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A LEVEL

Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H557
For first teaching in 2015

H557/02 Summer 2019 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR Interchange.

Paper 2 series overview

Scientific Literacy in Physics is a synoptic paper that includes questions on an advance notice article. The questions in Section A are of medium length, usually contributing around ten marks each to the paper total. Section B comprises longer questions, including level of response questions. Section C is based on the advance notice article and can include both short and long questions.

This is a challenging assessment. The questions cover all areas of the specification and some require extended explanation or calculations. It is encouraging that the majority of the candidates attempted all the questions. There was very little evidence of candidates running out of time.

Generally, the more able candidates demonstrated the ability to apply physics to novel areas.

Candidate performance overview

Candidates who performed well on this paper generally:

- Performed short calculations accurately, using units in answers where appropriate and giving values to the correct number of significant figures.
- Showed clear and logical thinking in longer calculations such as Questions 2 (b) , 2 (c) (ii), 8 (b) and 11 (a).
- Produced accurate and concise responses to the level of response questions on wave - particle duality (4 (c)) and gravitational potential (8 (b)).
- Used clear and accurate technical vocabulary throughout the paper – thus performing reasonably well on Question 3

Candidate who did less well on this paper generally:

- Found unstructured calculations difficult to break down into individual steps and so found Questions 2 (b), 2 c (ii) and 11 challenging.
- Showed a lack of knowledge and understanding of technical vocabulary. This is particularly evident in responses to Question 3 (a), (b), and (c) (i) as well as the level of response Questions 4 (c) and 8 (b).
- Did not read the questions carefully – for example answering Question 9 by suggesting why the value of the height measured might be inaccurate rather than the value of the pressure, as required.

Section A overview

This 33 mark section comprises 3 short questions. Most candidates completed all the questions in this section although Question 2 in particular challenged the lower-ranked candidates. Question 3 in particular required a clear understanding of technical vocabulary – this was not always evident

Question 1 (a) (i)

1 This question is about momentum and force.

(a) A block of mass 0.20 kg has velocity +1.8 m s^{-1}. It collides with a stationary block of mass 0.30 kg. The two blocks stick together after the impact.

(i) Calculate the velocity of the two blocks after impact. Ignore the effects of friction.

velocity = ... m s^{-1} **[2]**

This is a standard calculation that proved accessible to most candidates. The rare candidates that made errors divided the initial momentum by 0.3 kg rather than 0.5 kg, showing a lack of understanding of the conservation of momentum.

Question 1 (a) (ii)

(ii) Show that kinetic energy is **not** conserved in this collision.

[2]

A second straightforward calculation to begin the paper.

Question 1 (a) (iii)

(iii) The collision took place over time, Δt. By calculating the change of momentum of both blocks, show that the force on one block is equal and opposite to the force on the other block, an example of Newton's third law of motion.

[3]

This part of the question was more challenging. Although most responses showed that the magnitude of the momentum change is the same for both blocks, a proportion did not give the vector sense of the answer (not stating that one block had a momentum change of +0.216 Ns and the other a change of -0.216 Ns). The third marking point, linking equal and opposite momentum changes to equal and opposite forces as the time of interaction for both bodies is the same, was often missed.

Question 1 (b)

(b) In a crash test, a driverless car strikes a wall and stops. The graph in Fig. 1.1 shows the variation of the force on the car over the time of the collision.

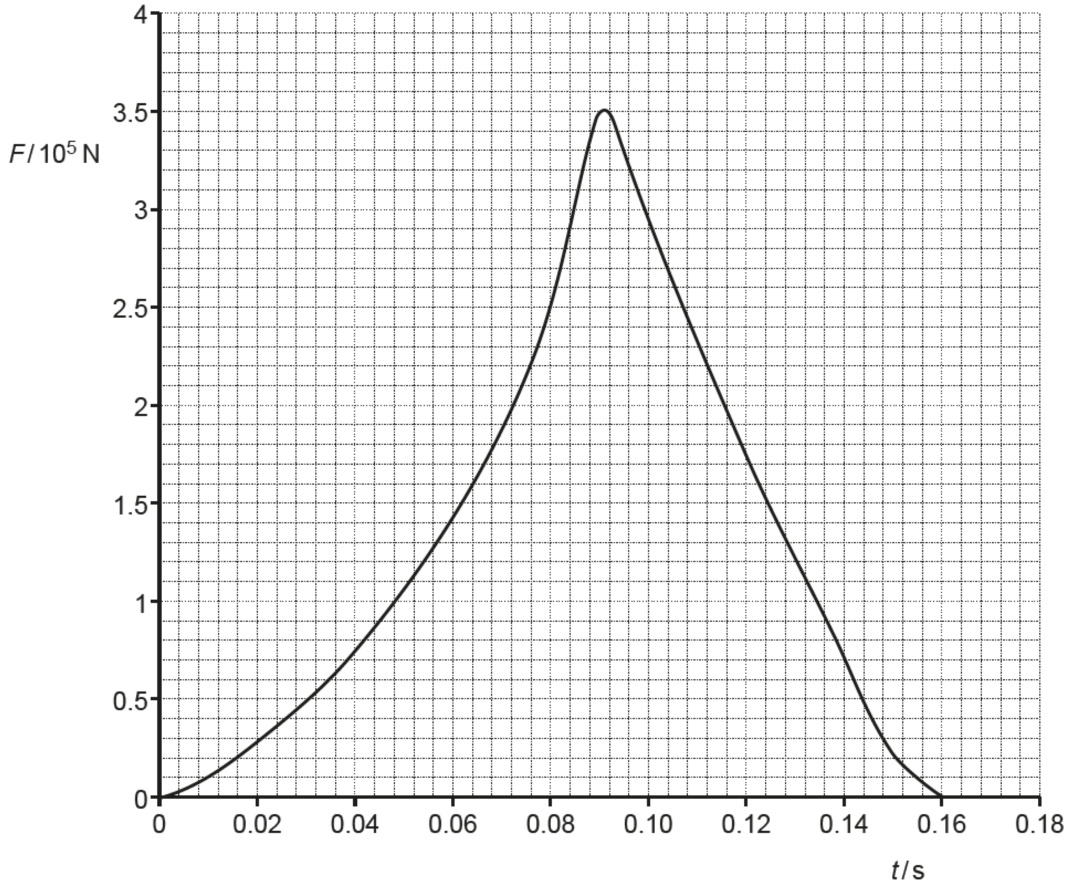


Fig. 1.1

The impulse on the car is given by the area under the curve. Use data from the graph to calculate the initial velocity of the car. Explain your method and reasoning.

mass of car = 1400 kg

initial velocity of car = ... m s^{-1} **[3]**

Most responses showed an attempt to calculate the whole area under the line. However, many of the values obtained were inaccurate. Candidates commonly assumed that the area was a triangle and calculated accordingly. Other incorrect responses missed the 10^5 factor of the force values.

A more interesting error was to find the initial area under the graph (e.g. the area between 0.00 and 0.02s). It is assumed that the candidates who made this error missed the point that the car had zero momentum after 0.16 s of the collision so the change of momentum is equal to the initial momentum.

Exemplar 1

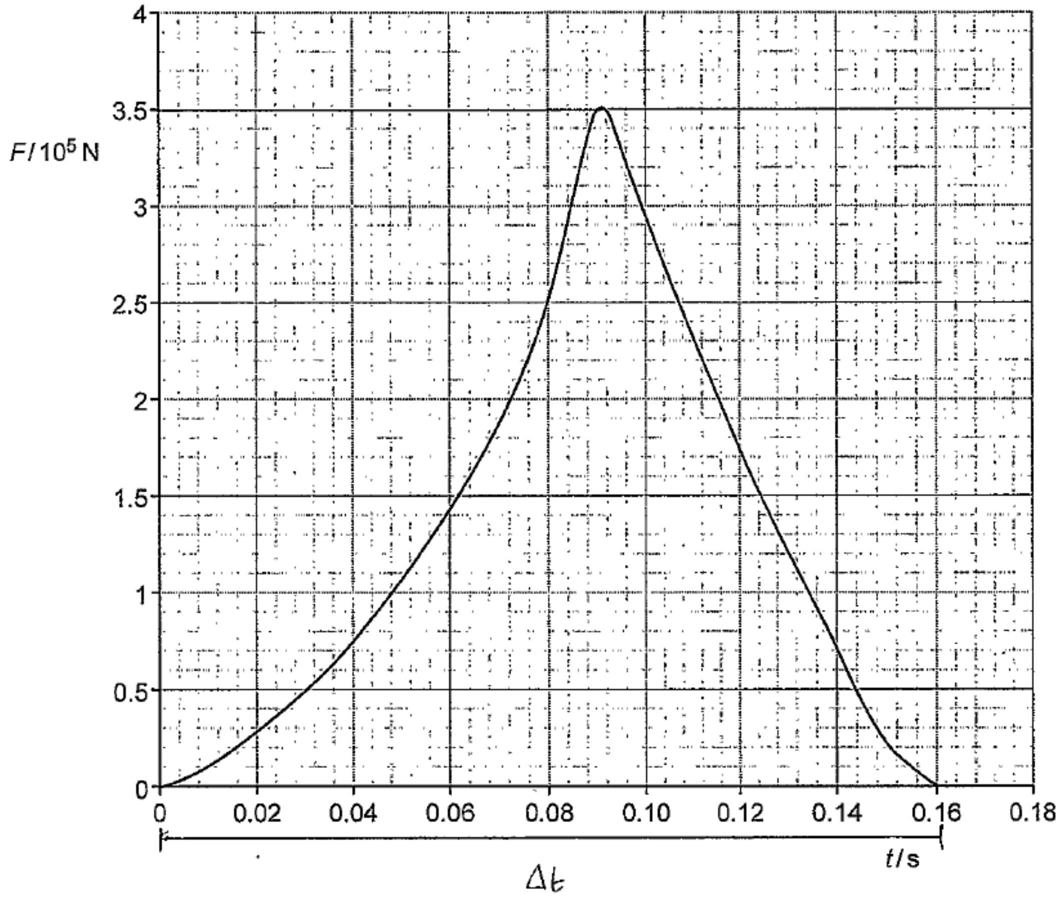


Fig. 1.1

The impulse on the car is given by the area under the curve. Use data from the graph to calculate the initial velocity of the car. Explain your method and reasoning.

mass of car = 1400 kg

impulse = ~~Δt~~ change in momentum.
final momentum = 0
impulse = ½ area = $\frac{1}{2} \times \Delta t \times F = \frac{1}{2} \times 0.16 \times 3.5 \times 10^5$
= 28,000 Ns
change in momentum = initial momentum − 0
initial velocity = $\frac{28,000}{1,400}$ = 20 ms^{-1}

initial velocity of car = ...20...... ms^{-1} **[3]**

This candidate lost one mark by assuming that the area was that of a simple triangle. The candidate gained the final mark through error carried forward.

Question 2 (a)

2 Fig. 2.1 shows a potential divider circuit using cells with very low internal resistance.

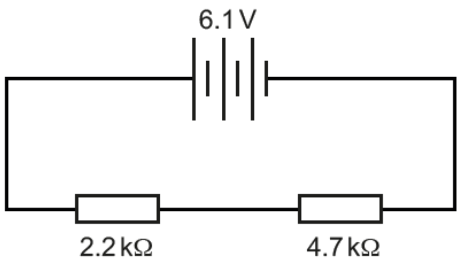


Fig. 2.1

(a) Show that the potential difference across the 4.7 kΩ resistor is 4.2 V to 2 significant figures.

[1]

Question 2 is quite challenging for less confident candidates. However, part (a), a standard potential divider question was answered accurately by the majority of the cohort.

Question 2 (b)

(b) An analogue voltmeter connected across the 4.7 kΩ resistor reads 3.2 V.

Show that the resistance of the voltmeter is about 5 kΩ.

[3]

Part (b) was one of the most discriminating questions on the paper. Unusually for a 'show that' question, having the value to aim for did not help the candidates. Answering correctly required recognising that the voltmeter and 4.7 kΩ resistor act as a parallel combination of resistors in series with the 2.2 k Ω resistor. This was clearly a novel situation for some candidates who could not reach the first step of finding the total resistance of the parallel combination. This will be a useful question to use in class.

Interestingly, very few candidates attempted the reverse method given in the mark scheme. This may have been an easier route for some but it is good to see that the majority of the cohort try to work towards the expected value rather than use the expected value and work backwards.

?	**Not recognising the voltmeter as a resistor**	Students may have assumed that all meters are perfect, voltmeters with infinite resistance and ammeters with zero resistance. This question requires that they understand the meter making the measurement will have an impact on the circuit.

Question 2 (c) (i)

(c) A cell is made by inserting a zinc strip and a copper strip into a potato. When the same analogue voltmeter is connected to the cell as shown in Fig. 2.2, it registers a potential difference of 0.50 V.

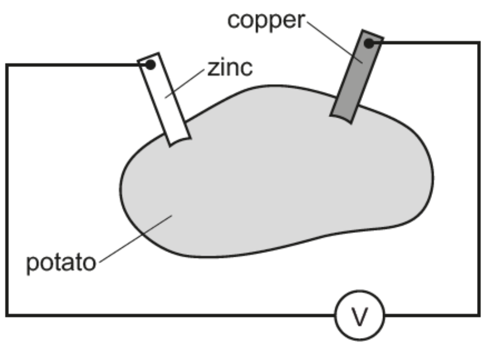


Fig. 2.2

(i) Using your answer to **(b)**, calculate the current in the circuit.

current = ... A **[1]**

In contrast to part (b) this was a very straightforward task and the majority of candidates gained the mark.

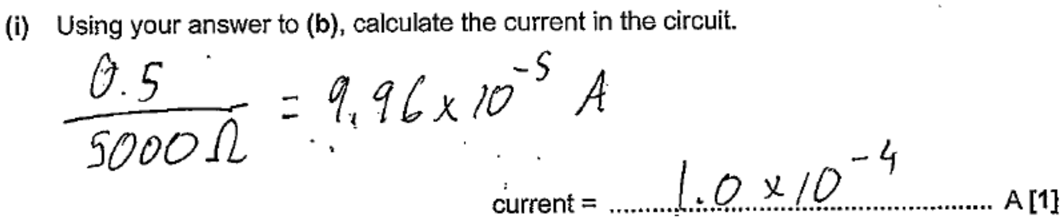
Question 2 (c) (ii)

(ii) When a digital voltmeter of resistance 1.0 MΩ replaces the analogue voltmeter in Fig. 2.2, it registers a potential difference of 0.93 V. Use the readings from the two meters to calculate an estimate for the internal resistance of the potato, stating any assumptions you make.

internal resistance = ... Ω **[3]**

Another challenging calculation. The best responses laid out the simultaneous equations clearly and worked through to the correct value. This was very encouraging. Candidates scoring two out of the possible three marks tended to assume that the emf of the potato cell is 0.93 V but did not clearly state their assumption.

Exemplar 2


(i) Using your answer to (b), calculate the current in the circuit.

$\frac{0.5}{5000\,\Omega} = 9.96 \times 10^{-5}$ A

current = 1.0×10^{-4} A [1]

This exemplar has been included to show a clear and unambiguous response. The examiners did not see many with the reasoning laid out so clearly.

Question 3 (a)

3 This question is about electromagnetic induction and eddy currents.

(a) A bar magnet is dropped through a vertically mounted coil connected to a data-logger, as shown in Fig. 3.1.

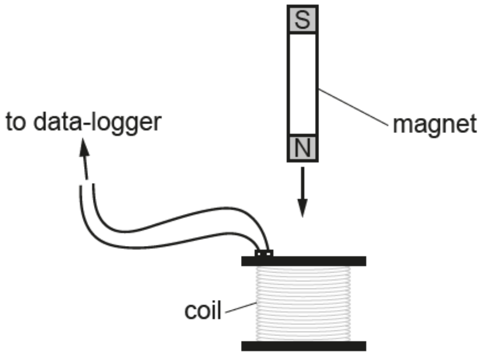


Fig. 3.1

The e.m.f. recorded by the data-logger varies as shown in Fig. 3.2.

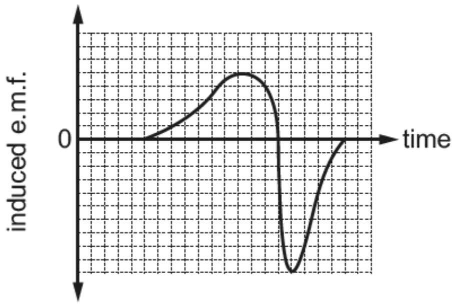


Fig. 3.2

Use the ideas of electromagnetic induction to explain the variation in e.m.f. in Fig. 3.2. **[4]**

Candidates often find questions taken from the Electromagnetic section of the specification difficult to gain high marks from. This difficulty is compounded if the questions require explanatory responses. As Question 3 was firmly based in this section of the course and was had a high proportion of non-arithmetical questions it is unsurprising that many found this the most challenging whole question on the paper. Part (a) asked candidates to explain the variation in e.m.f. shown in a figure. A complete explanation required linking the movement of the magnet through the coil to the generation of e.m.f. and finally an explanation of the shape of the trace in the figure. Many candidates missed marks by not linking their answer to the figure. Responses also showed a confusion between change in flux and change in flux linkage – many candidates seeming not to appreciate the difference between the two. This will be another useful question to promote discussion in class to encourage students to hone their use of technical vocabulary.

Exemplar 3

The e.m.f. recorded by the data-logger varies as shown in Fig. 3.2.

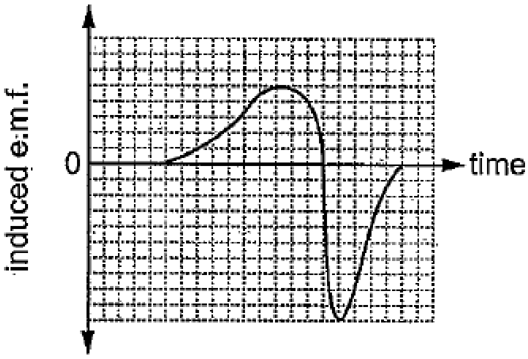


Fig. 3.2

Use the ideas of electromagnetic induction to explain the variation in e.m.f. in Fig. 3.2. **[4]**

When the magnet enters the coil, the coil is cutting the flux lines of magnet. ~~T~~ It will produce induce current. As ~~current~~ $I \propto B$, ~~If the flux~~ ~~to~~ and $\phi = BA$, the ϕ is produced ~~e.m.f~~ e.m.f ~~$= \frac{\Delta N\phi}{\Delta t}$~~, e.m.f = $\frac{dN\phi}{dt}$, ~~th~~ so the induced emf is produced. ~~So the~~ As the magnet is falling down, the flux lines ~~is~~ are increasing, flux density is ~~inde~~ increasing, the rate is increasing. more and more e.m.f is produced. So the curve before the first peak is increasing and the gradient is increasing. As the ~~to~~ gravity force, the acceleration of magnet is increasing so the speed of magnet is increasing. That's why the negative part ~~has~~ a is different from positive part.

This response gained the mark for using the equation correctly in the explanation. Although the candidate seemed to have a basic understanding of the situation, the explanation was not precise enough and not linked to Fig. 3.2 sufficiently to gain more credit.

Question 3 (b)

(b) An aluminium disk, mounted horizontally on a low-friction pivot, is placed between the poles of a strong magnet, as shown in Fig. 3.3. There is a uniform magnetic field between the poles of the magnet.

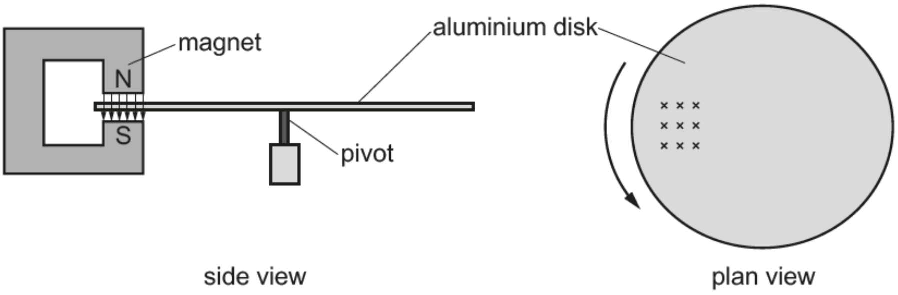


Fig. 3.3

A student sets the disk spinning in the direction shown by the arrow in the plan view above.

Explain how eddy currents are produced in the spinning disk and why these eddy currents make the disk slow down.

.... **[4]**

This is another challenging question, requiring a link between how the eddy currents are produced and how they exert a braking force. Many candidates, who seemed to understand the physics of the situation, lost marks through not giving each step in their explanations. For example, stating that a changing magnetic field in the disk produces an eddy current is less explanatory than describing the changing magnetic field inducing an e.m.f. which drives the current.

Exemplar 4

(b) An aluminium disk, mounted horizontally on a low-friction pivot, is placed between the poles of a strong magnet, as shown in Fig. 3.3. There is a uniform magnetic field between the poles of the magnet.

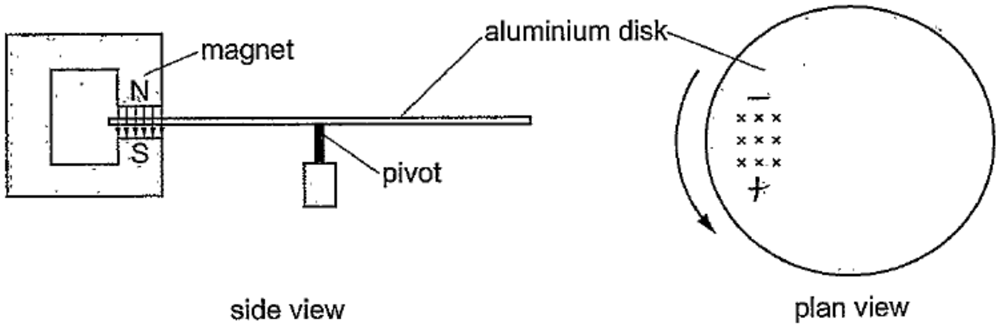


Fig. 3.3

A student sets the disk spinning in the direction shown by the arrow in the plan view above.

Explain how eddy currents are produced in the spinning disk and why these eddy currents make the disk slow down.

~~electrons in~~ Aluminium is made of a lattice of positive ions and ~~a sea~~ of negative ~~electrons~~, as these electrons pass through the magnetic field they produce eddy currents that act in the opposite to the direction of motion, they counteract the force that's changing the field in the metal, they make the disk slow. ~~Item~~ Eddy currents are made by the current being induced in the metal by the field all currents have a magnetic field of their own, ~~they add~~ eddy currents add * ~~to~~ at the bottom of the field as shown and cancel the field at the top as field lines want to straighten out the disk is slowed. Don't get energy for free so must cancel

* to the field

[4]

This exemplar once again shows some understanding of the situation. The candidate gains marks for showing a reasonable understanding of the application of Lenz's law to the situation described and linking the braking effect to the field produced by the eddy currents but other parts of the response are less clear.

Question 3 (c) (i)

(c) The student monitors the slowing of the aluminium disk using light gates to measure the speed of a card fastened to the edge of the disk, as shown in Fig. 3.4.

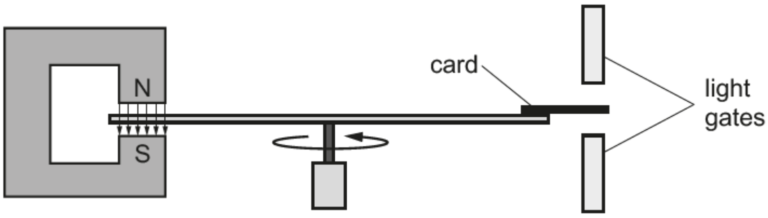


Fig. 3.4

Fig. 3.5 shows how the speed falls over time.

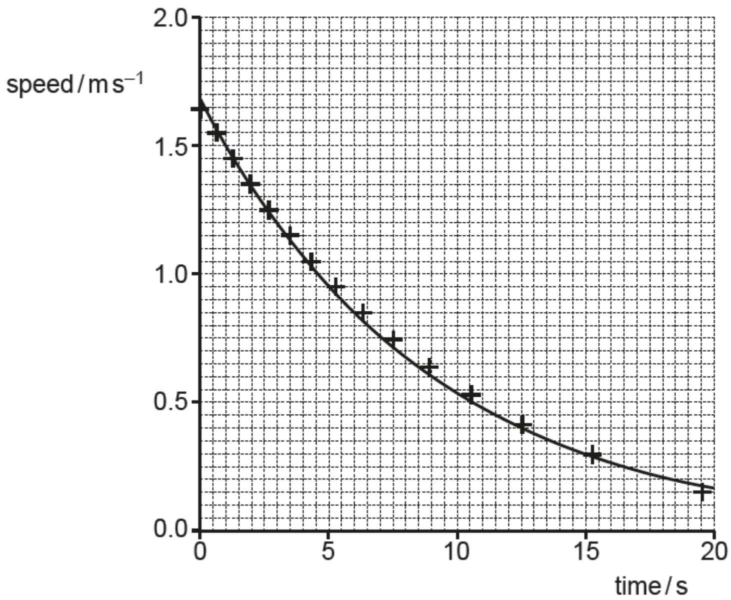


Fig. 3.5

The student suggests that the speed decreases exponentially.

(i) Explain what the student means by 'decreases exponentially' and, using ideas from part **(b)**, explain whether you would expect the speed of the disk to decrease in this way.

....

.... **[4]**

The majority of the candidates correctly described exponential decay – some describing constant fractional decrease over equal time periods, others giving a more general description of a change in a quantity proportional to the magnitude of the quantity. Some candidates attempted more mathematical definitions but these were occasionally confused.

As in parts (a) and (b), the explanatory responses were less secure, candidates showing a broad grasp of the phenomenon but not providing each step in the argument.

Exemplar 5

Decreases by the same ratio over a given time period, for example the speed halves every second, or something like that. Yes I would expect this as the force produced by the eddy currents ~~would~~ is related to the velocity so as velocity decreases force decrease so change in velocity would decrease

In this case the candidate correctly describes the idea of exponential decrease although the answer is not as clear as the best responses. The candidate also gains credit for linking the braking force to the rate of rotation but misses the steps in the argument.

Question 3 (c) (ii)

(ii) Use data from the graph to test whether there is an exponential decrease in speed over time. Make your conclusion clear.

.... **[3]**

This form of question has appeared a number of times over the years. The majority of the candidates gained at least one mark. Those that did not score tried unsuccessfully to link the gradient of the line to exponential decay whereas those that demonstrated the constant ratio or simple 'half-lives' on three or more ratios gained all the marks if they made a reasonable conclusion.

Section B overview

This section comprises three longer questions which contribute 42 marks to the paper. It includes one level of response question. The section includes explanatory questions and multi-stage calculations. Lower ability candidates managed to gain marks in most areas but the multi-stage calculations in Question 5 proved more challenging. Higher ability candidates performed well throughout the section which included a lot of familiar physics.

Question 4 (a) (i)

4 This question is about electrons showing wave-like properties.

(a) **(i)** An electron is accelerated through a p.d. of 4.3 kV. Calculate the velocity of the accelerated electron. Ignore relativistic effects.

velocity = ... $m\,s^{-1}$ **[2]**

This standard calculation was accessible to most candidates. The main source of error was in rearranging the kinetic energy equation. Some candidates gave velocity values far greater than *c* – perhaps showing a lack of thought about what their calculators showed them.

Question 4 (a) (ii)

(ii) Explain whether it is reasonable to ignore relativistic effects in the calculation in **(a)(i)**. Include a calculation in your explanation.

[3]

Another accessible, familiar calculation. Some candidates did not perform a calculation but gained a mark for stating that the velocity of the electron is about 0.1 *c* and linking this to the statement that it is reasonable to ignore relativistic effects at this speed. The majority of correct answers were based on calculating the gamma factor through the Lorentz equation rather than using the rest energy and k.e. of the particle.

Question 4 (a) (iii)

(iii) Calculate the de Broglie wavelength of the accelerated electron.

wavelength = ... m **[1]**

A third standard calculation which only caused difficulties to the weakest candidates.

Question 4 (b)

(b) Accelerated electrons can be diffracted by layers of graphite in a very similar way to light diffracted through a grating. When electrons are accelerated in a glass vessel and pass through graphite, they diffract and form circular rings on a fluorescent screen. Each electron striking the screen emits a tiny flash of light.

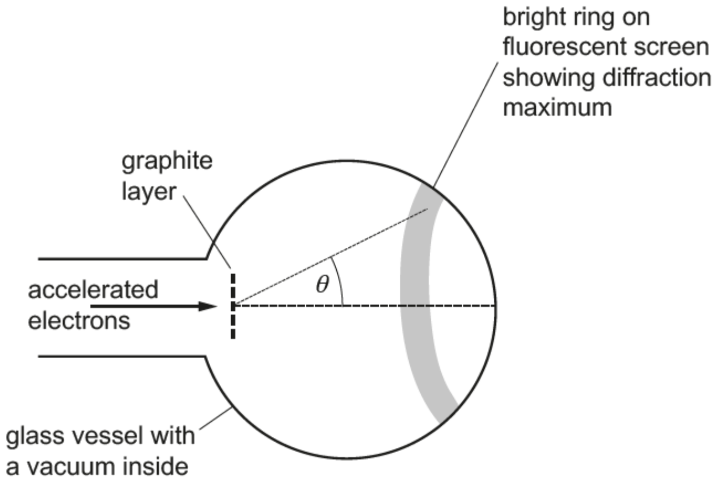


Fig. 4.1

Explain why the rings on the screen become smaller and brighter when the accelerating p.d. the electrons pass through is increased.

.... **[3]**

Many responses correctly linked increasing velocity to decreasing wavelength and then made the link between wavelength and angle of diffraction, often quoting the diffraction grating equation which, although the situation is not the one-dimensional phenomenon the equation relates to, nonetheless shows an understanding of the essential physics.

Candidates found it more difficult to account for the brightening of the rings. Many candidates suggested that released photons had more energy (individually) rather than a greater number of photons released. Another error was to think that more electrons struck the screen per second.

Relatively few candidates suggested that more photons are released – the more common accepted answer was that as the rings are smaller the electron-screen collisions are more densely packed.

Question 4 (c)

(c)* Explain how this demonstration shows that electrons can be considered as 'quantum particles' showing both wave-like and particle-like behaviour. Your answer should describe which aspects of the demonstration show each type of behaviour and explain how diffraction effects can be explained using ideas about phasors. **[6]**

The majority of the responses gained Level 2 or 3 on this level of response question. Most candidates clearly stated the link between diffraction and wave-like behaviour, the better responses explaining diffraction in terms of wave superposition. The description and explanation of particle-like behaviour were less secure – few responses used the 'tiny flash of light' described in part (b) as an identifier of quantisation whereas a good number of responses stated that waves cannot be accelerated – this was accepted by the examiners as the situation under consideration has the electrons travelling through a uniform medium (so waves would travel at constant speed through the medium).

The phasor explanation was often attempted and the best responses showed a solid understanding of the model and were clear and detailed.

Exemplar 6

the wavelike properties are shown
in its ability to diffract, as
particles dont do so under normal
conditions, and its particle like behaviour
is shown by how they can be
accelerated as if they were
solid entities, as waves can
increase frequency and length but
are restricted in speed as they must
travel at the speed of light (max universal
speed)

Phasors help to explain the phenomenon of both behaviours as they use .

Additional answer space if required

rotating vectors to show formation of maximas (bright rings) and minimas (places of no light) but can also have direction and magnitude with these values being easily changeable by applied forces ~~like~~ like particles would.

This Level 2 response includes a number of the indicative points suggested in the mark scheme but does not develop the ideas. In particular, there is no discussion of superposition of waves or addition of phasor amplitudes.

Exemplar 7

This demonstration ~~so~~ suggests electron have wave ~~particle~~-like behaviour because they display properties of waves - namely, they diffract around the graphite. When electrons are accelerated through the graphite layer, electron "waves" exit ~~throug~~ the graphite and explore all possible paths. ~~For~~ At some parts of the screen, the ~~~~ resultant phasor from all the different electrons and their paths is zero - all the individual phasors curl up and cancel. As probability of an electron arriving (resultant phasor amplitude)^2, this mean that here there is zero probability of arrival, so there is a dark ring. On other point, the resultant phasor is larger, a the phasors from all different path line up, ~~a~~ so the probability

Additional answer space if required

of arrival of an electron is much larger if electrons were waves, however, a smooth image would build up - instead it is speckly and grainy. This shows the particle ~~p~~ behaviour of electron - a grainy image means that individual electrons are hitting the screen slowly building up the image of concentric rings. Therefore electrons must have wave and particle-like behaviour.

This Level 3 response shows understanding of the wave-like and particle-like behaviour of electrons, includes sufficient detail and is a well-constructed piece of writing.

Question 5 (a)

5 A radioisotope that decays forming another isotope is known as a **parent** isotope and the newly formed isotope is known as the **daughter** product. For a sample initially made up of pure parent isotope, with a daughter product which does not decay, Fig. 5.1 shows how the number of parent and daughter nuclei change with time. The daughter product in this case is described as 'stable'.

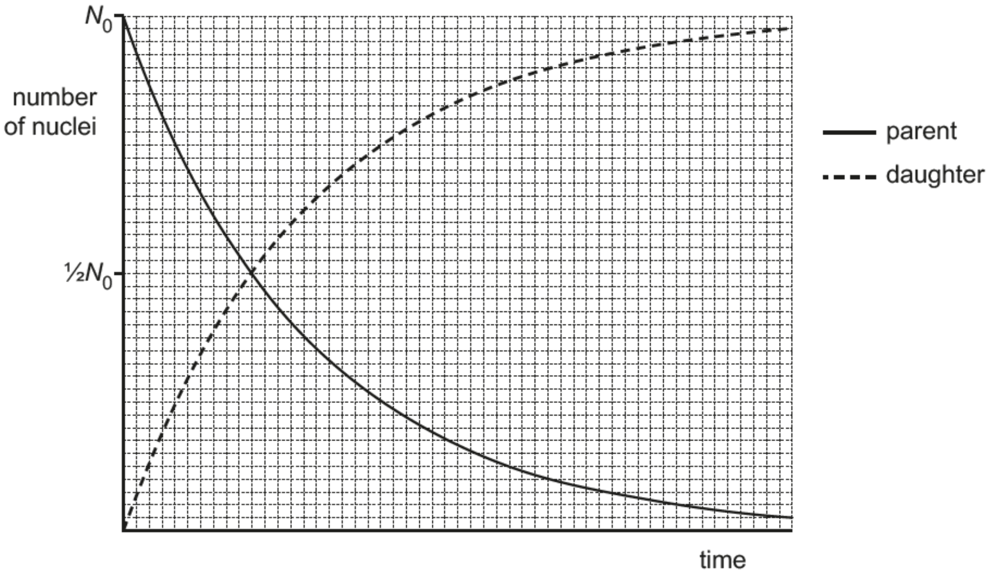


Fig. 5.1

(a) For a stable product, the number of daughter nuclei D at time t is given by the equation

$D = N_0 - N$

where N_0 is the original number of parent nuclei and N is the number of parent nuclei at time t.

Show that the number of daughter nuclei after time t is given by

$D = N_0(1 - e^{-\lambda t})$

[1]

This question put the students' understanding of radioactive decay into a slightly different context. This provided a little more challenge to the question.

In part (a), most candidates clearly and unambiguously performed the simple rearrangement required in this question.

Question 5 (b) (i)

(b) The ratio of the number of parent nuclei to number of daughter nuclei can be used to calculate the age of rocks.

The uranium isotope $^{238}_{92}U$ is the beginning of a 'radioactive series' that ends with the stable isotope of lead, $^{206}_{82}Pb$.

(i) Show that a total of eight alpha decays and six beta decays will produce $^{206}_{82}Pb$ from $^{238}_{92}U$.

[2]

Most candidates accomplished this task -the challenge is to show each step in the argument as clearly as possible. Those candidates who lost marks usually did so because of a lack of clarity about the change in proton number.

Question 5 (b) (ii)

(ii) The half-life of the series is 4.47×10^{9} years. This means that it will take about 4.5 billion years before half the uranium-238 (^{238}U) has decayed into lead-206 (^{206}Pb).

Show that the decay constant for this process is about 1.6×10^{-10} year^{-1}.

[1]

This accessible question was answered correctly by most candidates. The most common error was giving the calculated value as 1.5×10^{-10} year^{-1}, a rounding error.

Question 5 (b) (iii)

(iii) A rock is assumed to have contained no lead-206 when it was formed.

In a sample of the rock, the ratio

$$\frac{\text{number of lead-206 atoms present in rock sample}}{\textbf{original}\text{ number of uranium-238 atoms present in rock sample}}$$

is measured to be 0.39.

Calculate how long ago the rock formed, assuming that all the lead-206 formed has remained in the rock.

time since formation of rock = ... years **[3]**

This standard calculation posed few problems although a significant proportion of the candidates used 0.39 in their calculations – perhaps through not reading the question stem carefully enough.

Exemplar 8

(iii) A rock is assumed to have contained no lead-206 when it was formed.

In a sample of the rock, the ratio

$$\frac{\text{number of lead-206 atoms present in rock sample}}{\textbf{original}\text{ number of uranium-238 atoms present in rock sample}}$$

is measured to be 0.39.

Calculate how long ago the rock formed, assuming that all the lead-206 formed has remained in the rock.

$$\frac{N}{N_0} = 0.39 = e^{-\lambda t}$$

$$\ln 0.39 = -\lambda t$$

$$-\frac{\ln 0.39}{\lambda} = t = 6.0722 \times 10^9 \text{ years}$$

time since formation of rock = 6.07×10^9 years **[3]**

This response is an example of the not-infrequent mistake of using 0.39 as the ratio rather than 0.61.

Question 5 (c) (i)

(c) The same rock sample also contains uranium-235, which undergoes a series of decays to form the stable isotope lead-207.

The half-life of this series is 7.0×10^8 years. The ratio

$$\frac{\text{number of lead-207 atoms present in rock sample}}{\text{number of \textbf{remaining} uranium-235 atoms present in rock sample}}$$

is measured to be 22.8.

(i) Use the relationship $N = N_0 e^{-\lambda t}$ to show that the number of daughter nuclei after time t is given by

$$D = N\left(\frac{1}{e^{-\lambda t}} - 1\right)$$

where N is the number of parent nuclei remaining at time t.

[1]

This proved a little more difficult than the previous rearrangement in part (a) with only around half of the candidates gaining the mark.

Question 5 (c) (ii)

(ii) Use the equation for D given in **(c)(i)** and the data given to calculate the value for the age of the rock based on the uranium-235 decay series.

age of rock = ... years **[3]**

This question required candidates to use a new equation given in the stem and tested the candidates understanding of natural logarithms. Most candidates rose to the challenge although the weaker mathematicians struggled and clearly spent time trying to reach an answer to no avail.

Question 5 (c) (iii)

(iii) Rocks are often dated using three separate decay series. Suggest and explain an advantage of three decay series to date rocks rather than just one.

....

....

....

....

.... **[2]**

Many candidates gained a mark for the low-level response 'you can take a mean' but did not develop this. The better responses considered loss of daughter product or contamination.

	Misconception	Some candidates considered the expression 'three separate decay series' to mean 'three decay processes', that is, alpha, beta and gamma decay – even though the term 'radioactive series' was introduced at the beginning of the question and the term 'decay series' used throughout.

Question 6 (a)

6 Fig. 6.1 shows the basic components of a mass spectrometer. This is an instrument which separates ions according to the ratio of their charge to mass.

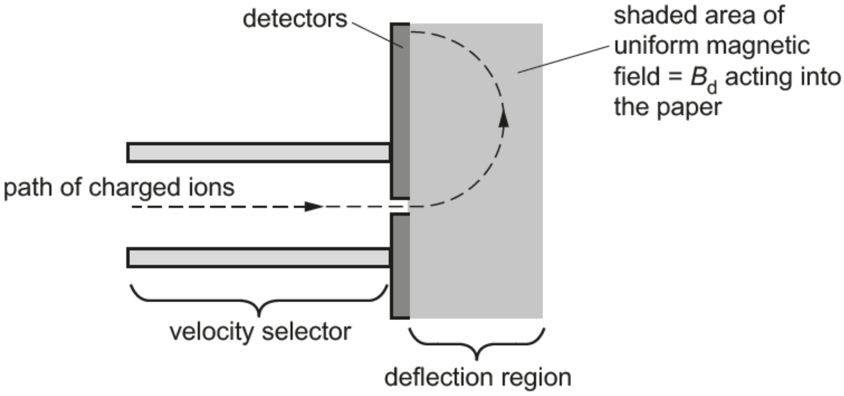


Fig. 6.1

Ions from an ion source (not shown in Fig. 6.1) pass into a region of uniform electric and magnetic fields called a velocity selector. Ions of different mass but with the same velocity will pass through to the deflection region. The ions are then deflected by a separate magnetic field in the deflection region and are detected by a bank of detectors. The position at which the ion is detected depends on the charge-to-mass ratio of the ion.

Fig. 6.2 indicates the uniform electric and magnetic fields in the velocity selector. The magnetic field is acting into the paper. A positive charge q is entering the selector at velocity v.

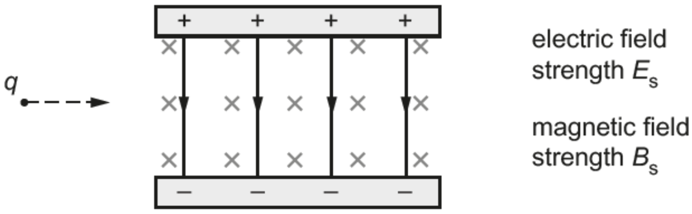


Fig. 6.2

(a) State how Fig. 6.2 shows that the electric field is uniform within the selector.

....

.... **[1]**

This question is about the motion of charged particles through uniform electric and magnetic fields.

Nearly all candidates gained the mark for part (a). A small minority focused on the magnetic field rather than the electric field as required.

Question 6 (b) (i)

(b) A positive charge q moving horizontally through the selector at velocity v as shown in Fig. 6.2 will experience a downwards electric force and an upwards magnetic force.

(i) By considering the forces on the charge, explain why the charge will **not** be deflected when

$$v = \frac{E_s}{B_s}.$$

[2]

Whereas the majority of candidates correctly identified that this equality shows that the forces on the charge are equal, few stated that the forces acted in opposite directions. About a third of the candidates gained both marks by algebraically equating the electric and magnetic forces on the charge

Question 6 (b) (ii)

(ii) Show that the units of $\frac{\text{electric field strength}}{\text{magnetic field strength}}$ are equivalent to the unit of velocity.

[2]

This proved to be challenging with a good proportion of the candidates confusing force and field strength or simply using the incorrect units.

?	**Misconception**	Some candidates confused units with quantities in this question.

Question 6 (b) (iii)

(iii) Describe and explain the motion of charges moving through the region if their velocities are not equal to $\frac{E_s}{B_s}$.

....

....

....

....

....

....

.... **[3]**

This question stretched the most able, even though the marking scheme is quite generous. Most candidates identified that there is a vertical force present, the better responses suggested that the electric and magnetic forces would no longer sum to zero and that the path followed would be a curve.

Once again, there was some confusion between force and field strength – a possible area for class discussion.

?	**Misconception**	Some candidates thought this part of the question concerned the deflection region rather than the velocity selector.

Question 6 (c) (i)

(c) When charges enter the deflection region shown in Fig. 6.3, they experience a force due to the magnetic field.

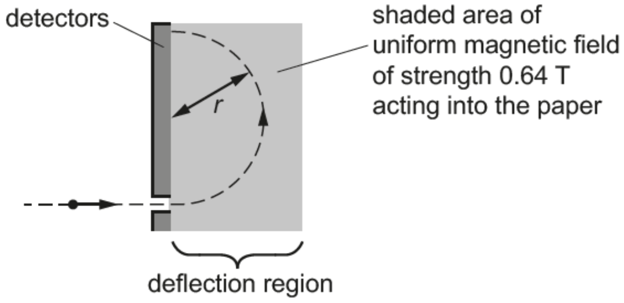


Fig. 6.3

(i) Show that the force on a proton moving at a velocity of $5.2 \times 10^6\,m\,s^{-1}$ at right angles to a field of strength 0.64 T is about 5.3×10^{-13} N.

[1]

A very simple calculation that was accessible to all but a small minority of candidates.

Question 6 (c) (ii)

(ii) Calculate the radius *r* of the path the proton will follow.

radius = ... m **[2]**

Although this seems a simple task, it is not trivial as it requires the candidates to realise that the magnetic force on the charge acts centripetally. Figure 6.3 points the candidates in the right direction but candidates often pay little attention to details on diagrams.

Question 6 (c) (iii)

(iii) A beam of $^{12}_{6}C$ and $^{14}_{6}C$ singly charged positive ions with equal velocities enters a deflection region, travelling at right angles to a uniform magnetic field of unknown strength.

Showing your working, calculate the ratio:

radius of path of $^{14}_{6}C$

[3]

This is a standard calculation. Credit was given for making the initial statement, carrying out the calculation and giving the answer to a reasonable number of significant figures.

Section C overview

This 25 mark section is based on the Advance Notice article 'Is there Life on Mars?'. It includes a number of short questions as well as more extended tasks and an LOR question. There was little evidence of candidates rushing this part of the paper. It was clear that many Centres have prepared their candidates carefully for this section and had spotted areas in which questions could be asked.

	AfL	If there is time, it is a useful exercise to ask the students to work through the Advance Notice article and write their own questions for one another, or to share with the class. This not only helps with Section C of this paper, it can provide a focus for revision of areas that could be tested on other papers in the session.

Question 7

7 Fig. 7.1 is an image from Mariner 9. It shows most of the crater at the top of Olympus Mons.

Item removed due to third party copyright restrictions

Fig. 7.1

Use data from Fig. 7.1 to calculate the resolution of the image.

resolution = ... km pixel^{-1} **[2]**

This is a straightforward question based on work covered early in the course. A large majority of the candidates gained both marks.

Question 8 (a)

8 This question is about Martian meteorites (lines 43–47).

(a) Use the value of *G* and data from the article (lines 56–62) to show that the radius of Mars is about 3.4×10^6 m.

[2]

A standard calculation made more accessible as given as a 'show that'. Some candidates did not gain the second mark because they did not give their own value (either 3.404 or 3.397) before rounding to the 'show that' value.

Question 8 (b)*

(b)* Calculate the gravitational potential at the surface of Mars and use this value to estimate the energy needed to eject a 0.2 kg rock from the surface to a great distance from the planet. Explain your reasoning.

Use ideas about the gravitational potential of the Sun and the Earth to explain why your calculated value is higher than the energy required for the rock to reach Earth but lower than the value required for the rock to escape from the Solar System. **[6]**

This LOR question was well answered by many candidates, with more than half the cohort gaining 3 or more marks. Many responses showed calculations leading to the correct values for V_{grav} and the energy required to remove the rock from the gravitational potential well of Mars. However, the explanations of why the energy required is the value it is were often superficial or incomplete. Candidates' explanations of the second part of the question (to explain why the calculated value is higher than that to reach the Earth but lower than that to escape the Solar System) usually gained some credit but the responses often conflated/confused field strength and potential. The best responses were framed in terms of potential wells.

Exemplar 9

[2]

V GPE

(b)* Calculate the gravitational potential at the surface of Mars and use this value to estimate the energy needed to eject a 0.2 kg rock from the surface to a great distance from the planet. Explain your reasoning.

Use ideas about the gravitational potential of the Sun and the Earth to explain why your calculated value is higher than the energy required for the rock to reach Earth but lower than the value required for the rock to escape from the Solar System. **[6]**

$V = \frac{GM}{r} = \frac{6.67\times10^{-11}\times6.4\times10^{23}}{3.4\times10^{6}}$

$V = -1.26\times10^{7}\ \mathrm{JKg^{-1}}$

$V\times m = E = 1.26\times10^{7}\times0.2 = 2.5\times10^{6}\ \mathrm{J}$

Energy required to escape Mars

The Earth has a higher potential than Mars as the Earth is more massive this means the rock can reach earth as it is attracted by its gravitation field. The sun has an even greater potential which the rock must over come to escape the Solar System as even though it will leave Mars it will be stuck in orbit of the sun.

This Level 2 response correctly calculates the gravitational potential at the surface of Mars and gives the energy required to escape the planet. However, the candidate has not explained the link between the two values. In common with many responses, the use of technical vocabulary is a little limited; for example, describing the Earth as having 'a higher potential than Mars' can be taken to mean a greater negative potential or a potential nearer zero.

Exemplar 10

(b)* Calculate the gravitational potential at the surface of Mars and use this value to estimate the energy needed to eject a 0.2 kg rock from the surface to a great distance from the planet. Explain your reasoning.

Use ideas about the gravitational potential of the Sun and the Earth to explain why your calculated value is higher than the energy required for the rock to reach Earth but lower than the value required for the rock to escape from the Solar System. **[6]**

$V_{grav} = -\frac{GM}{r} = -1.26 \times 10^7 \text{ JKg}^{-1}$

$-1.26 \times 10^7 \times 0.2 = -2.51 \times 10^6 \text{ J}$

$E_{grav} - K_E = 0$

The kinetic energy of the rock should be equal to the gravitational potential energy, so 2.51×10^6 J.

For the rock to reach earth, it only needs to escape the potential well of mars, so the initial eregy required would be lower. For the rock to escape the potential well of mars and the sun, the energy would need to be greater.

This Level 2 response gets closer to an explanation of the link between the value for gravitational potential on the surface of Mars and the kinetic energy required to eject a rock from the surface but the explanation is incomplete. The explanation of the difference in energy required for a rock to reach Earth or escape from the Solar System is very brief and superficial.

Question 9

9 An estimate of the atmospheric pressure p at height h above the surface of Mars can be found from the equation

$$\ln p = \ln p_s - \frac{mgh}{kT}$$

where p_s is the pressure at the average surface level, g is the gravitational field strength at the surface, k the Boltzmann constant and T the temperature of the atmosphere.

The pressure at the top of Olympus Mons is 0.03 kPa. Assuming that the Martian atmosphere is carbon dioxide (mass of one molecule = 7.3×10^{-26} kg), use the equation given and data from the article (lines 56–62) to calculate an estimate for the height of Olympus Mons above average surface level.

Suggest **one** reason why this method of estimating the height may be unreliable and explain how this would affect the value of the pressure at the top of Olympus Mons.

Calculation:

height = ... m

Suggestion and explanation:

....

....

....

....

.... **[4]**

Although the required equation for this calculation is given in the stem of the question the less mathematically confident candidates found it difficult to correctly rearrange the equation. There was no evidence that candidates were not referring to the article to find the required data.

Although the calculation was generally well answered the reasoning for an inaccurate value was less often present. Many candidates did not read the stem of the question carefully enough and wrote about the effect of varying temperature or field strength on the calculation of height rather than the pressure at the top of Olympus Mons. Some responses seemed to be guesses more than considered answers: for example, there is a difference in quality between an answer which states 'the temperature might not be constant' and an answer which suggests 'the article gives the surface temperature of Mars, it is unlikely that this temperature is maintained above the surface of the planet'. In this question both responses would gain the mark for temperature variation but in preparation candidates should be encouraged to give as full responses as time allows.

Exemplar 11

Calculation:

$p = 30$ $k = 1.38\times10^{-23}$ $g = 3.7$

$p_0 = 600$ $T = 210$ $m = 7.3\times10^{-26}$

$\ln 30 = \ln 600$

$\ln\frac{30}{600} = -\frac{mgh}{kT}$

$-\frac{\ln\frac{30}{600}\times kT}{\frac{m}{g}} = h$

$h = \frac{\frac{\ln\frac{30}{600}\times 1.38\times10^{-23}\times 210}{7.3\times10^{-26}}}{3.7}$

$h = 32,142.29$

height = 32,140 m

Suggestion and explanation:

At this height the gravitational field strength would be lower as it is furthur from the ground The temperature would also be less as it is furthur from the ground

[4]

A typical response, gaining three marks. The candidate has reached the correct value for height, identified reasons for the unreliability of the estimate but has not linked the reasons to the pressure at the top of Olympus Mons.

Question 10 (a)

10 A large proportion of the radiation absorbed by astronauts comes from high-energy protons in cosmic rays. The American space agency, NASA, estimates that the dose equivalent received by an astronaut on a three-year return trip to Mars is about 1200 mSv. The calculation assumes that the astronaut spends 18 months on the surface of the planet.

(a) The risk of contracting cancer due to radiation exposure is 5% per Sievert. The percentage risk of contracting cancer for an astronaut on a three-year mission to Mars is about 6%. Compare this with the risk for someone on Earth over the same period. Give reasons for the difference in risk on the two planets.

Annual dose equivalent on Earth from cosmic rays = 0.4 mSv.

risk on Earth = ... %

....

....

....

.... **[3]**

The calculation in this question proved to be surprisingly challenging. A reasonable proportion of the candidates forgot to multiply their answer by three – even though the word 'annual' was emboldened in the text. Most candidates only gave one reason for the difference and some missed a mark by simply citing Earth's 'thicker' atmosphere but not suggesting why this reduces the cosmic ray flux on the surface.

Question 10 (b)

(b) Explain why exposure to radiation increases the risk of contracting cancer and how the high level of radiation on the surface of Mars may affect the design of the buildings for a human colony on the planet.

....

....

....

....

....

....

....

.... **[2]**

Most responses gained the low-level mark about cell damage from radiation. In addition, many candidates gained credit for a design constraint – even when suggesting lead walls to absorb radiation (how all that lead ends up on Mars was clearly not considered to be a problem!). However, some responses did not gain the mark because they simply described a solution (thick walls) but did not give a reason why their solution would reduce the risk of contracting cancer – a reason was required for the mark.

Question 11 (a)

11 This question is about placing a 'magnetic shield' at the L1 point between Mars and the Sun (lines 86–95). Fig. 11.1 shows the position of the L1 point.

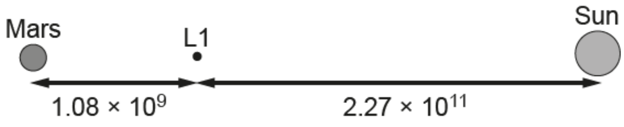


Fig. 11.1 (not to scale)

(a) Calculate the centripetal force required to keep a 1000 kg 'shield' in orbit around the Sun at the L1 point with an orbital period the same as the orbital period of Mars.

Show that the combined gravitational force from the Sun and Mars acting on the 'shield' is approximately equal to the centripetal force required.

orbital period of Mars = 5.94×10^{7} s
mass of Sun = 2.00×10^{30} kg

[5]

Many candidates had prepared well for a question on the gravitational forces acting on the shield. Some missed out on full marks because they added the force on the shield from Mars to the force on the shield from the Sun – assuming that the two forces acted in the same direction. The examiners saw some pleasingly clear responses to a long calculation at the end of a long paper.

Exemplar 12

11 This question is about placing a 'magnetic shield' at the L1 point between Mars and the Sun (lines 86–95). Fig. 11.1 shows the position of the L1 point.

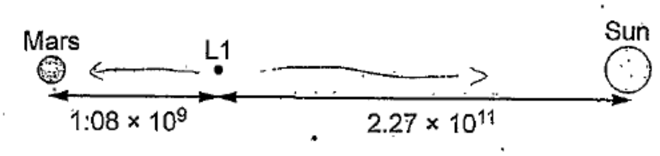


Fig. 11.1 (not to scale)

(a) Calculate the centripetal force required to keep a 1000 kg 'shield' in orbit around the Sun at the L1 point with an orbital period the same as the orbital period of Mars.

Show that the combined gravitational force from the Sun and Mars acting on the 'shield' is approximately equal to the centripetal force required.

orbital period of Mars = 5.94×10^7 s
mass of Sun = 2.00×10^{30} kg

$F_{sun} = \frac{6.67\times10^{-11} \times 2\times10^{30} \times 1000}{(2.27\times10^{11})^2} = 2.59\,N$

$V = \frac{S}{t} = \frac{2\pi \times 2.27\times10^{11}}{5.94\times10^{7}}$

$V = 2.4\times10^4\,m/s$

$F_{mars} = \frac{6.67\times10^{-11} \times 6.4\times10^{23} \times 1000}{(1.08\times10^{9})^2} = 0.037\,N$

$F = \frac{mv^2}{r} = \frac{MmG}{r^2}$, $v^2 = \frac{MG}{r}$

$F = \frac{1000\times(2.4\times10^4)^2}{2.27\times10^{11}} = 2.54\,N$

$2.59 - 0.037 = 2.553\,N$

$2.553 \approx 2.54\,N$

$F_{sun} - F_{mars} = F_c$

This is an example of a well-constructed response. It has been included to show the clarity of thinking and presentation the examiners saw in many candidates' answers to this question, perhaps reflecting good use of the advance notice article in class. The answer gained all five marks but could have been improved by a clear statement that the calculated force of 2.54 N is the centripetal force required for the shield to orbit at the particular radius and speed.

Question 11 (b)

(b) Suggest why the shield may not remain at the L1 point even though the net force from Mars and the Sun is equal to the centripetal force required.

....

....

.... **[1]**

This final question gave few candidates any problems.

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