Markscheme

(i) $\omega = \frac{2\pi}{1.4}$;

$\left(\frac{1}{2} \times 3.5 \times 10^{-3} \times \left[\frac{4\pi^2}{1.4^2}\right] \times \left[1.7 \times 10^{-2}\right]^2\right) = 1.0 \times 10^{-5}\text{J}$;

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

(ii)



correct shape ($\sin^2$) ; *(allow any phase for this graph)*

varying between 0 and 1.0×10^{-5}J; { *(allow ECF from (c)(i) but do not allow E to be negative)*

one period takes $\frac{T}{2}$;

Examiners report

[N/A]

37d. *[5 marks]*

Markscheme

(i) reduced wavelength;
reduced amplitude;

(ii) speed reduced and frequency constant;
therefore wavelength reduced;
some energy reflected at boundary / second string is denser/greater mass per unit length;
therefore amplitude reduced;

Examiners report

[N/A]

38a. *[3 marks]*

Markscheme

effect caused by gas such as H_2O/NH_3/CH_4/CO_2/greenhouse gas in the atmosphere;
gas absorbs outgoing (long wave) radiation from Earth;
gas re-radiates some of the energy back to Earth;

Examiners report

[N/A]

38b. *[9 marks]*

Markscheme

(i) $\frac{3.0\times10^{8}}{6.5\times10^{13}} = 4.6\,(\mu m)$;
≈5(μm)

(ii) water vapour molecules have a natural frequency of oscillation;
if this frequency of oscillation is 6.5×10^{13} / reference to frequency at X;
due to resonance this radiation is readily absorbed by the molecules / the radiation matches the natural frequency of oscillation;

or

X is a natural frequency (of oscillation) of water molecule;
so resonance effects mean that molecules are excited at this frequency;
and energy is removed/less energy transmitted from electromagnetic waves at this (particular) frequency;

(iii) energy gained by absorption needs to be re-emitted (as molecules de-excite);
in other directions / some returns to Earth;

(iv) more greenhouse gases means that there is more absorption of outgoing radiation;
therefore more energy returns to Earth;
leading to a further/greater increase in the temperature of the surface (of Earth);

Examiners report

[N/A]

39a.

[1 mark]

Markscheme

standing waves do not transfer energy;
standing waves do not have a constant amplitude;
points on a standing wave between consecutive nodes have a constant phase;
standing waves have permanent nodes/antinodes;

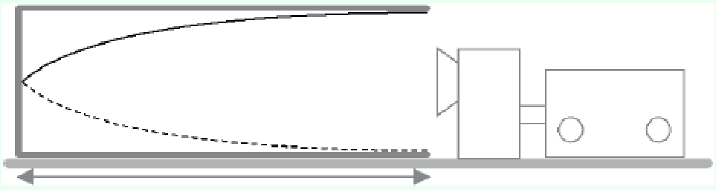
Examiners report

39b.

[3 marks]

Markscheme

(i) correct diagram as shown; *(dotted line not essential for the mark)*



(ii) wavelength of sound is (4×0.910)=3.64m;
speed of sound 3.64×92=335ms^{-1};

Examiners report

39c.

[2 marks]

Markscheme

the next harmonic has wavelength $\frac{4\times0.910}{3}=\frac{3.64}{3}\text{m}$;
and so frequency 3×92=276Hz ;

Examiners report

40a.

[1 mark]

Markscheme

light in which the electric field oscillates in the same plane;

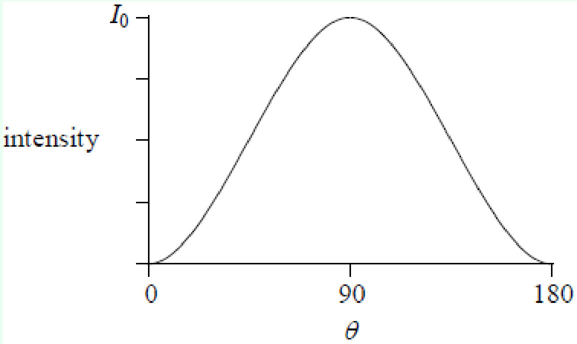
Examiners report

40b.

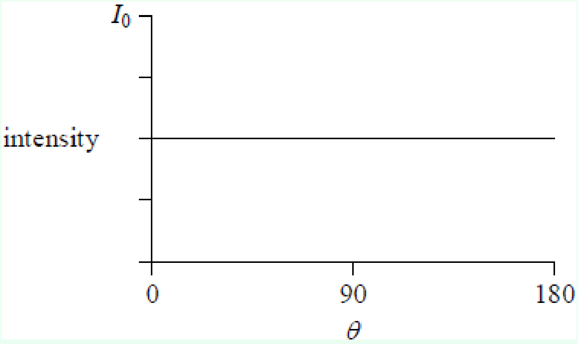
[4 marks]

Markscheme

(i) zero at 0 and 180 degrees;
peak at 90 degrees;



(ii) horizontal straight-line;
through half the incident intensity;

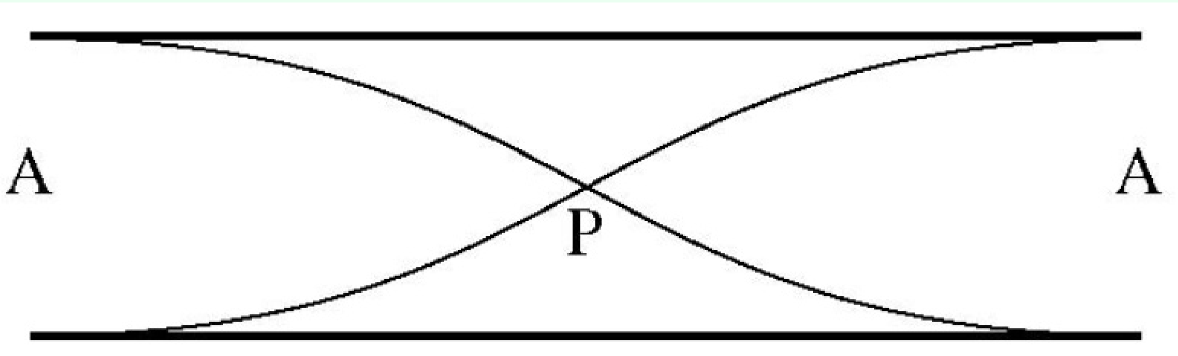


Examiners report

41a.

[3 marks]

Markscheme



(i) waveform showing node at centre and antinodes at end;

(ii) P as shown;

(iii) A as shown;

Examiners report

[N/A]

41b. *[3 marks]*

Markscheme

for open pipe $f = \frac{v}{2l}\left(= \frac{v}{3.0}\right)$;
for closed pipe $f = \frac{v}{4l} = \frac{v}{3.0}$;
so *l* = 0.75m

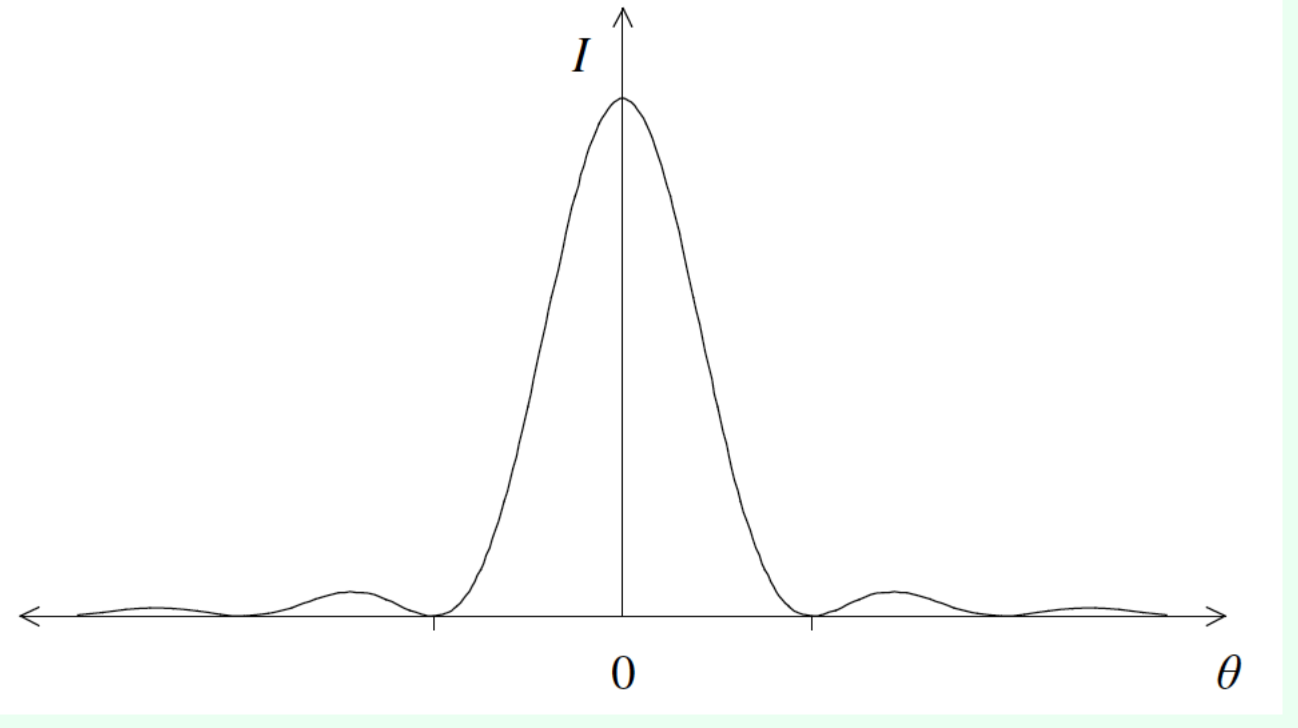
Examiners report

[N/A]

42a. *[5 marks]*

Markscheme

(i)



overall correct shape with central maxima at *θ*=0; { *(only one secondary maximum required each side of θ=0)*
secondary maximum no greater than ¼ intensity of central maximum; { *(judge by eye)*

(ii) $\theta = \frac{\lambda}{b} = \frac{x}{D}$ (where *x* is the half width of central maximum);
$2x = 2\frac{D\lambda}{b}$;
$\left(\frac{2\times1.2\times4.8\times10^{-7}}{10^{-4}}\right) = 12\text{mm};$

Examiners report

[N/A]

42b. *[3 marks]*

Markscheme

diameter of pupil =3.0 mm; *(accept answers in the range of 2.0 mm to 5.0 mm)*
$\theta = \left(1.22 \times \frac{\lambda}{b} = 1.22 \times \frac{4.8\times10^{-7}}{3.0\times10^{-3}} =\right) 1.95 \times 10^{-4}\ (\text{rad});$
$d = \frac{8.0\times10^{-3}}{1.95\times10^{-4}} = 41\text{m};$ *(accept answer in the range of 20m to 70m)*

Examiners report

[N/A]

42c.

[3 marks]

Markscheme

in unpolarized light the plane of vibration of the electric (field) vector is continually changing / *OWTTE*;
in polarized light the electric vector vibrates in one plane only;
a polarizer is made of material that absorbs/transmits either the horizontal or vertical component/only one component of the electric vector;

Examiners report

[N/A]

43.

[2 marks]

Markscheme

a varying magnetic and electric field at right angles to each other;
vibration of *E* and *B* fields at right angles to the direction of propagation of the wave;
transverse wave;
same speed in a vacuum;

Examiners report

[N/A]

44a.

[2 marks]

Markscheme

oscillating/vibrating electric and magnetic fields;
at right angles to each other;
at right angles to the direction of propagation/energy transfer of the wave/ velocity/transverse;
can travel through vacuum;
*Award **[2]** for a clearly drawn, correctly labelled diagram i.e. E and B fields at right angles to each other and at right angles to the direction of propagation.*

Examiners report

44b.

[2 marks]

Markscheme

electrons that oscillate/accelerate/move on curved paths;
electrons making transitions between energy levels;
Accept two specific instances of electrons being accelerated/decelerated e.g. electrons hitting metal target or electrons moving in magnetic fields.

Examiners report

45. *[1 mark]*

Markscheme

C

Examiners report

46. *[1 mark]*

Markscheme

D

Examiners report

47a. *[1 mark]*

Markscheme

the maximum displacement of the system from equilibrium/from centre of motion / *OWTTE*;

Examiners report

47b. *[5 marks]*

Markscheme

(i) the amplitude of the oscillations/(total) energy decreases (with time); because a force always opposes direction of motion/there is a resistive force/ there is a friction force;
Do not allow bald "friction".

(ii) $\omega = \sqrt{\frac{2g}{l}}$;
$T = 2\pi\sqrt{\frac{0.32}{2\times 9.81}}$;
=0.80s;

Examiners report

47c. *[9 marks]*

Markscheme

(i) upwards;

(ii) y_0 = 0.050(m) and y = 0.030(m);
$\omega = \left(\frac{2\pi}{0.80} =\right) 7.85 \left(\text{rads}^{-1}\right)$;
$v = 7.85\sqrt{[0.05]^2 - [0.03]^2}$;
=0.31ms^{-1} ; (*allow working in cm to give 31 cms^{-1}*);

(iii) λ=4.0m;
recognition that $f = \frac{1}{0.80}(= 1.25)$;
($f\lambda$=)v=1.25×4.0;
(=5.0 ms^{-1})

(iv) y=-3.0 cm, d=0.6 m;

Examiners report

48a. *[7 marks]*

Markscheme

(i) the amplitude of the oscillations/(total) energy decreases (with time); because a force always opposes direction of motion/there is a resistive force/ there is a friction force;
Do not allow bald "friction".

(ii) the displacement and acceleration/force acting on (the surface); are in opposite directions;

(iii)
$\omega = \sqrt{\frac{2g}{l}}$;
$T = 2\pi\sqrt{\frac{0.32}{2\times 9.81}}$;
=0.80s;

Examiners report

Candidates had some uncertainty in discussing the negative sign in the SHM equation for the U-tube example. They were unclear about the terms in the equation and the relative direction of the vector quantities concerned.

48b. *[6 marks]*

Markscheme

(i) wave reflects at ends (of string);
interference/superposition occurs (between waves);
regions of maximum displacement/zero displacement form (that do not move);
one region of max displacement/antinode forms at centre with zero displacement/node at each end; {*(allow these marking points from clear diagram)*

(ii) the waves (in a string) are transverse and vibrate only in one plane;
light waves are transverse electromagnetic waves;
(and) for polarized light the electric field vector vibrates only in one plane;

Examiners report

(i) Although there were many suggestions that the wave is reflected at one end of the string and that this interferes in some way with the incident wave to produce the standing wave these were generally weak and incomplete. Some candidates focussed entirely on the shape of the standing wave (not really the question). It was rare to see 3 marks awarded; 2 was more common.

(ii) Candidates were vague as to the nature of polarized light (a clear description in terms of the field vectors was required), as to the description of the travelling wave on the string, and as to the way in which it could be used. Many will have seen the demonstration in the laboratory but could not describe it with clarity.

49a.

[3 marks]

Markscheme

(i) $L=4\lambda$ or $\lambda = \frac{L}{4}$;

(ii) two antinodes labelled;
with separation of integral number of wavelengths;

Examiners report

[N/A]

49b.

[3 marks]

Markscheme

$f\lambda$ is the speed of the wave;
standing wave formed by interference of an incident and a reflected progressive wave;
speed is the speed of this progressive wave;

Examiners report

[N/A]

50a.

[2 marks]

Markscheme

transverse;
can be polarized;
all have same speed in a vacuum;

Examiners report

[N/A]

50b.

[3 marks]

Markscheme

each colour/wavelength has different refractive index;
different focal lengths/amount of diffraction for each wavelength/colour;
so all coloured images do not overlap completely/not at same place;

Examiners report

[N/A]

51a. *[1 mark]*

Markscheme

constant phase difference;

Examiners report

[N/A]

51b. *[1 mark]*

Markscheme

path difference between beams$=n\lambda$, where n is an integer/is one wavelength;

Examiners report

[N/A]

51c. *[2 marks]*

Markscheme

(i) wavelength decreases;
(ii) (effective/optical) path/phase difference changes;

Examiners report

[N/A]

52. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

53. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

54. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

55. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

56. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

57. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

58a. *[6 marks]*

Markscheme

(i) the amplitude is constant;

(ii) period is 0.20s;

$a_{\text{max}} = \left(\left[\frac{2\pi}{T}\right]^2 x_0 = 31.4^2 \times 2.0 \times 10^{-2}\right) = 19.7 \approx 20\text{ms}^{-2}$

*Award **[2]** for correct bald answer and ignore any negative signs in answer.*

(iii) displacement at t = 0.12cm is (−)1.62cm;

$v\left(= \frac{2\pi}{T}\sqrt{x_0 - x^2}\right) = 31.4\sqrt{\left(2.0 \times 10^{-2}\right)^2 - \left(1.62 \times 10^{-2}\right)^2} = 0.37\text{ms}^{-1};$

Accept displacement in range 1.60 to 1.70 cm for an answer in range 0.33ms^{-1} to 0.38ms^{-1}.

or

$v_0 = \frac{2\pi}{T}x_0 = 0.628\text{ms}^{-1};$

$|v| = \left(\left|-v_0 \sin\left[\frac{2\pi}{T}t\right]\right| \Rightarrow |v| = |-0.628\sin[31.4 \times 0.12]| = |0.37|\right) = 0.37\text{ms}^{-1};$

or

drawing a tangent at 0.12s;
measurement of slope of tangent;
Accept answer in range 0.33ms^{-1} to 0.38ms^{-1} .

Examiners report

[N/A]

58b.

[4 marks]

Markscheme

(i) use of $f = \frac{1}{T}$;
and so $f \left(= \frac{1}{0.20}\right) = 5.0\text{Hz}$;

(ii) wavelength is 16cm;
and so speed is $v(=f\lambda=5.0\times0.16)=0.80\text{ms}^{-1}$;

Examiners report

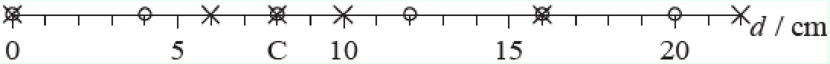
[N/A]

58c.

[4 marks]

Markscheme

(i) points at 0, 8 and 16 cm stay in the same place;
points at 4 and 20 cm move 2 cm to the right;
point at 12 cm moves 2 cm to the left;



(ii) the point at 8 cm;

Examiners report

[N/A]

59a.

[1 mark]

Markscheme

light for which the electric field is oscillating in (only) one plane;

Examiners report

[N/A]

59b.

[2 marks]

Markscheme

at a particular angle of incidence the reflected light is horizontally polarized;
and will be blocked by an analyser/polarizer with a vertical transmission axis;

or

at a particular angle of incidence when the reflected and refracted rays are at right angles the reflected light/rays will be horizontally polarized;
and will be blocked by an analyser/polarizer with a vertical transmission axis;

Examiners report

[N/A]

59c.

[4 marks]

Markscheme

(i) mention of superposition/interference;
interference is destructive and so there will be no light at P;
*Award **[0]** for correct answer with no or wrong argument.*

(ii) there will be light at P;
the two sources cannot interfere because their planes of polarization are at right angles;
*Award **[0]** for correct answer with no or wrong argument. Award **[0]** if answer mentions no light at P irrespective of anything else said.*

Examiners report

[N/A]

60a.

[2 marks]

Markscheme

energy is propagated by travelling waves / energy is not propagated by standing waves;
amplitude constant for travelling waves / amplitude varies with position for standing waves;
phase varies with position for travelling waves / phase constant for standing waves;
travelling waves do not have nodes and antinodes / standing waves do have nodes and antinodes;
travelling waves can have any wavelength/frequency / standing waves can only have certain wavelengths/frequencies (to fit boundary conditions);

Examiners report

[N/A]

60b.

[3 marks]

Markscheme

(i) wave from tuning fork travels down tube and is reflected;
incident and reflected waves interfere/superpose/combine/add together to give a standing wave (that fits the boundary conditions);

(ii) the surface of the water (in/at the bottom of the tube);

Examiners report

[N/A]

60c.

[2 marks]

Markscheme

$\frac{\lambda}{2} = 0.368 \Rightarrow \lambda = 0.736\text{m}$;
$v=f\lambda=440\times0.736=320\text{ms}^{-1}$;

Examiners report

[N/A]

61.

[1 mark]

Markscheme

any value within the range 320 − 780 nm;

Examiners report

[N/A]