



Award Summary

Outstanding Achievement (OA)	139
High Achievement (HA)	172
Satisfactory Achievement (SA)	119
Reassessed into neighbour	30
Total candidates	460

Gender Breakdown

Males	314
Females	146

Ratings awarded (internally and externally)

Criterion	A		B		C		D	
	int	ext	int	ext	int	ext	int	ext
Criterion 1	288		115		56		0	
Criterion 2	234	160	167	204	59	88	0	3
Criterion 3	322		111		27		0	
Criterion 4	227		160		64		2	
Criterion 5	300		117		42		1	
Criterion 6	225		143		82		9	
Criterion 7	198	169	139	93	102	99	21	91
Criterion 8	258		163		34		2	
Criterion 9	135	128	173	199	129	64	21	64
Criterion 10	161	140	123	162	139	79	36	72

**Question 1**

- (a)(b) (i) Most knew to find the area – about 40% miscalculated this.
- (b) (ii) A mark was awarded for correct interpretation of their answers to (a) and (b)(i) – most got a mark.
- (c) Most knew to find the slope – about half did this correctly. Others took the slope over the whole period.

Many did not realise that the scale was in *minutes*.

Units were a problem. Energy given in MW or MWh^{-1} or even in Joule (without appropriate conversion for MWh Joule).

- (d) Only 25% got this fully correct. Lots of attempts and partial marks. The sloping part $t = 6\text{h}$ to $t = 8\text{h}$ and $t = 16\text{h}$ to $t = 24\text{h}$ causing the main problem.

Question 2

Most students were aware of the concept of drawing tangents and calculating slopes, and many produced excellent answers. Tangents were often poorly drawn, using triangles that were far too small. The most common errors were:

1. 30% said that $v = 0$ when $t = 0$ without inspecting the graph.
2. Forgetting that a change in sign of the gradient meant that the velocity also changed in sign.
3. Numerous velocity (and acceleration) graphs were sketched as straight line segments (sawtooth shape), indicating some lack of understanding.

The markers felt that even though *sketch* graphs were stipulated, critical points should have been indicated on the axes of these sketches. Another interesting observation was that a significant number of students obtained a correct graph for part (c) having not done or incorrectly done part (b).

Question 3

This question was successfully attempted by most students. Main areas of difficulty and error included:

1. When squaring or cubing the values, errors occurred in the resulting units and powers of ten.
2. Some students plotted r^3 on the y axis and incorrectly identified the gradient as $\frac{4\pi^2}{GM}$ rather than its reciprocal.

It was considered by the marking panel that to obtain full marks for this question, students should use the graph as stipulated in the question rather than substituting the values of a single point from the data table, even though the latter method would result in a correct answer.

Question 4

Comments overall well done by most.

- (a) (i) Most used $v = \frac{s}{t}$'s being the circumference t being the period. Some went the long way and found M the mass of Eros, then used Keplers Law or similar to arrive at the same answer.
- (ii) Most got this right.
- (iii) Most received full or partial marks.
- (b) (i) Very few used Law of Conservation of p correctly with regard to the mass of expelled gas m and the mass of NEAR = (600m).
- (ii) Average force was well done by most.

Question 5

Generally well done. Problems included:

- confusion in charges, field direction for the parallel plates in question 5(b)(ii);
- confusion between $k = 9 \times 10^9$ and $K = 2 \times 10^{-7}$;
- inability to determine the mass of the chlorine atom in question 5(d).

Question 6

Generally well done except for part (c). Many students attempted a range of complicated (and incorrect) techniques for part (a)(ii). In part (c), few students used $r = 0.05\text{m}$ (most choosing $r = 0.1\text{m}$) and there was widespread confusion over field directions and the most appropriate formula to use.

Question 7

- (a) Generally well done, with many student gaining the bonus marks. The most common mistake was to use Snells Law in reverse in part (i).
- (b) (i) Well done by almost all.
- (ii) Students were asked to use the figures to explain positions of constructive and destructive interference, so were expected to calculate distance between maxima/minima and then comment.
- (iii) W 1m all people were in a position of constructive interference – all hear flute lovely.

Question 8

- (a) (i) Students were able to calculate energy of electrons but only about $\frac{1}{2}$ could calculate minimum wavelength of X-rays.

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- (ii) Only about 15% of students had 3 photons emitted – most had 2 photons and so only calculated 2 wavelengths.
 - (b) A great deal of difficulty even once λ had been calculated to then find time to reach new activity level.
 - Difficulties in converting from yrs to seconds.
 - about 40% of students completed this section.
 - (c) (i)(ii) Confusion as to whether original or final mass should be greater for decay to be energetically possible. Many students only wrote a balanced nuclear equation and did not consider masses at all.
 - (iii) Generally well done using answers from (i) or (ii) except for those who used $E = mc^2$ and mass in amu not kg.

Question 9

- (a)(b) The majority of candidates gained some marks on these two parts of the question. “What is *the* evidence?” implies that the answer should be fairly wide-ranging and not just devoted to one piece of evidence eg the photo-electric effect for particles. Similarly, students were expected to spend four minutes on each point and a simple list of evidence without some additional explanation was not enough for full marks.
- (c) Most candidates knew something about Compton scattering. There was some confusion with X-ray production and Rutherford’s experiment.
- (d) Quite well answered though only a few students stated that the slits needed to be very close together. Quite a lot of students thought that light and X-rays travelled at different speeds.

Question 10

- (a) Millikan’s oil drop experiment – few students chose this part. However most who did gained good marks. Many diagrams poorly labelled. Some students did not explain the theory behind the experiment eg Force due to gravity = Electric force when stationary. Many students did not comment on how to find mass of oil drop eg diameter of drop and density of oil.
- (b) Very poorly answered – diagrams poor or non existent.
 - (i) Many students described how to polarise light not what was polarised light.
 - (ii) Most students did not suggest reflected light was polarised. Many gave the impression that sunglasses have large numbers of lines scratched in them which block the light. Many assumed light was reflected by glasses and not absorbed.
 - (iii) Generally well answered.
- (c) (i) Many students had the beta particles on the reactant side of the equations.
 - (ii) Common belief that the energy for fuel from plutonium was due to its natural decay rather than fission.

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- (d) (i) Some students seemed to think that the momentum of an individual particle remained unchanged. Common confusion with law of conservation of energy. Newton's Laws also got a good run.
- (ii) Force diagrams very badly drawn – labelling generally poor and magnitude ignored – many did not show the forces acting on different objects – many stated that net force was zero.
- (iii) Most students discussed kinetic energy rather than energy as a whole, however, credit given if they did so. Any deeper understanding of energy transfer given credit also. Students often talked about momentum and energy as the same thing.

Question 11

Majority of students chose to do parts a, b and c.

- (a) (i) Well done.
- (ii) Well done although some students drew only a small section of the wave.
- (iii) Well done.
- (iv) Often attempted but generally only few received full marks. Most students were unsure on the units for the time axis preferring to use seconds instead of periods or else showing no units.
- (b) (i) Well done.
- (ii) Well done.
- (c) Generally poorly done. Answers were very wordy but lacked physics content and terminology. Many students concentrated on the workings of the speaker and microphone.
- (d) (i) Poorly drawn vectors often confused and poorly labelled.
- (ii) OK with some simply stating 'forward'.
- (e) (i) Poorly drawn vectors often all over the place.
- (ii) Occasionally well done. Many attempts did not indicate current flow in coil or drew coil in a way that could be interpreted as being wound either way.
- (f) (i) Well done.
- (ii) Well done.
- (iii) Most students referred to using this to brake the train. A few also stated that it could also be used to charge the battery.

All correspondence should be addressed to:

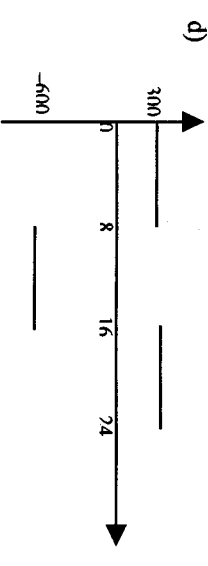
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Q1. a) Area beneath the graph (from the axis up to the "curve") is energy. Units are MWh (MW hours)
 Area = $1100 \frac{1}{24} + 400 \frac{1}{2} [(24 - 6) + (16 - 8)]/2$
 = 31600MWh.

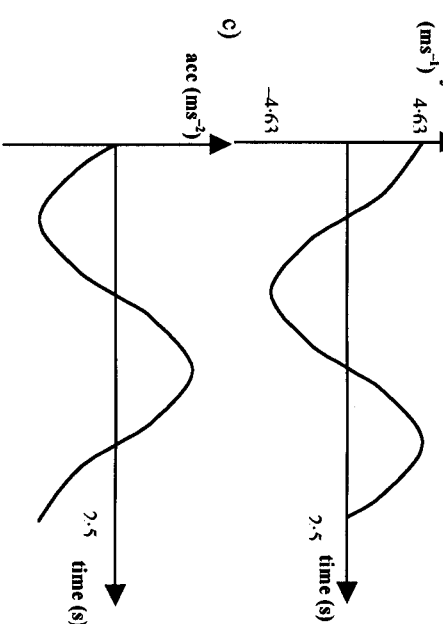
b) i. Area = $800 \frac{1}{24} + 400 \frac{1}{2} [(24 - 6) + (16 - 8)]/2$
 + $900 \frac{1}{2} (16 - 8)$.
 = 31600MWh.
 ii. neither, since total consumed = total generated.

c) maximum rate of change of power production is the gradient of the steepest section = $900 \text{ MW} / 4 \text{ min}$
 = 225 MW min^{-1} .
 To compare with Victoria, this is 13500 MW h^{-1} .



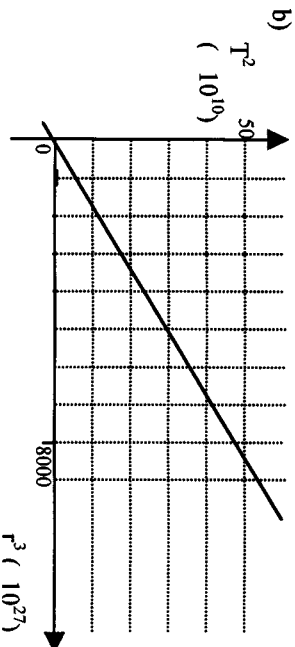
Q2. a) At 0 seconds a tangent to the curve will have a gradient given by rise/run. For example $1.85 \text{ (m)} / 0.4 \text{ (s)}$, giving a value of 4.63 ms^{-1} .

At 0.5s, the gradient of tangent is zero (0 ms^{-1}).
 At 0, 1 and 2 seconds velocities will be $+4.63$, -4.63 , and $+4.63 \text{ ms}^{-1}$, respectively. At 0.5, 1.5 and 2.5 seconds, velocity will be zero.



Q3. a) Kepler's law suggests that "T" should be squared and "r" cubed. A table of results follows:-

T (10 ⁵)	2.43	4.47	6.91
r (10 ⁹)	10.0	15.0	20.0
T ² (10 ¹⁰)	5.90	20.0	47.7
r ³ (10 ²⁷)	1000	3380	8000



b) The gradient of this straight line graph is equal to the constant k in the linear relationship between T² and r³, T² = kr³. By comparing this with Kepler's Law, it can be seen that $k = 4\pi^2 / GM$. This can be used to evaluate M by re-arranging to give:-
 $M = 4\pi^2 / Gk$.

d) From the graph, $k = (47.7 \cdot 10^{10}) / (8000 \cdot 10^{27})$
 = $5.96 \cdot 10^{-20} \text{ (s}^2 \text{ m}^{-3}\text{)}$

The mass of the star is
 $M = 4\pi^2 / [(6.67 \cdot 10^{-11}) / (5.96 \cdot 10^{-20})]$
 = $9.93 \cdot 10^{30} \text{ kg}$

Q4. a) i. The satellite travels one "circumference" per "period" of revolution, so its speed is given by:-
 $v = 2\pi r / T = 2\pi (327 \cdot 10^3) / (27 \cdot 24 \cdot 3600)$
 = $0.881 \text{ ms}^{-1} \approx 0.88 \text{ ms}^{-1}$

ii. acceleration due to gravity will be the same as the centripetal acceleration of the satellite, since it is in a circular orbit. $a_c = v^2 / r = (0.88)^2 / (327 \cdot 10^3)$
 = $2.37 \cdot 10^{-6} \text{ ms}^{-2}$.

iii. The mass of Eros can be found using $g = GM/d^2$.
 Rearranging gives
 $M = gd^2 / G$
 = $(2.37 \cdot 10^{-6}) (327 \cdot 10^3)^2 / (6.67 \cdot 10^{-11})$
 = $3.80 \cdot 10^{15} \text{ kg}$

b) i. momentum is conserved.
 initial mass of NEAR = 600kg
 initial speed of NEAR = 10ms⁻¹
 ∴ initial momentum = 6000kgms⁻¹

After thruster has fired, mass of Near = 600 - m, speed of Near = +0.88, speed of gases = +2400, (assuming the thruster is facing "forwards"), gas mass = m.

Since momentum is conserved,

$$6000 = (600 - m) \cdot 0.88 + m \cdot 2400.$$

This solves, giving $m = 2.281 \approx 2.3 \text{ kg}$.

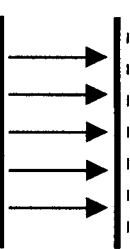
[Note: the assumption is that NEAR is initially travelling in the same direction as in its final orbit, if not, then the mass of gases ejected will be greater, but not more than 2.72kg, provided of course that the maneuver is conducted efficiently - the "worst case" scenario is NEAR reversing in its direction of travel.]

ii. Using the 2.3kg of ejected gas at 2400 ms^{-1} in a burn lasting 57 seconds, the impulse of the force acting on the gases, $I = Ft = \Delta p = m\Delta v = 2.3 \cdot 2400 = 5520 \text{ Ns}$.

The force required is $F = \Delta p / t = 5520 / 57 = 96.8 \text{ N}$
 Newton's third law suggests that this is also the force exerted on NEAR by the thruster. ie average force on NEAR = 96.8N (backwards).

Q5. a) For a velocity filter, the electric force and the magnetic force on the moving charge must balance, that is:- $F = qE = qvB$. Consequently $E = vB$.
 In this instance $E = (2.00 \cdot 10^5) / (0.5)$
 = $1.00 \cdot 10^5 \text{ NC}^{-1}$

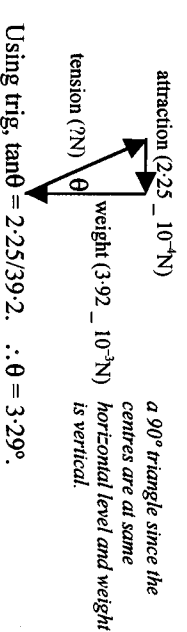
b) i. For parallel plates, $E = V/d$, so $V = Ed$. Potential difference, $V = (1.00 \cdot 10^5) (1 \cdot 10^{-2}) = 1000 \text{ V}$.

ii. 
 positive ions ⇒ "current" to the right. RHPRule ⇒ magnetic force is down. Hence electric force is up. ∴ electric field is up.

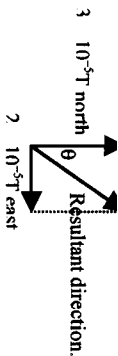
c) Using the formula $r = mv / qB$ and rearranging:-
 $m = r q B / v$
 = $(6.675 \cdot 10^{-2}) (1.6 \cdot 10^{-19}) (0.5) / (2 \cdot 10^5)$
 = $2.67 \cdot 10^{-26} \text{ kg}$

d) Since $r = mv / qB$, increasing mass from 16 to 36 and doubling charge, the radius will change by $36/16 \cdot 1/2$
 The new radius will be $6.675 \cdot 36/32 = 7.509 \text{ cm}$.

Q6. a) i. Coulomb's Law, $F = kQq/d^2$, gives
 $F = (9 \cdot 10^9) (5 \cdot 10^{-7}) (2 \cdot 10^{-9}) / (20 \cdot 10^{-2})^2$
 = $2.25 \cdot 10^{-4} \text{ N}$ (attraction) - "opposite" charges
 ii. $W = mg = (0.4 \cdot 10^{-3}) \cdot 9.8 = 3.92 \cdot 10^{-3} \text{ N}$, down.
 iii. Forces on ball are balanced, so add to zero.



b)



Using trig, $\tan\theta = 2/3$, $\therefore \theta = 33.7^\circ$.

The compass needle will point N33.7°E.

c) Midway between the wires the field due to each separate wire will have a value given by $B = \mu_0 I/d$. In this case $B = (2 \times 10^{-7}) \frac{(10)}{(0.05)} = 4 \times 10^{-5} \text{T}$.

Using the RHR, the upper wire has a field into the page, as does the lower wire. The two fields combine to give a total magnetic field of $8 \times 10^{-5} \text{T}$, into the page.

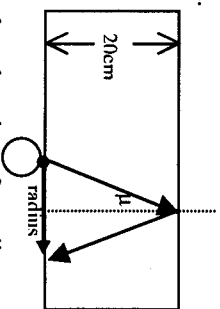
Q7 a) i. Using $n \sin i = n' \sin r$:-

$$1.33 \sin 40^\circ = 1 \sin x, \text{ hence } x = 58.7^\circ$$

ii. Critical angle for light passing from medium to air is given by $\sin \mu_c = 1/N$. In this case $\sin \mu_c = 1/1.33$, and so μ_c , the critical angle, = 48.8° .

iii. This light ray strikes the water surface at an angle greater than the critical angle ($60^\circ > 48.8^\circ$) and so the ray will be totally internally reflected. It will pass back into the water with an angle of reflection of 60° .

iv. The globe, being recessed, has a filament below the level of the base of the tank. Light cannot pass directly from the filament to the base unless it is reflected. Some light will be reflected (from the water surface) at angles less than the critical angle but will only give reduced illumination (the area will appear darker). Once the critical angle has been exceeded, all light will be reflected back to the base of the tank and it will be better illuminated.



Mathematical explanation: from diagram, radius of circle = $2 \times 20 \tan \mu_c = 40 \tan 48.8^\circ = 45.6 \text{ cm}$.

b) i. $\lambda = v/f$.

In this case $\lambda = 320/800 = 0.40 \text{ m}$ (40 cm)

ii. Sue, Gill and Liz are sitting at points of constructive interference (they are on "anti-nodal lines"), the others are on "nodal lines" where destructive interference is occurring. Because the girls are sitting where the "path length difference" from each speaker is a whole number of wavelengths a "compression" from each speaker will

arrive at the same time and reinforce. "Rarefactions" also arrive simultaneously. The boys have a path length

difference that is an odd number of half wavelengths and so "rarefactions" and "compressions" arrive together and cancel each other out. The "fringe width" of Young's experiment, given by $W/\lambda = \lambda/d$, gives a result of $W = \lambda \lambda/d = 20 \times 0.4/4 = 2 \text{ m}$. The interference fringes are 2 m wide, Since the audience is sitting 1 m apart each alternate person experiences the extremes of the interference pattern. The blocks hear little.

iii. At 1600 Hz, the frequency has doubled, and so the wavelength has halved. Since W is proportional to λ , the width of the pattern will halve (become 1 m), thus all guests will be exposed to constructive interference and will hear the sound clearly and loudly.

Q8. a) i. Each electron has 50 keV of energy. If all is lost in one interaction, the X-ray photon will have (max) energy of 50 keV = $(50 \times 10^3) (1.6 \times 10^{-19}) \text{ J}$. The minimum wavelength $\lambda = hc/E$

$$= (6.63 \times 10^{-34}) / (3 \times 10^8) / (8 \times 10^{-15}) \\ \approx 2.49 \times 10^{-11} \text{ m}$$

ii. Three different energies are involved, 1×10^{-19} , 2×10^{-19} and $3 \times 10^{-19} \text{ J}$. Wavelengths are given by $\lambda = hc/E$, giving 1.99×10^{-6} , 9.94×10^{-7} and $6.63 \times 10^{-7} \text{ m}$, respectively.

b) $A = A_0(0.5)^n$, where n is the number of half-lives. Rearranging gives $n = \log(A/A_0)/\log(0.5) \approx 15.18$. hence number of years will be $15.18 \times 1620 \approx 24600$.

c) i. mass loss = original – final
 $= m(\text{Ra224}) - m(\text{Rn220} + \alpha)$
 $= 224.020 - (220.011 + 4.003)$
 $= 0.006$

Since there is a mass loss, the decay should be spontaneous. It is energetically feasible.

ii. mass loss = $m(\text{Ra224}) - m(\text{Ra223} + \text{neutron})$
 $= 224.020 - (223.019 + 1.009)$
 $= -0.008$

This reaction would result in a mass gain and so it is not energetically possible.

iii. The emission of the α -particle would result in the release of 931 MeV per unit of atomic mass. Since 0.006 units of atomic mass are converted to energy, 5.586 MeV would be released (as energy of α -particle, recoil energy of Rn220 and possibly a γ -ray)

Q9 a) The evidence that light is a wave is based on its behaviour during reflection, refraction, diffraction and interference. Light behaves exactly as predicted using wave models based on observations of "macro" waves, such as water waves and sound waves. Essentially all of these behaviours can be explained using Huygen's constructions, which uses the concept of the envelope of wavelets formed by a wave-front, generating the next wave-front.

b) Some phenomena related to the emission of light and the absorption of light, particularly "black body radiation", the "photo-electric effect" and "Compton scattering", all suggest that light is made up of particles. These three phenomena cannot be adequately explained using any aspect of wave theory, but can be explained with the assumption that light is a particle with energy given by $E = hf$, and momentum by $p = h/\lambda$.

c) When X-ray photons interact with electrons in thin metal foils, they are scattered in all directions and undergo a change in wavelength. The principle evidence that light has a particle nature comes from the fact that the direction of scatter of any X-ray and the corresponding change in wavelength of that scattered X-ray has a definite experimental relationship. The relationship is identical to that predicted and observed for the scatter pattern of real particles in collision situations. The determination of wave-length shift relies on the assumption that light "particles" have momentum given by $p = h/\lambda$, and so $\Delta\lambda = h/p_f - h/p_i$.

d) X-rays are waves with small wavelengths [24.9 pm in Q8(a)] and so any interference pattern will need to be produced by a pair of slits very close together – fractions of nano-metres apart. Also the pattern produced will be very fine and difficult to detect. The advent of improved technology has enabled the pattern to be produced, usually by crystals of ionic solids as the "diffracting" medium with very localized detectors (semi-conductors) to delineate the pattern. Light waves (400 to 700 nm), on the other hand, only need a slit spacing of a few micro-metres in size and give a pattern that is visible to the naked eye.

Q10 a) A description of Millikan's oil drop experiment would do. Essentially charged oil droplet (of known volume and density, hence mass) is held stationary by the opposing actions of a gravitational field and an electric field. The two forces acting on the oil drop, being equal,

can be equated by $mg = qE$. The charge on the droplet can then be evaluated using mg/qE .

The values that Millikan obtained were all multiples of a certain number, and all differed by multiples of that same number. The number was $1.6 \times 10^{-19} C$, the charge on an electron.

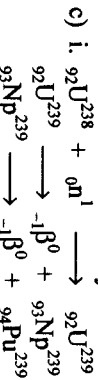
It should be noted that the values obtained were the charges on oil droplets, but the oil droplets were all negatively charged, presumably by the addition of a whole number of electrons, the hypothesized fundamental charge.

b) i. Light can be polarized because it is a transverse electromagnetic wave. It is thought to be composed of a pair of self-sustaining fields that are at right angles to each other and the direction of propagation. When the fields (of either type) all have the same direction in a bundle of light waves, then that bundle is said to be polarized.

ii. Reflected light from horizontal surfaces tends to be polarized "horizontally". Polarizing filters can block

polarized light when oriented correctly. If the sunglasses are made of "vertically" polarizing filters, then they will effectively reduce much of the "glare" from horizontal surfaces.

iii. The screen would appear less bright with vertically polarized sunglasses. As the sunglasses rotated (around an axis perpendicular to the screen and sunglasses) the screen would appear lighter when rotated one way, and darker when rotated the other way.



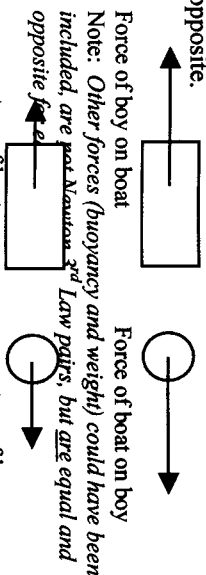
ii. If plutonium is absorbed by the human body and is an α -emitter, then the α -particles will cause damage to surrounding tissue - α -particles are highly ionizing and have very low penetrating power, thus all will be absorbed by tissue surrounding the plutonium and all will cause damage.

iii. For: effective fission fuel; recycles "waste" from other nuclear processes.

Against: can be used for nuclear weapons; danger if absorbed by reprocessing workers, due to long half-life.

d) i. The vector sum of the momenta of each of the particles (total momentum) remains unchanged (conserved) by any interactions within an isolated (no external forces) system (collection of particles).

ii. Forces shown are Newton 3rd Law pairs, so are equal and opposite.

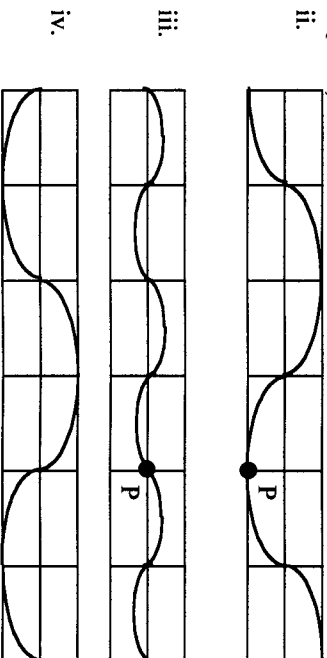


If boat and boy are initially at rest, then the two momenta have equal magnitudes, and opposite directions.

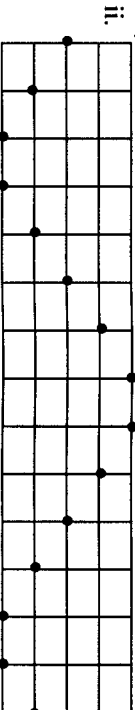
iii. Case 1: - momentum of Joe totally transferred to momentum of Gill (momentum conserved as skaters isolated from external forces) - kinetic energy of Joe totally transferred to Gill (elastic collision - kinetic energy conserved). [Note: This answer obtained full marks, although it is not correct if Joe and Gill have unequal mass - an unlikely situation.]

Case 2: - momentum of Joe partially transferred to Gill (Joe retains some momentum). Combined momentum of Joe and Gill after interaction equals Joe's momentum before interaction (momentum conserved as system is isolated) - kinetic energy not conserved - some energy is transferred to keeping bodies together (deformation, heat), therefore combined kinetic energy is less than the initial kinetic energy of Joe.

Q11. a) i. $\lambda = 40\text{cm}$.

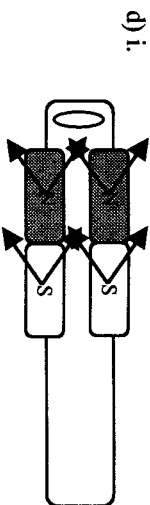


b) i. $\lambda = 60\text{cm}$.



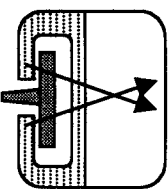
c) The speaker cone pushes forwards and backwards producing areas of compression and rarefaction in the

surrounding air. The compressed air expands thereby compressing air in front of it, similarly the rarefied air contracts creating an area of rarefaction in front of it. When the wave reaches the microphone the compressions push a diaphragm forwards and the rarefactions allow it to move backwards (pushed by the uncompressed air on the other side of the diaphragm).

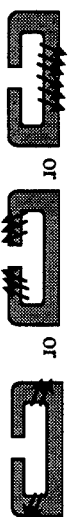


ii. Forwards (to the left on the page)

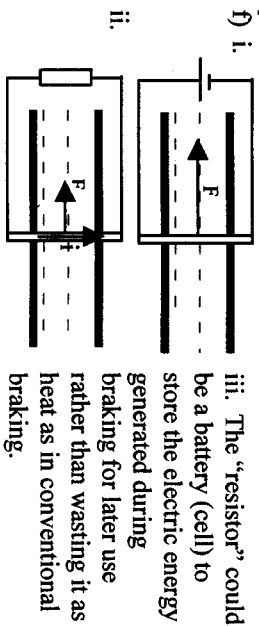
e) i.



ii. By winding a coil of wire (a solenoid) around the shaded "magnet" on the train and passing a current through it. The winding could be done in a number of ways. The field lines will "follow" the iron (shaded).



The field lines try to flow into the steel rail and hence provide the lift.



iii. The "resistor" could be a battery (cell) to store the electric energy generated during braking for later use rather than wasting it as heat as in conventional braking.