PAPER 1

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
B	C	C	D	C	C	C	C	A	C
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C	A	C	C	C	D	C	A	D	A

PAPER 2

1 **(a)** $u_x = 10.8 \cos(40.0°)$

$= 8.27 \text{ m s}^{-1}$

Almost all candidates got this question correct.

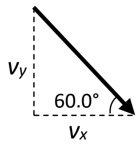
(b) Horizontal component of the velocity remains constant, hence

$u_x = v_x$

$v_y = v_x \tan(60.0°)$

$= 8.27 \tan(60.0°)$

$= 14.3 \text{ m s}^{-1}$



Many candidates failed to notice that the question is asking for v_y at **point B**, not point A and gave the answer 10.8 sin(40.0°) instead. By considering that the initial horizontal component of velocity u_x = final horizontal component of velocity v_x. This question could have been solved efficiently. However some candidates used the equations of motion to calculate v_y from u_y.

(c) Initial vertical velocity at point A, $u_y = -10.8 \sin(40.0°) = -6.94 \text{ m s}^{-1}$

Consider the vertical motion,

$v_y = u_y + at$

$14.3 = -6.94 + 9.81t$

$t = 2.17 \text{ s}$

Consider the horizontal motion,

$x = s_x$

$s_x = u_x t$

$= 8.27(2.17)$

$= 17.9 \text{ m}$

A lot of candidates **got the signs wrong in the first step**. The initial velocity is upwards while the final velocity and the acceleration is downwards so they should not all be of the same sign. Getting the signs wrong would result in loss of all the marks as the candidate is unable to use the equations of motion properly right at the start.

Many candidates also separated the motion into 2 parts for analysis, the part where the rock is going up to the highest position and the subsequent part from the highest position to the ground. Note that **this is not required and results in unnecessary steps**. The equations of motion can be used throughout the whole motion even when there is a change in direction of motion *as long as acceleration is constant and all the signs are correct*!

The second step $s_x = u_x t$ is quite straightforward except for some students who used $s_x = ½ (u_x + v_x) t$ without realizing u_x and v_x are the same.

(d) $h = s_y$

$s_y = u_y t + ½ a_y t^2$

$= -6.94(2.17) + ½ (9.81)(2.17)^2$

$= 8.00$ m

OR

$v_y^2 = u_y^2 + 2a_y s_y$

$(14.3)^2 = (-6.94)^2 + 2(9.81)s_y$

$s_y = 8.00$ m

OR

$s_y = ½ (u_y + v_y)t$

$= ½ (-6.94+14.3)(2.17)$

$= 8.00$ m

This question is generally well done except for candidates who got the signs wrong. As there are many methods to solve this question, even when part (c) is not done properly, most were still able to identify and use one of the appropriate equations of motion to solve this.

(e)(i) Consider rock's vertical motion,

$s_y = u_y t + ½ a_y t^2$

$8.00 = 0 + ½ (9.81)t^2$ ($u_y = 0$ as rock is thrown to the right)

$t = 1.28$ s or $t = -1.28$ s (reject)

time after ball is thrown = 2.17 – 1.28

= 0.89 s after first ball is thrown

(1.28 s is time taken for *rock* to reach B from A)

(2.17 s is time taken for *ball* to reach B from A in part (c))

This part is the most poorly done in question 1. A number of students gave up and left this question blank. Again, some students separated the motion into 2 parts for analysis, as in part (c), which is unnecessary. Some students also failed to realize that analysis is needed only in the vertical direction.

Misconception: Some students thought that when the rock is thrown, the ball must have travelled up and down back to the same height as the building (i.e. s_y of ball is 0) and proceeded to calculate the time when this happens. This is a misconception because at this time the ball has some vertical velocity downwards while the rock is thrown horizontally without any vertical velocity. Hence if the rock is thrown at this time, it would reach the ground only after the ball has reached.

A separate mark is awarded for the step 'time after ball is thrown = 2.17 – 1.28 s', even when time calculated in the first part is wrong. However marks are only awarded if the time taken for **ball** to reach B (most calculated this in part (c)) and the time taken for **rock** to reach B are both clearly stated.

(e)(ii) $s_x = u_x t$

$17.9 = u_x (1.28)$ (17.9 m is from part c)

$u_x = 14.0$ ms^{-1}

Generally well done. However some students wrote a value of *t* in part (e)(i) and substituted into the *t* in this part to try and get e.c.f.. However, this is wrong as the answer in (e)(i) is the time that rock is thrown *after* ball is thrown, not time taken for rock to travel from A to B as in this part.

2 **(a)** The Principle of Conservation of Momentum states that the total momentum of a system remains constant provided no net external force acts on the system.

Underlined words are important words yet easily missed by students. Many students wrote 'object' / 'objects'/ '2 bodies' instead of 'system', this is not general enough and not accepted.
Some students wrote 'conserved' instead of 'constant', this is not accepted as the word 'conserve' is already present in the name of this principle and needs paraphrasing.
Many students forgot to write 'net' or 'external' as well.

(b) (i) $\Delta p_B = m_B(v_B - u_B)$
$= 1.2(-0.8 - 4)$
$= -5.76$ kg m s^{-1}
Magnitude = 5.76 kg m s^{-1}
Direction = to the left for correct magnitude *and* direction

A significant number of students read the final velocity of B as -1.0 instead of -0.8, some students missed out the negative sign in the -0.8. A few students divided $m_B(v_B - u_B)$ by the time of collision, but this formula gives the force (rate of change of momentum), not the change in momentum alone.

For direction, 'negative', 'to the left', 'opposite to the direction of initial velocity', 'horizontal and away from ball S' are accepted. Simply writing 'opposite' or 'away from Ball S' are not accepted as it is unclear what the exact direction is.

Some students gave the magnitude as negative, which is wrong.

(b) (ii) By principle of conservation of momentum,
$m_B u_B + m_S u_S = m_B v_B + m_S v_S$
$1.2(4) = 1.2(-0.8) + 3.6 v_S$
$v_S = 1.6$ m s^{-1}

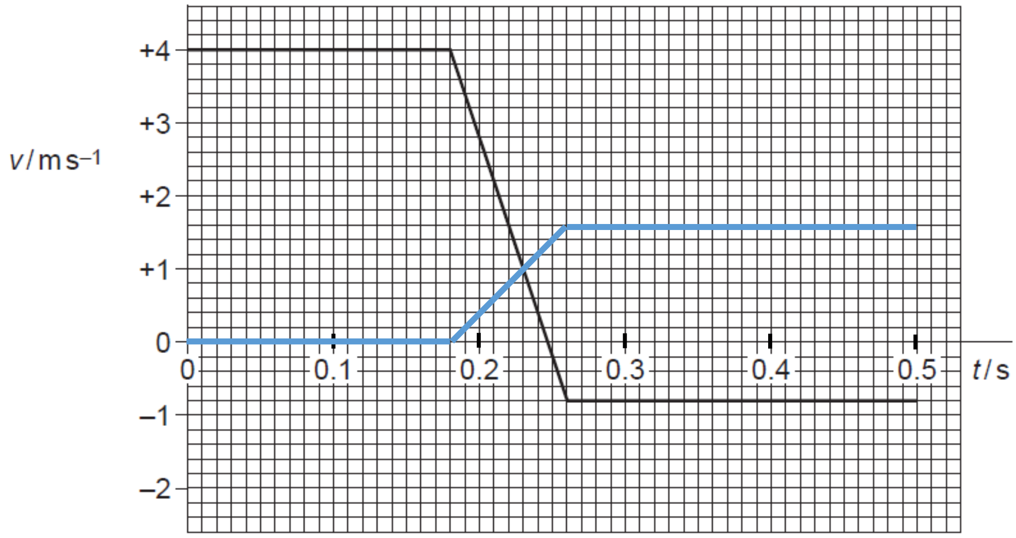
This question is generally well done. Some students read off the -0.8 as -1.0 again, but this will be ECF if the same value has already been read off wrongly in the previous part. A few students used the wrong mass (3.6 kg instead of 1.2 kg) to calculate.

A few students used $u_B - u_S = v_S - v_B$ to calculate but this only applies for elastic collisions and it cannot be assumed that the collision is elastic unless explicitly stated.

OR

change in momentum of ball S = -change in momentum of ball B = 5.76 kg m s^{-1}
$m_S (v_S - u_S) = 3.6(v_S - 0) = 5.76$ kg m s^{-1}
$v_S = 1.6$ m s^{-1}

(b) (iii)



<u>Before and after collision:</u>
Correct initial and final speeds and correct shape (horizontal lines) [B1]

<u>During collision:</u>
Change in momentum occurs between 0.18s to 0.26s and correct shape (straight upward sloping line)

This question is generally well done. A significant number of students did not look at the diagram carefully and start drawing the change in momentum from 0.20 s to 0.26 s instead.

(b) (iv) time over which collision occurs = Δt = 0.26 – 0.18 = 0.08 s

force = $\Delta p_S / \Delta t$

= $m_S (v_S - u_S)$ / 0.08

= 3.6 (1.6 – 0) / 0.08

= 5.76 / 0.08 [M1] (5.76 kg m s^{-1} might have been calculated earlier also)

= 72 N

Magnitude = 72 N

Direction = to the right

A significant number of students read 0.18 s and 0.26 s as 1.8 s and 2.6 s, some students read 0.18 s as 0.20 s. Also some students forgot did not divide by Δt as they probably have forgotten that force is the *rate of change* of momentum. A few students used the wrong mass (1.2 kg instead of 3.6 kg) to calculate.

A significant number of students read off Δt as 0.1 s instead of 0.08 s.

Similar to (b)(i), for direction, ‘positive, ‘to the right’, ‘same as the direction of initial velocity of ball B’ are accepted. Simply writing ‘same direction’ is not accepted as it is unclear what the exact direction is.

(b) (v) speed of approach = $u_B - u_S = 4.0 - 0 = 4.0$ m s^{-1}
speed of separation = $v_S - v_B = 1.6 - (-0.8) = 2.4$ m s^{-1}
speed of approach and separation are different, hence inelastic

OR

KE before collision = $\frac{1}{2} m_B u_B^2 + \frac{1}{2} m_S u_S^2 = \frac{1}{2}(1.2)(4.0)^2 + 0 = 9.6$ J
KE after collision = $\frac{1}{2} m_B v_B^2 + \frac{1}{2} m_S v_S^2 = \frac{1}{2}(1.2)(-0.8)^2 - \frac{1}{2}(3.6)(1.6)^2 = 5.0$ J

KE before and after collision are different, hence inelastic

The keyword in this question is 'quantitatively', meaning students have to provide values to justify their answers (even if the calculation steps are not provided, at least the final calculated values must be given e.g. 4.0, 2.4). Without the values, the entire question, including the conclusion, will be marked wrong as the conclusion is not justified.

The presentation of some students is inappropriate as well.
For example,
$u_B - u_S = v_S - v_B$
$4.0 - 0 = 1.6 - (-0.8)$
$4.0 \neq 2.4$
is not accepted as the candidate is contradicting himself/herself.

Misconception: Many students thought that momentum is conserved only in an elastic collision. However, momentum is always conserved. It is the KE that is conserved on top of momentum.

3(a) For the block to be floating,
Upthrust = weight of the block
$0.20 \times 0.20 \times h \times 1000 \times 9.81 = 0.20 \times 0.20 \times 0.10 \times 560 \times 9.81$
$h = 0.056$ m

Most students managed to get the correct answer. However, the few who did not made careless mistakes such as omitting g.

(b)(i)

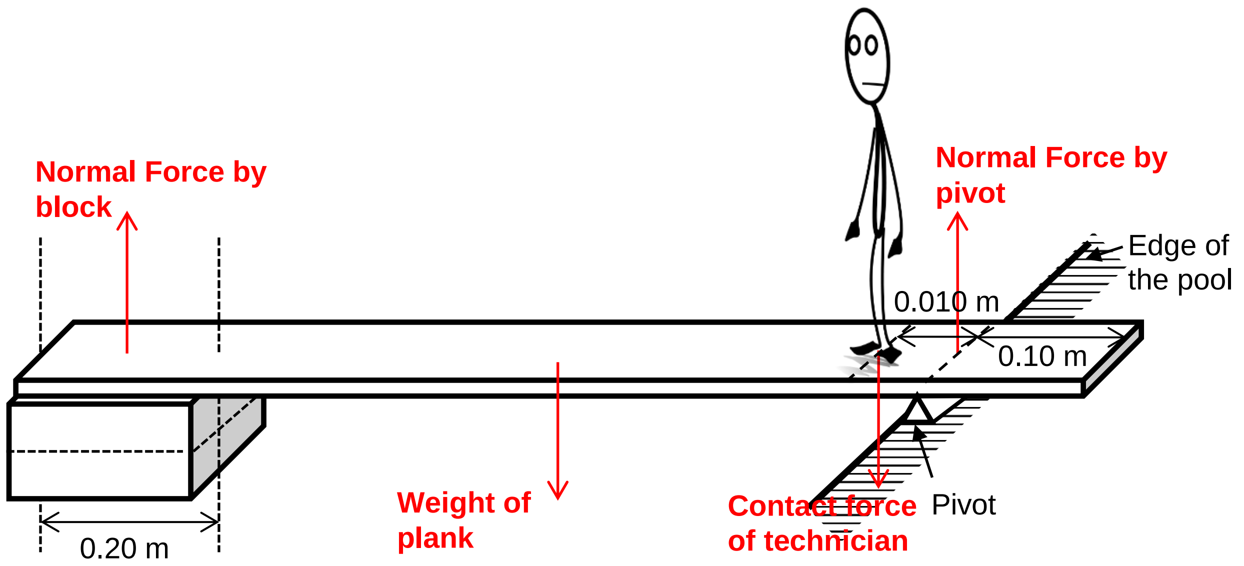


Fig. 3.2

Most students made the mistake of labelling the contact force of the technician as weight of technician. Students need to realise that weight of technician acts on the technician and not on the plank, as required by the question. Another common mistake is to label the forces as N or W without explicitly naming them. It is also important to name the forces as Normal Force by block or Normal Force by pivot instead of just generalizing the forces as Normal. Some students also unnecessarily drew the force of the plank on the technician or force of the plank on the pivot.

(b)(ii) Taking moments about the pivot, cwm = acwm
$(40 \times 9.81)(0.010) + (1.5 \times 9.81)(0.40) = N \times 0.80$
$N = 12.26$ N $= 12.3$ N

Most students were able to get this question correct. However some mistakes made include not putting in g or incorrectly measuring the distance of block, technician or c.g from the pivot.

(iii) Looking at FBD of the block,
$\Sigma F = 0$
$U = N + W$
$\rho_{water} Vg = N + \rho_{block} Vg$
$1000\,(0.20 \times 0.20 \times h')(9.81) = 12.26 + (560)(0.20 \times 0.20 \times 0.10)(9.81)$
$h' = 0.087$ m

Some students failed to visualize a proper FBD for the block. The weight of the block and the normal contact force by the plank on the block are downwards and balanced by the upthrust on the block. There is ECF for this question.

4(a) A motion where the acceleration of an object is always directed towards the equilibrium position,[1] and proportional to its displacement from that position

Most obtained at least part of this question correctly. Students need to realise that they need to give a very precise answer for such "definition" questions. It is important

(b)(i)

$$a = -\omega^2 x$$

$$\omega = \sqrt{gradient}$$

$$= \sqrt{\frac{7.6-0}{0.10-0}}$$

$$= 8.7 \text{ rad s}^{-1}$$

Question was generally well done

(ii) $T = 2\pi / \omega$

$= 2\pi / 8.7$

$= 0.72$ s

Question was generally well done

(iii) $x = -x_o \cos \omega t$

(Since starting point is at lowest point of motion)

A considerable number did not get this question right. They failed to read the question properly. Most assumed that timing starts from the equilibrium position.

(iv) $-0.025 = -0.10 \cos (8.7\,t)$

$t = 0.15$ s

There is no ECF from the previous question for this question as students should be able to solve this question without referring to the previous question. Another reason for not being able to get this question completely correct is the careless mistake of not realizing that 8.7t is in radian mode.

(v) **Resonance** occurs.
The **frequency of passing over the bumps is near the natural frequency** of the suspension of the truck.

Alternatively students can mention that maximum energy has been transferred to the suspension of the truck. It is not acceptable to write that the speed of the truck is equal to the natural frequency of the suspension.

5

(a) One radian is the angle subtended at centre of circle by an arc equal in length to the radius.

A lot of candidates did not write "at centre of circle". Incomplete answer scores zero mark.

(b) (i) Either $\frac{GM}{x^2}$ or $-\frac{GM}{x^2}$

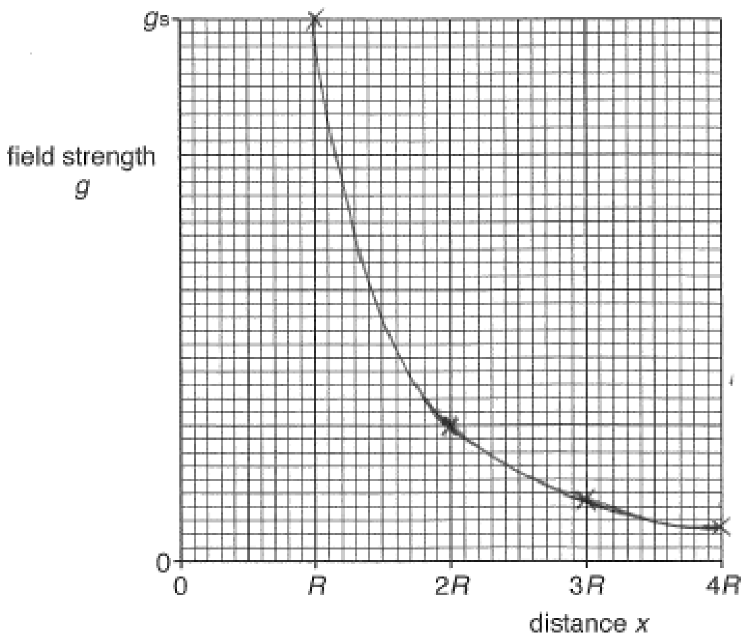
A significant number of candidates wrote $\frac{Gm}{x^2}$

Good handwriting is important to differentiate "*M*" from "*m*"

A number of students include unit which is not needed for this case.

(ii) $-\frac{2GM}{x}$

(iii)



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Care has to be taken to draw the graph precisely.

Some candidates did not follow the instruction given in the question and draw the graph out of the range.

(iv) By Principle of Conservation of Energy, Total initial energy at surface of sphere = Total final energy at infinity

$KE_i + GPE_i = KE_f + GPE_f$

$\frac{1}{2} mv^2 + (-\frac{GMm}{R}) = 0 + 0$

$$v = \sqrt{\frac{2GM}{R}}$$

$$= \sqrt{\frac{2GMR}{R^2}} = \sqrt{2\left(\frac{GM}{R^2}\right)R}$$

$$= \sqrt{2g_s R}$$

Steps for "Show" question:
(1) Start with a statement
(2) All steps clearly developed and explained. Do not skip steps.
(3) Show ALL substitutions clearly
(4) New term used must be defined (if any)

Common mistakes

$E_p = E_K$
$\Delta E_P = \Delta E_K$
No statement
Statement not spelled in FULL
No substitution
$\frac{GMm}{r^2} = \frac{mv^2}{r}$
$v^2 = u^2 + 2as$

(c) (i) Gravitational force provides centripetal force.
By Newton's third law, gravitational force by A on B is equal in magnitude and opposite in direction to gravitational force by B on A.

Common mistakes

Centripetal force is *due to* gravitational force.

A number of candidates wrote there is no net force at the centre of the circle.

(ii) $\omega = \frac{2\pi}{T}$

$$\omega = \frac{2\pi}{3.5 \times 365 \times 24 \times 60 \times 60}$$

$= 5.7 \times 10^{-8}$ rad s^{-1}

Common mistake

One year = 12 x 30 days

(iii) From (i) centripetal force on A = centripetal force on B

$M_A r_A \omega_A^2 = M_B r_B \omega_B^2$ where r is the radius of the orbits

$M_A r_A = M_B r_B$ since ω is a constant

$$\frac{M_A}{M_B} = \frac{r_B}{r_A} = 4.0$$

$$\frac{d - r_A}{r_A} = 4.0$$

$$\frac{5.0\times10^{11} - r_A}{r_A} = 4.0$$

$r_A = 1.0 \times 10^{11}$ m

Common mistake

A significant number of candidates thought that the "r" in $\frac{GMm}{r^2}$ stand for radius rather than separation.

(iv) Gravitational force provide centripetal force

$$\frac{GM_A M_B}{d^2} = M_A r_A \omega^2$$

$$\frac{GM_B}{d^2} = r_A \omega^2$$

$$\frac{(6.67\times10^{-11})M_B}{(5.0\times10^{11})^2} = (1.0\times10^{11})(5.7\times10^{-8})^2$$

$M_B = 1.22 \times 10^{30}$ kg

$$\frac{M_A}{M_B} = 4.0$$

$$\frac{M_A}{1.22\times10^{30}} = 4.0$$

$M_A = 4.88 \times 10^{30}$ kg

Common mistake

A significant number of candidates thought that the "*r*" in $\frac{GMm}{r^2}$ stand for radius rather than separation.

(v) The light intensity reaching the Earth will decrease when one star is blocked by another.
The time interval between the lowered intensity is half a period.
Thus period can be determined.

Common mistake

Wrong Use of Rayleigh criterion in this context

7 (a)(i) A polarized wave is where particles oscillate only along one axis/ plane and this axis/ plane is perpendicular to the transfer of energy as a result of the oscillation.

Many candidates described the direction of the wave travelling in one direction rather than the oscillation's direction.

Some compared intensities of the incident and emergent wave which is not necessary.

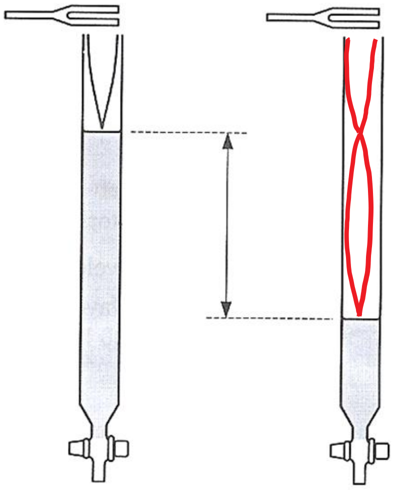
Only a handful of students recognizes the need to explain the meaning of both polarized and wave.

(a)(ii)

$$I' = I\left(\cos 30^o\right)^2\left(\cos 60^o\right)^2$$
$$I' = 0.18I$$

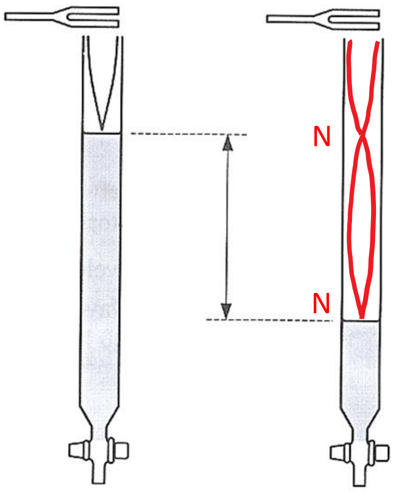
Most candidates leave in their answer in fractional form and this is strongly discouraged.
Many candidates could not recognize the angle between the two polarizers.
Some assumed that the incoming wave is already polarized, hence losing half of its intensity after passing through the first polarizer.
Some did not include the square in Malu's law.

(b)(i)1.



Almost half the number of candidates fail to recognize that the question is asking for the 1st overtone. They drew the other overtones instead. Some did not end with a node at the surface of the water (closed end).

(b)(i)2.



Most students fail to recognize that more than one node is required in this question. A handful mistook the antinodes to be the nodes.

(ii)

$$\frac{1}{2}\lambda = 40.0$$

$$\lambda = 80.0cm$$

$$v = f\lambda$$

$$v = (413)(80.0)$$

$$= 330ms^{-1}$$

Many could not relate one wavelength (2 loops) to the diagram that they have drawn, hence ending up finding the wrong wavelength.

(c)(i)

$$d\sin\theta = n\lambda$$

$$\left(\frac{1}{6.00 \times 10^5}\right)\sin 90^o = n(450\times 10^{-9})$$

$$n = 3.7$$

$$n = 3$$

Some candidates interpret *d* as lines per metre instead of spacing between lines.
A handful rounded up instead of rounding off.
Some candidates worked out values that are orders that are too high or low which do not make logical sense.

(c)(ii)1. 3

Some failed to recognize that the answer to this is the same as the answer from (c)(i).

(c)(ii)2.

$$d\sin\theta = n\lambda$$

$$\left(\frac{1}{6.00 \times 10^5}\right)\sin\theta = n(449\times 10^{-9})$$

$$\theta = 53.92^o$$

$$d\sin\theta' = n\lambda$$

$$\left(\frac{1}{6.00 \times 10^5}\right)\sin 90^o = n(452\times 10^{-9})$$

$$\theta' = 54.45^o$$

$$\theta' - \theta = 53.92 - 54.45$$

$$= 0.529^o$$

(Since the angular separation is larger than 0.20º)
They can be distinguished

Many used Rayleigh criterion to solve the question, failing to recognize that the slit width is not given.
For some of those who used Diffraction Grating formula, they found n and assumed angle from normal to be 0.20º.

(d)(i) Radio/microwaves
Most students are able to get this answer.

(d)(ii) constructive interference
Most students are able to get this answer.

(d)(iii) Path difference = 18 x 2 = 36 cm = 4.5 λ
Destructive interference
Minimal

More than half the candidates are able to arrive at the answer. Quite a number did not mention the phase difference or type of interference point D.