OCR
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Friday 24 May 2019 – Morning

A Level Physics B (Advancing Physics)

H557/02 Scientific literacy in physics

Time allowed: 2 hours 15 minutes

You must have:
- the Insert (inserted)
- the Data, Formulae and Relationships booklet (sent with general stationery)

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) ______________________

Last name ______________________

INSTRUCTIONS
- The Insert will be found inside this document.
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **28** pages.

Turn over

SECTION A

Answer **all** the questions.

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]**

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

[2]

(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]

(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.

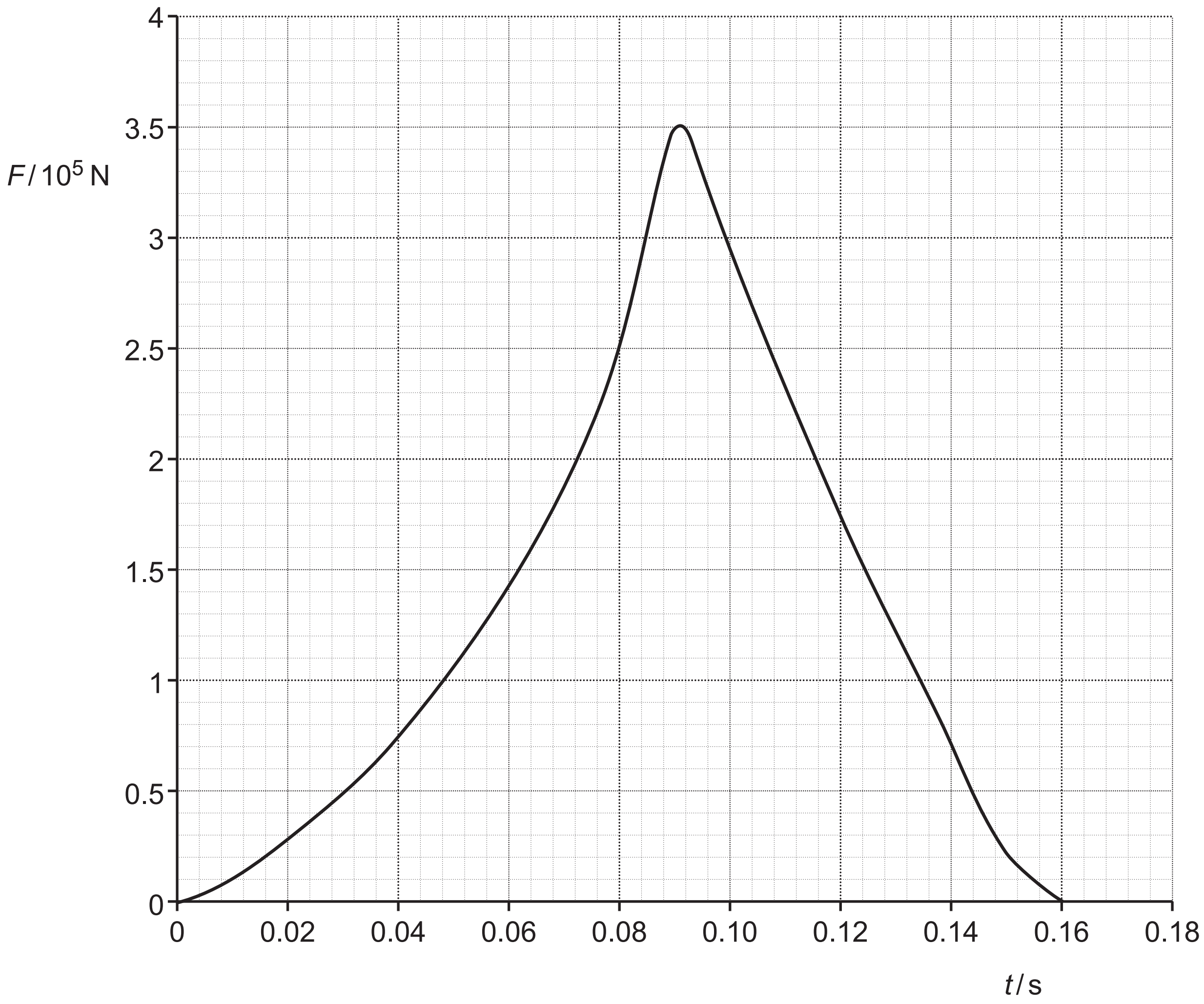

Fig. 1.1

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]**

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

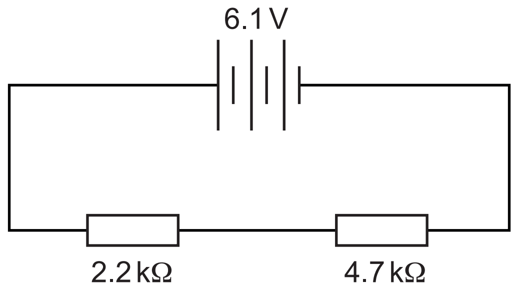

Fig. 2.1

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

[1]

(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]

(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.

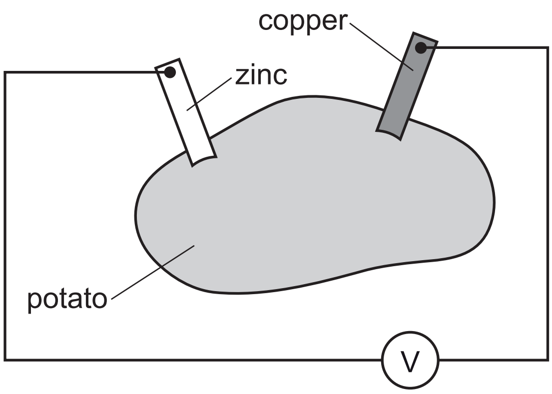

Fig. 2.2

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

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

(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]**

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.

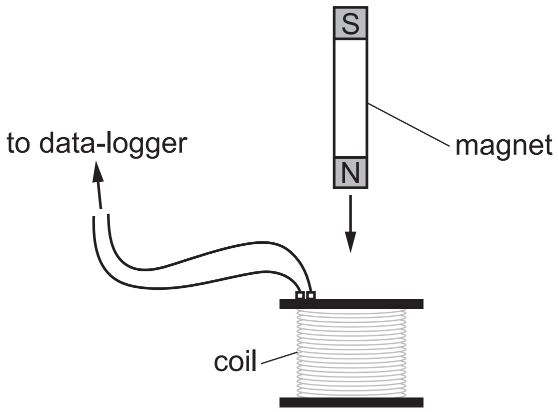

Fig. 3.1

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

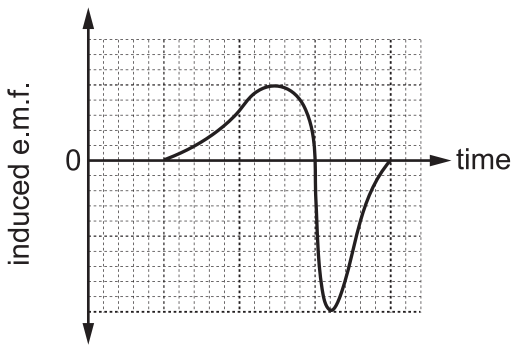

Fig. 3.2

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

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(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.

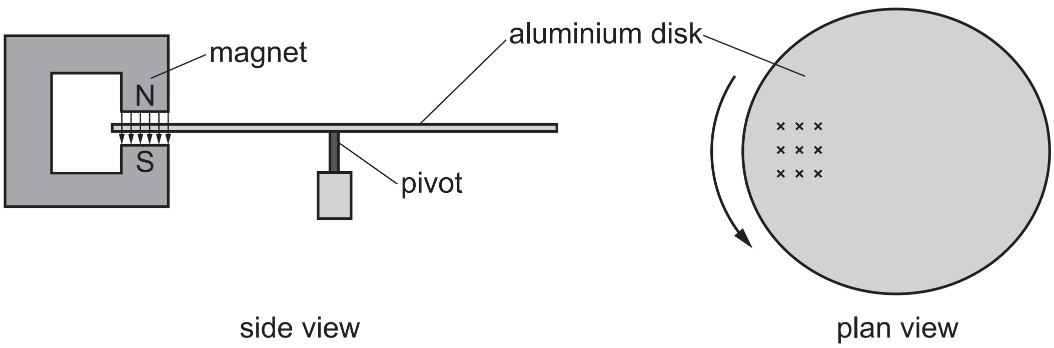

Fig. 3.3

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.

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.... **[4]**

(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.

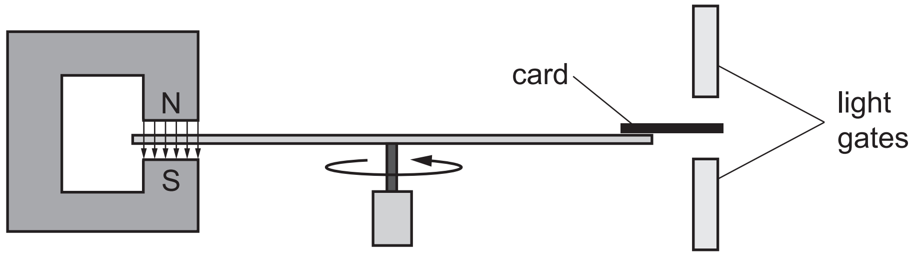

Fig. 3.4

Fig. 3.5 shows how the speed falls over time.

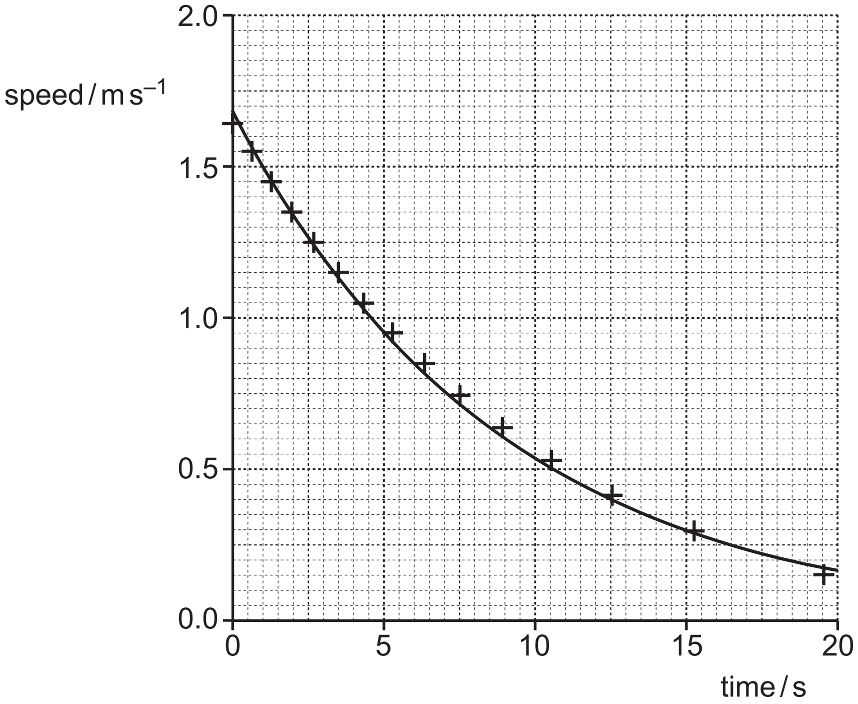

Fig. 3.5

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.

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.... **[4]**

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

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.... **[3]**

SECTION B

Answer **all** the questions.

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]**

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

[3]

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

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

(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.

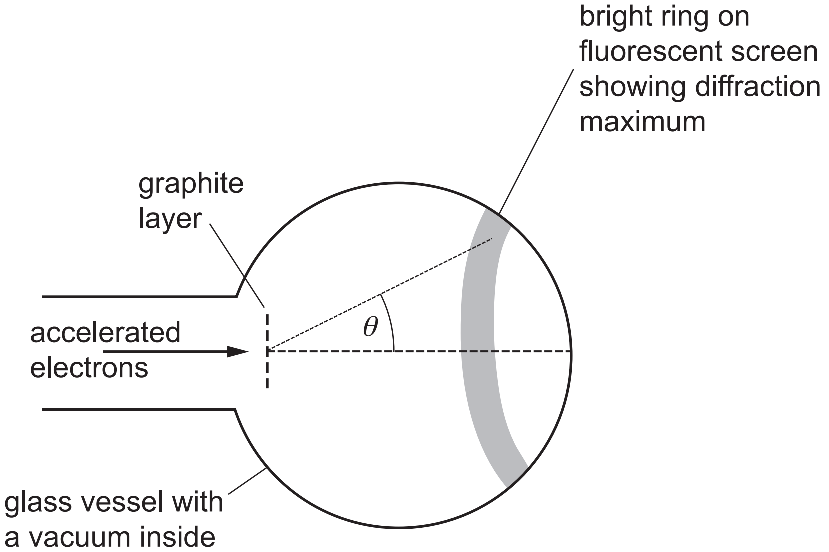

Fig. 4.1

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

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.... **[3]**

(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]**

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Additional answer space if required

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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'.

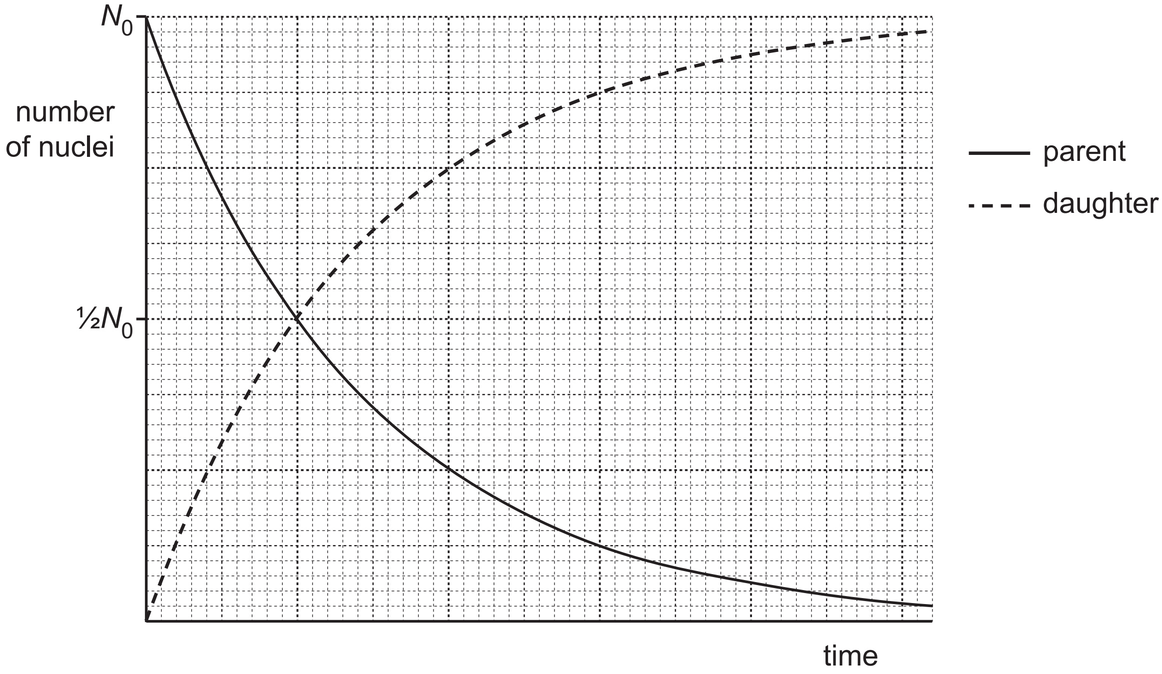

Fig. 5.1

(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]

(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]

(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]

(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]**

(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]

(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]**

(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.

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.... **[2]**

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.

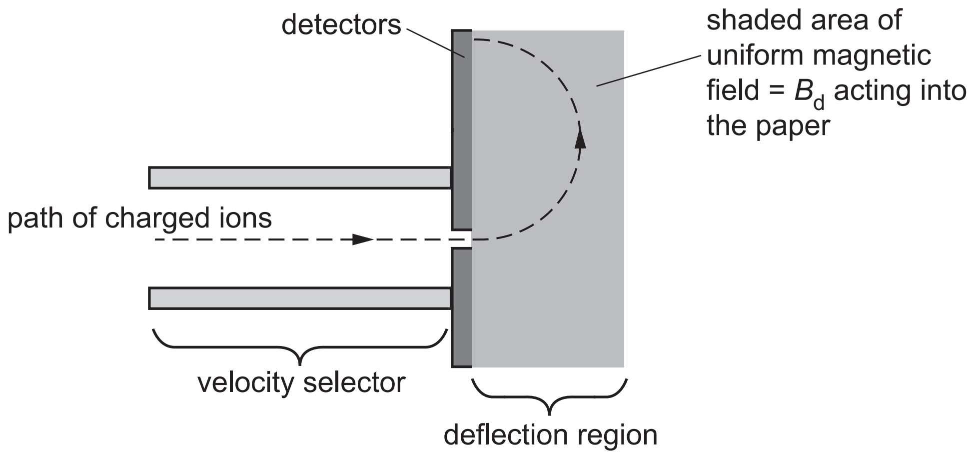

Fig. 6.1

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.

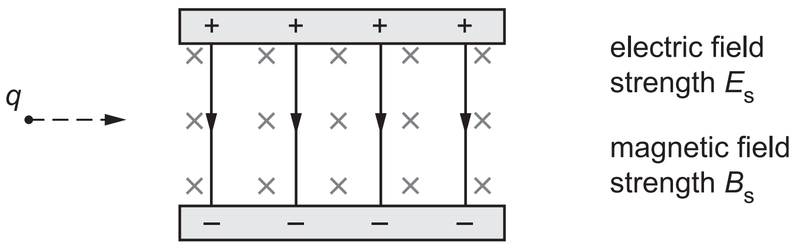

Fig. 6.2

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

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.... **[1]**

(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]

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

[2]

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

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.... **[3]**

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

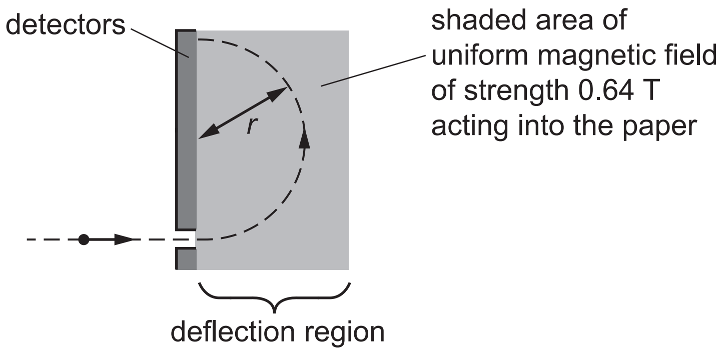

Fig. 6.3

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

[1]

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

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

(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:

$$\frac{\text{radius of path of } ^{14}_{6}C}{\text{radius of path of } ^{12}_{6}C}$$

[3]

SECTION C

Answer **all** the questions.

This section is based on the Advance Notice Article, which is an insert.

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

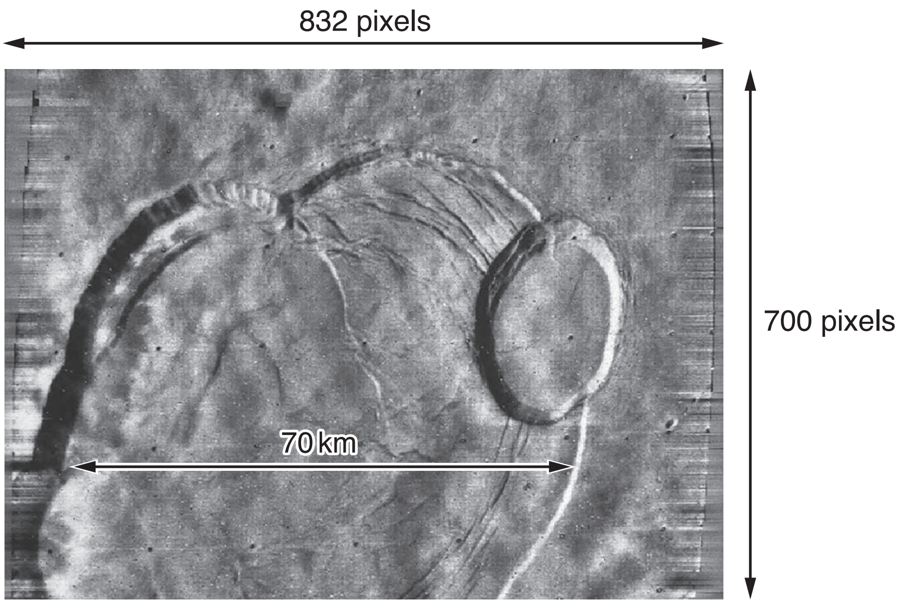

Fig. 7.1

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

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

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]

(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]**

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Additional answer space if required

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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:

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.... **[4]**

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 = ... %

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.... **[3]**

(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.

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.... **[2]**

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]

(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.

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.... **[1]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

Oxford Cambridge and RSA

Friday 24 May 2019 – Morning

A Level Physics B (Advancing Physics)

H557/02 Scientific literacy in physics

Insert

Time allowed: 2 hours 15 minutes

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INSTRUCTIONS
- Do not send this Insert for marking; it should be retained in the centre or recycled.
- Please contact OCR Copyright should you wish to re-use this document.

INFORMATION
- This Insert contains the Advance Notice.
- This document consists of **4** pages.

Is there Life on Mars?

Observations from Earth

The planet Mars appears as a red star-like object to the unaided eye. Its reddish colour encouraged the Romans to name the planet after their god of war and, since then, Mars has caught the imagination of astronomers and writers alike.

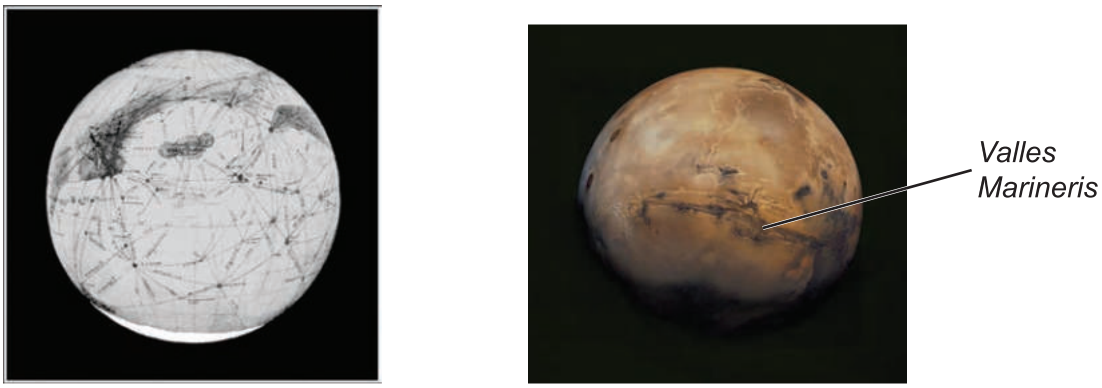
Mars does not take a simple path through the skies that the ancient observers could easily explain using their model of an Earth-centred Universe with the Sun, Moon, planets and stars revolving around a stationary Earth. It took the genius of Johannes Kepler in the early decades of the seventeenth century to provide a simple explanation for Mars's reversals of direction in its journey through the constellations. Kepler reasoned that the planets, including Earth, travel around the Sun in ellipses and that the square of the orbital period of a planet is proportional to the cube of its mean distance from the Sun. Kepler's laws, an explanation for the puzzling behaviour of Mars, gave a new perspective on the Universe which Isaac Newton embraced in his theory of universal gravitation published in 1687.

Visual observations of the planets improved as telescopic astronomy developed, but some observers recorded details that have since proved to be illusions. In 1877, the Italian Giovanni Schiaparelli used favourable observing conditions to draw a map of Mars. He observed what he called *canali*, translated as canals, on the surface of Mars. This apparent observation was interpreted as evidence of liquid water on the planet.

Some other observers reported similar features. The American astronomer Percival Lowell made detailed drawings and believed that canals were made by intelligent beings in an attempt to transport water from the poles of the planet to the barren equatorial regions. Many astronomers were sceptical about Lowell's claims because of the limited resolution of the telescopes of the time but his ideas caught the popular imagination. For example, H.G. Wells took Lowell's idea of a dying Mars and imagined its inhabitants attempting to colonise the Earth in his 1897 novel *The War of the Worlds*.

A closer look

In 1971, Mariner 9 became the first space probe to orbit Mars and it succeeded in sending images back to Earth of a barren landscape that showed signs of water flow in the distant past but no evidence of liquid water on the surface. However, Mariner revealed that Mars has a dramatic geological past that produced, among many other features, a huge system of canyons, the *Valles Marineris*, which cuts across 4000 km of the surface of the planet, reaching depths of 7 km. This can be seen in the right-hand image of Fig. 1. Mariner 9 also discovered the largest volcano in the Solar System, Olympus Mons, with a crater 80 km wide and standing about 27 km above the average surface height.



Map by Lowell's team (left) and an image from the Viking 1 orbiter (1976)

Fig. 1

Mariner was followed by the Viking 1 lander, which touched down on the surface of Mars in 1976. One of the purposes of the mission was to search for evidence for simple life on the planet. Viking found no such evidence and data from more recent landers suggests that Mars is unlikely to have ever supported even the simplest life form.

Visitors from Mars

The Earth is frequently struck by small fragments of rocky material. Some of these are known to have originated on Mars. It is thought that a collision between the planet and an asteroid or comet could give the fragments sufficient energy to escape Mars. Some scientists think that there is fossil evidence of possible simple life forms in samples of the Martian meteorites, but this is disputed.

Visitors to Mars

Recent years have seen a growing interest in human missions to Mars. Perhaps, rather than the terrifying machines of *The War of the Worlds* colonising Earth from a failing planet, humans will colonise Mars from an overcrowded, resource-hungry world. It is known that there is sufficient water-ice on and under the planet for a colony to be set up and Mars has many minerals vital to maintaining such a venture. However, there are numerous practical problems to overcome because Mars is a very different world from Earth. Colonising Mars is a technical and scientific challenge that dwarfs any other attempted by humankind.

Mars data: gravitational field strength at surface = $3.7\,\text{N}\,\text{kg}^{-1}$
mass = $6.4 \times 10^{23}\,\text{kg}$
average surface temperature = 210 K
atmospheric pressure at surface = 0.6 kPa
orbital radius = $2.3 \times 10^{11}\,\text{m}$

Atmosphere: 95% carbon dioxide, 3% nitrogen, remaining fraction composed of argon and trace amounts of other gases

The small size of Mars means that it has kept little of any atmosphere it may have once had. The Earth's atmosphere is protected from a large proportion of cosmic rays and other charged particles by its magnetic field, producing a magnetic barrier around the Earth known as the magnetosphere. Although Mars had a magnetic field in earlier times, it now has no such field and a greater proportion of charged particles from the Sun reach the surface of the planet, giving a higher intensity of radiation and increasing the rate of loss of atmosphere. The low pressure on the surface of Mars means that humans will be required to wear pressure suits when outside their pressurised cabins. The dangers from radiation will limit time spent outside living quarters, which will need to be carefully designed and located. Such buildings require materials and energy to construct. If the materials are not transported from Earth, the early missions to the planet will need to seek the minerals required and set up production plants. Some energy will be available from sunlight, but the inverse-square law shows that the available energy will be lower than that at Earth.

Terraforming Mars

An even more ambitious plan than setting up colonies on Mars and protecting the new Martians from their hostile environment is to change the environment to suit humans, a process known as *terraforming*. Two major challenges faced are: (a) to increase the amount of carbon dioxide in the atmosphere to produce global warming and (b) to create a magnetosphere to reduce the intensity of radiation at the surface and slow down the loss of the new gases pumped into the atmosphere. Mars has sufficient carbon dioxide as dry ice in its polar regions to significantly increase the atmospheric pressure. One suggestion is to use orbiting mirrors to focus sunlight on the polar regions to release gaseous carbon dioxide. If sufficient carbon dioxide is introduced into the atmosphere, liquid water will remain on the surface rather than rapidly evaporating.

Pumping more gas into the atmosphere will not be worthwhile if cosmic rays are allowed to strip the atmosphere away. It has been suggested that a magnetic shield might be placed between the Sun and Mars to direct cosmic rays away from the planet in a similar fashion to the magnetosphere around Earth.

The idea is that the shield is placed at the 'L1' point between Mars and the Sun (Fig. 2). At this position, the shield will orbit the Sun at the same rate as Mars so the shield, Mars and the Sun will remain in line. The gravitational pull of Mars reduces the centripetally acting gravitational force on the shield from the Sun as the force due to Mars acts in the opposite direction to that of the Sun. The values of the forces due to Mars and the Sun give a net force on the shield that is precisely that required to orbit the Sun at the same rate as Mars, even though it is nearer the Sun.

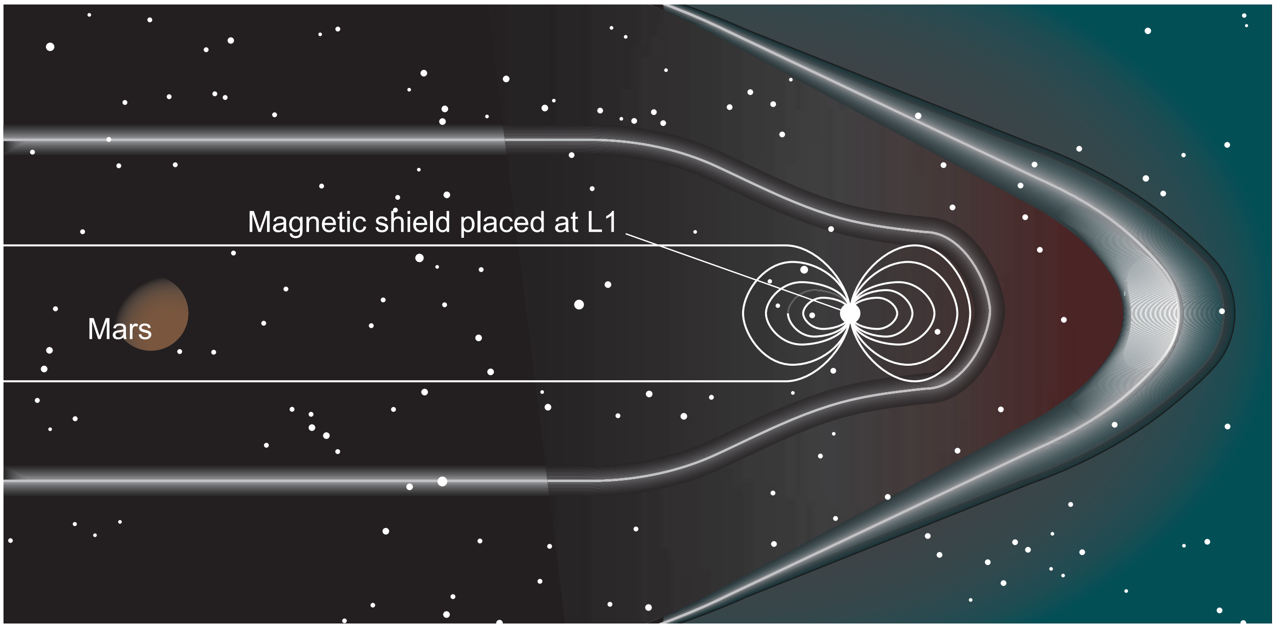


Fig. 2

Many scientists and engineers are working on developing technologies and systems to allow humans to reach Mars, and possibly stay on the surface of the planet. NASA has recently stated that it hopes to have humans on the surface in the 2030s and Russia has made a similar statement of intent. Private companies are also investigating missions to the red planet. Perhaps the answer to David Bowie's question 'Is there life on Mars?' is: not at the moment, but in a few decades' time, who knows?