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Examiners' Report
June 2018

GCE Physics 9PH0 01

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June 2018
Publications Code 9PH0_01_1806_ER

Introduction

This paper is the first of three available at A level. It covers the following topics: Mechanics and Further Mechanics, Electric Circuits, Electric and Magnetic fields and Nuclear and Particle Physics. The question styles include multiple-choice, short open, open-response, calculations and extended writing.

Learners who had prepared well and understood their physics scored high marks on this paper.

A small number of learners appeared to run out of time during the last question but the evidence would suggest the time allowed was appropriate.

The following multiple choice questions proved relatively accessible to all learners: 3, 4, 5 and 8.

The following multiple choice questions proved highly discriminating: 2 and 7.

Most learners produced good answers to basic calculations such as Q11(a), Q13(b) and the more challenging calculation in Q18(b).

It was particularly pleasing to note how well learners performed in the indicative content style question Q12. This topic is difficult and yet clear fluently written answers worth 5 marks or more were often seen.

Learners who had carried out thorough revision were well rewarded in Q15(a) and Q17(a) which carried a total of 10 marks.

Most of the "explain" questions carried three marks such as Q15(c)(i), Q16(c) and Q18(a). Learners often made at least one good point in these questions but then failed to develop their answer further.

It was very pleasing to note that the responses to the "deduce" questions were much improved with many answers including sensible comparisons with data given in the question.

Question 11 (a)

This question tested the use of the resistivity equation.

A small proportion of learners misread diameter for cross-sectional area or omitted the unit to the answer.

This shows an answer which confuses the diameter for the area of the wire.

11 A "metre bridge" is a circuit which can be used to measure an unknown resistance accurately. The metre bridge includes a metre length of nichrome wire.

(a) Calculate the resistance of a 1.00 m length of the nichrome wire.

(3)

resistivity of nichrome = $1.12 \times 10^{-6}\ \Omega m$

diameter of wire = 4.00×10^{-4} m

$R = \frac{\rho l}{A}$ $\quad R = \frac{(1.12 \times 10^{-6}) \times 1}{4 \times 10^{-4}}$

$R = 2.8 \times 10^{-3}\ \Omega$

Resistance = $2.8 \times 10^{-3}\ \Omega$

ResultsPlus Examiner Comments

The equation is dimensionally incorrect - a diameter does not have the same dimensions as area. This answer cannot be awarded the "use of" the resistivity formula mark.

It also cannot gain MP2 so gets 0 out of 3 marks.

This answer shows that the learner has forgotten to square the radius when calculating the cross-sectional area.

11 A "metre bridge" is a circuit which can be used to measure an unknown resistance accurately. The metre bridge includes a metre length of nichrome wire.

(a) Calculate the resistance of a 1.00 m length of the nichrome wire.

(3)

resistivity of nichrome = $1.12 \times 10^{-6}\ \Omega m$

diameter of wire = 4.00×10^{-4} m

$r = 2.00 \times 10^{-4}$

$R = \frac{\rho L}{A}$ Area $= \pi r^2$

$\pi \times 2 \times 10^{-4} = 6.283 \times 10^{-4}\ m^2$

$6.283 \times 1m = 6.283 \times 10^{-4}$

$\frac{1.12 \times 10^{-6} \times 1}{6.283 \times 10^{-4}} = 1.783 \times 10^{-3}$

Resistance = $1.78 \times 10^{-3}\ \Omega$

ResultsPlus
Examiner Comments

As the learner does realise the area should have units m^2 the "use of" the resistivity equation was given credit.

This answer gets 1 out of 3 marks.

This answer shows that the cross-sectional area is being calculated correctly and the resistivity is therefore dimensionally correct.

11 A "metre bridge" is a circuit which can be used to measure an unknown resistance accurately. The metre bridge includes a metre length of nichrome wire.

(a) Calculate the resistance of a 1.00 m length of the nichrome wire.

(3)

resistivity of nichrome = $1.12 \times 10^{-6}\ \Omega m$
diameter of wire = 4.00×10^{-4} m

$R = \frac{\rho l}{A}$ $\quad$ $R = 8.91 \times 10^{-4}$

$R = \frac{1.12 \times 10^{-6} (1)}{\pi (2 \times 10^{-4})^2 \times 1}$

$R = \frac{1.12 \times 10^{-6}}{1.25 \times 10^{-3}}$

Resistance = 8.91×10^{-4}

ResultsPlus
Examiner Comments

The answer is incorrect and the unit is missing. This answer does achieve the two "use of" formula marks.

This answer shows a correct method and answer with unit.

11 A "metre bridge" is a circuit which can be used to measure an unknown resistance accurately. The metre bridge includes a metre length of nichrome wire.

(a) Calculate the resistance of a 1.00 m length of the nichrome wire.

(3)

resistivity of nichrome = $1.12 \times 10^{-6}\ \Omega m$
diameter of wire = 4.00×10^{-4} m

$R = \frac{\rho L}{A}$ Area of circle is πr^2

$\pi \times \left(\frac{4.00 \times 10^{-4}}{2}\right)^2 = 1.2566 \times 10^{-7}\ m^2$

$R = \frac{(1.12 \times 10^{-6}) \times 1}{\pi \times \left(\frac{4.00 \times 10^{-4}}{2}\right)^2} = 8.91267...\ \Omega$

Resistance = 8.91Ω

ResultsPlus
Examiner Comments

This answer gets 3 marks out of 3

Question 11 (b) (i)

Learners were expected to explain how the potential varied along the length of a (potentiometer) wire.

Many answers stated that the resistance of wire increases (or is proportional) with its length for MP1.

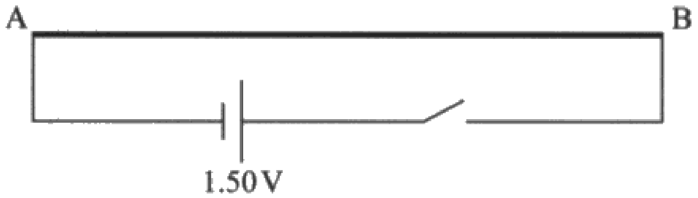
A number of answers did not state that the potential (or potential difference) would be proportional to the length of wire.

It was not sufficient to say that the resistance increased with length for the second mark.

Some learners opted to write down the resistivity equation and *V* = *IR.* This was not credited unless the student had drawn out the key relationship involved, i.e. *V* proportional to *l.*

This answer scores the mark for resistance increasing with length (MP1).

(b) This metre length of wire, labelled AB, is connected to a 1.50 V cell of negligible internal resistance and a switch as shown.



(i) Explain how the potential along this wire varies with distance from A when the switch is closed.

(2)

At A, p.d. is 0, as there is no resistence between the cell and point A. As the p.d. is measured along the wire towards B, the p.d. increases as there is more resistance due to wire length.

ResultsPlus
Examiner Comments

The learner does not make it clear that the potential increases proportionally to length so does not gain MP2.

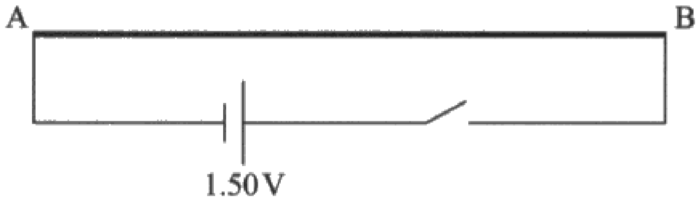
ResultsPlus
Examiner Tip

Make sure you address the question. In this case it asked for an explanation of how potential varies with distance.

In your answer, be as specific about this as you can.

This answer uses a slightly alternative but good approach.

(b) This metre length of wire, labelled AB, is connected to a 1.50 V cell of negligible internal resistance and a switch as shown.



(i) Explain how the potential along this wire varies with distance from A when the switch is closed.

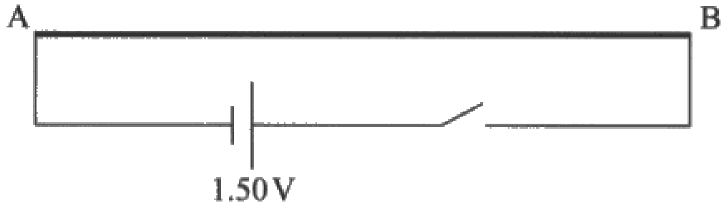
(2)

using V = IR by moving further along the wire the R increases since the current must pass through a greater length of wire and since I is constant then V must increase as distance increases.

ResultsPlus
Examiner Comments

The student did not clearly state that the relation between potential and length would be proportional so achieves MP1.

(b) This metre length of wire, labelled AB, is connected to a 1.50 V cell of negligible internal resistance and a switch as shown.



(i) Explain how the potential along this wire varies with distance from A when the switch is closed.

(2)

Potential ~~~~ is directly proportional to distance from A, as resistance ∝ length and voltage ∝ resistance.

ResultsPlus Examiner Comments

This answer has both points and achieves full credit.

Question 11 (b) (ii) - (c)

Question 11(b)(ii) was correctly answered in most cases.

Q11(c) was well answered by those learners who either understood how to correctly apply *V* =*IR* or spotted that the ratio of resistors would be the same as the ratio of lengths of wire or potential differences.

A number of students tried to use *V* =*IR* incorrectly. A total p.d. of 1.5 V is across the total resistance (3.30 + *R*) not the 3.30Ω resistor alone.

(b)(ii) is calculated correctly.

This learner correctly calculates the current through R using a corresponding *V* (1.125 V) and *R* (3.3 Ω).

The learner then correctly calculates the total resistance of the series pair of resistors but forgets to subtract 3.3 Ω.

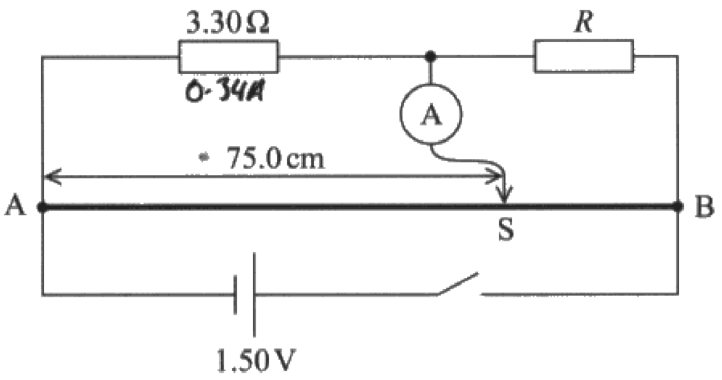
(ii) Show that the potential difference between A and a point 75.0 cm along the wire from A is about 1.1 V.

(2)

$\frac{0.75}{1} = 0.75$ $0.75 \times 1.50V = 1.125$

$\approx 1.1V$

(c) The metre bridge circuit is shown. The circuit includes a resistor of resistance 3.30 Ω, a very sensitive ammeter and a resistor of unknown resistance R.



A metal slider S can be moved along the nichrome wire and pressed firmly against it to make an electrical connection.

When the switch is closed and S is 75.0 cm along the nichrome wire, the ammeter reads 0 A because the potential difference across the ammeter is zero.

Calculate R.

(2)

V = IR

~~R = V/I~~ 1.125 V/R = I   1.125/3.3 = 0.34A

V/R1 = 1.5/0.34 = R

= 4.41

R = 4.41 Ω

(Total for Question 11 = 9 marks)

ResultsPlus
Examiner Comments

11(c) achieves 1 mark out of 2.

This learner used a laborious method for (b)(ii) but it is entirely correct.

(ii) Show that the potential difference between A and a point 75.0 cm along the wire from A is about 1.1 V.

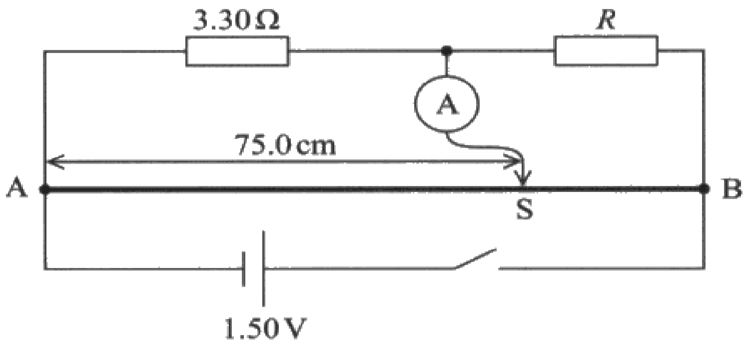
(2)

$V_{out} = \frac{V_{in} R_1}{R_1 + R_2}$ $R_1 + R_2 = 8.91\,\Omega$ $V_{in} = 1.5\,V$

$R_1 = 8.91 \times \frac{75}{100} = 6.685\,\Omega$

$V = \frac{1.5 \times 6.685}{8.91} = 1.125\,V$

(c) The metre bridge circuit is shown. The circuit includes a resistor of resistance 3.30 Ω, a very sensitive ammeter and a resistor of unknown resistance *R*.



A metal slider S can be moved along the nichrome wire and pressed firmly against it to make an electrical connection.

When the switch is closed and S is 75.0 cm along the nichrome wire, the ammeter reads 0 A because the potential difference across the ammeter is zero.

Calculate *R*.

(2)

~~$8.91 \times \frac{25}{100} = 2.2275\,\Omega$ = resistance of section SB~~

Ratio of resistances $\frac{AS}{AB} = \frac{3.3}{R}$

$\therefore R = 3.3 \times \frac{25}{75} = 1.10\,\Omega$

R = 1.10 Ω

(Total for Question 11 = 9 marks)

ResultsPlus
Examiner Comments

The learner then used a ratio of lengths method to calculate *R* for full credit in (c).

(ii) Show that the potential difference between A and a point 75.0 cm along the wire from A is about 1.1 V.

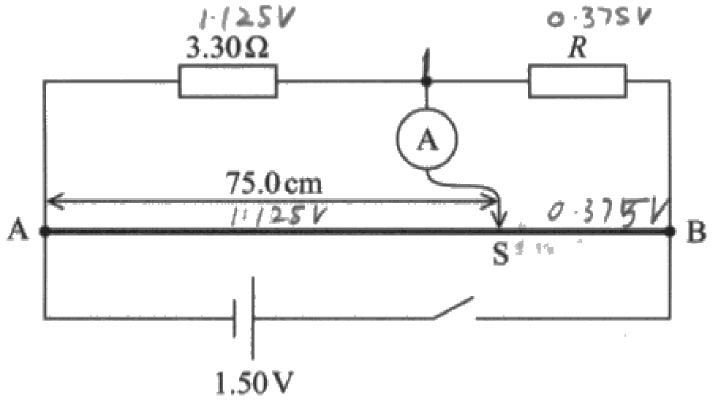
(2)

ratio 75cm : 25cm so $R_1 = 3R_2$

$\therefore V_{OUT} = \frac{V \times R_1}{R_1 + R_2} = \frac{1.5 \times 3R_2}{4R_2} = \frac{4.5}{4}$

$= 1.13\ V$

(c) The metre bridge circuit is shown. The circuit includes a resistor of resistance 3.30 Ω, a very sensitive ammeter and a resistor of unknown resistance R.



A metal slider S can be moved along the nichrome wire and pressed firmly against it to make an electrical connection.

When the switch is closed and S is 75.0 cm along the nichrome wire, the ammeter reads 0 A because the potential difference across the ammeter is zero.

Calculate R.

(2)

$I = \frac{V}{R} = \frac{1.125}{3.3} = 0.341\ A$

$R = \frac{V}{I} = \frac{0.375}{0.341}$

$= 1.10\ \Omega$

$R =$ 1.10 Ω

(Total for Question 11 = 9 marks)

ResultsPlus
Examiner Comments

This learner completed (b)(ii) correctly.

They have shown the potential differences across each resistor and correctly calculated the current.

The final use of $V = IR$ is correct for full credit.

ResultsPlus
Examiner Tip

Make sure you understand that when using $V = IR$ the potential difference has to correspond to that resistor.

Question 12

This question provided an opportunity for learners, with a thorough understanding of Faraday's and Lenz's laws of electromagnetic induction, to apply both laws to a novel context.

Many answers demonstrated a very sound understanding of this difficult topic.

The answer required learners to appreciate that the initial current within a magnetic field would produce rotation of the coil. The coil would cut magnetic flux and induce an emf.

Lenz's law states that the induced current will oppose the change that caused it and reduce the overall current in the circuit. The faster the coil rotates the larger the induced emf and hence the smaller the resultant current.

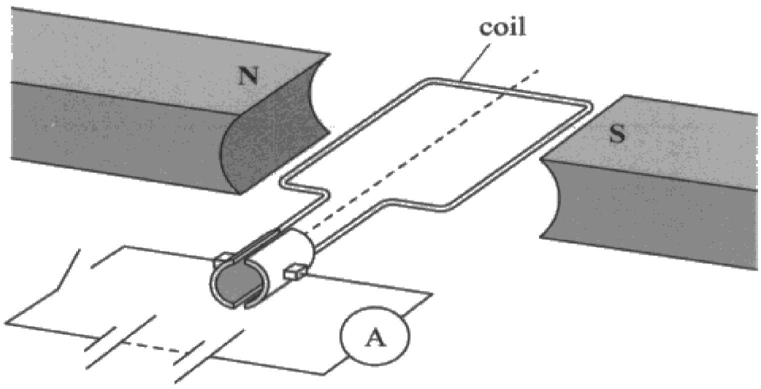
Some answers did not associate the movement of the coil with a rate of change of flux linkage. Simply quoting Faraday's law in isolation was not given credit.

A number of answers did not mention that the coil would rotate.

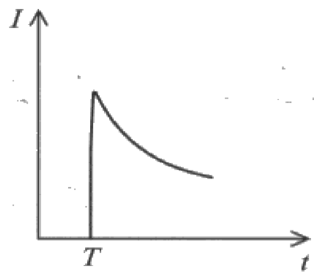
Without a movement of the coil, the magnetic flux of the magnets cannot be "cut" and the explanation becomes vague.

***12** A simple electric motor consists of a coil that is free to rotate in a magnetic field.

A student connects the motor to an ammeter and a battery.



The graph shows how the current I in the coil varies with time t. The switch is closed at time T.



Explain why the current rises to a maximum then decreases.
Your answer should include a reference to Faraday and Lenz's laws.

(6)

This is because the emf induced is the change in flux linkage over the change in time so when the switch is activated the current increases dramatically as the magnetic flux density has suddenly increased over a short period of time. This is suggested as Faraday states that emf induced is proportional to flux linkage and time.

~~tha~~ and by applying the equation $\mathcal{E} = \frac{\Delta N\phi}{\Delta t}$ this shows that. The reson the current drops off is due to the magnetic field no longer being perpendicular so less emf is induced as the angle gets further from the normal.

(Total for Question 12 = 6 marks)

$$\mathcal{E} = \frac{\Delta N\phi}{\Delta t.}$$

Flux linkage = $BAN\cos\theta$.

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Examiner Comments

This answer then does not gain any credit.

ResultsPlus
Examiner Tip

Although the question said include a reference to Faraday's and Lenz's laws you need to consider how they apply in the situation being described.

This answer collected the first four marking points.

However, it misquotes Lenz's law.

Using faradays law; as switch is closed there is a current in the coil, between the N and S poles there is also a magnetic field. This causes the force on the coil clockwise. Due to this there is coil moves and cuts magnetic flux lines. Hence suggesting that due to a rate in change of flux linkage an emf is induced, hence the current in the coil. ~~however as time increases the current~~ This causes the current to rise

as shown in the graph. However the current decrease area due to Lenz's law which suggests that the emf induced is opposed by the force causing it. Hence current decreases as coil moves slower in the magnetic field. ~~then~~ Thus less emf induced; less current produced

(Total for Question 12 = 6 marks)

ResultsPlus
Examiner Comments

Lenz's law is about the direction of induced current opposing the CHANGE that produced it.

ResultsPlus
Examiner Tip

Make sure you learn Lenz's law correctly.

This answer demonstrates a good understanding of both laws of electromagnetic induction.

When the switch is closed, a current flows through the coil. ~~At this~~ The current flowing in the coil creates a magnetic field. ~~The~~ This magnetic field interacts with the magnetic field of the permanent magnets. According to Fleming's left hand rule ~~this~~ a force acts on the coil perpendicular to both the direction of flow of current and the magnetic field. (marked on diagram). This causes the coil to rotate. This results in a change in magnetic flux linkage. As according to Faraday $\varepsilon = -\frac{d(N\Phi)}{dt}$ (emf; flux; coil no.; time) this rate of change in magnetic flux linkage ~~in the~~ induces an EMF in the coil. According to Lenz's law, this emf will be in a direction that opposes the change that caused it. Hence the ~~current will~~ EMF induced will cause the e^- to try to move in the opposite direction to that dictated by the battery. Hence the net current decreases as the coil rotates. The rotation gets slower as current decreases, hence the ~~decr~~ rate of decrease of current decreases as time progresses

(Total for Question 12 = 6 marks)

ResultsPlus
Examiner Comments

This answer achieves the first five mark points but does not collect the last marking point.

It suggests that the rotation of the coil gets slower rather than faster and loses the thread of a good argument.

ResultsPlus
Examiner Tip

Try to keep a clear head when discussing Lenz's law.

Question 13 (a)

This part of the question was about taking moments.

The answer required a moment of *T* around the pivot and a moment of weight around the pivot. The two expressions then had to be equated.

Some answers incorrectly took moments around the right-hand end of the beam using 5.5 m as a distance to the centre of mass of the beam.

It would have been useful to mark the weight and its position on the diagram.

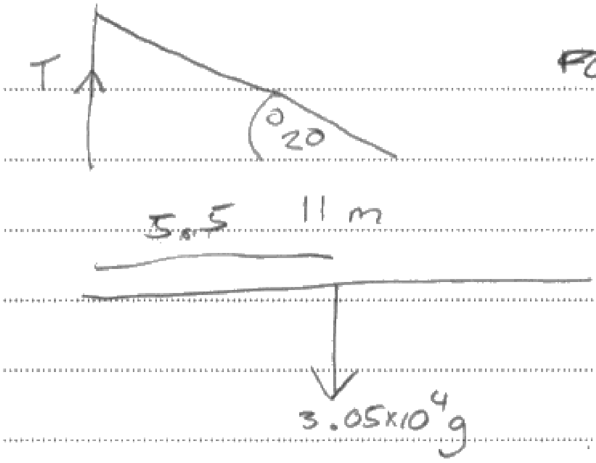
A significant number of students did not appreciate that the moment of a force requires a perpendicular component.

This answer shows an incorrect perpendicular component of force to the distance.

The steam cylinder rod exerts a force *T* on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force *T*.

(4)



F ⟹ M = F x D

1645628 = T sin(20) x 6

T = 164568 / 6 sin(20) ≈ 80195 N

~~T = 80 200 N~~

T = 802000 N

~~M = 1795230 Nm~~

M = 3.05x10^4 x 9.81 x 5.5 = 1645628 Nm

T = ~~80200 N~~ 802000 N

ResultsPlus
Examiner Comments

The moment of *T* around the pivot should be *T*cos20 x 6

The answer collects MP2 only for using *g*.

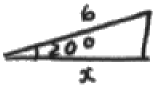
ResultsPlus
Examiner Tip

An alternative to finding the perpendicular component of force is to find the perpendicular distance from the pivot to the line of action of the force - in this case the vertical i.e. 6cos20.

This shows a correct moment for *T* around the pivot for mark point 1.

The steam cylinder rod exerts a force *T* on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force *T*.



(4)

horizontal distance rod to pivot: $\cos 20 = \frac{x}{6}$ ∴ $x = 6\cos 20$

horizontal d weigth to pivot: $\cos 20 = \frac{x}{1}$ ∴ $x = \cos 20$

moments about P: rod: $m = F \times d$

$= T \times 6\cos 20$ cw

weight: $m = 3.05 \times 10^4 \times \cos 20$

∴ $3.05 \times 10^4 \cos 20 = T 6 \cos 20$

$T = \frac{3.05 \times 10^4 \cos 20}{6 \cos 20}$

T = 5080 N

ResultsPlus
Examiner Comments

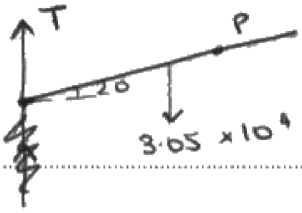
The learner has forgotten to convert the mass of the beam to weight and forgets to multiply by the perpendicular distance from the pivot to the centre of mass of the beam (0.5 m x cos 20).

This answer forgets to convert the mass of the beam to weight.

The steam cylinder rod exerts a force T on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force T.

(4)



$3{\cdot}05 \times 10^4$ ~~x3~~ $\cos 20^\circ \times (5{\cdot}5 - 5) = T\cos 20^\circ \times 6$

$\dfrac{14330{\cdot}3}{6\cos 20} = T$

$T = 2541{\cdot}67$

$\simeq 2540\,N$

ResultsPlus Examiner Comments

It does show a correct moment for T (MP1) and does appreciate the centre of mass of the beam is half way along the beam - a perpendicular distance of 0.5 x cos20 (MP3).

ResultsPlus Examiner Tip

If you decide to calculate moments using a perpendicular distance from the pivot to the force it is useful to sketch these distances onto the diagram.

The steam cylinder rod exerts a force T on the beam. The force exerted on the beam by the pump rod can be neglected.

Calculate the force T.

(4)

$6\cos 20 = 5.638\,m$ $\quad F\Delta s = M$

$0.5\cos 20 = 0.4698\,m$ $\quad \overset{\curvearrowright}{M} = \overset{\curvearrowleft}{M}$

$(6\cos 20)(T) = (0.5\cos 20)(3.05\times 10^4)(9.81)$

$= 140580.3653$

$T = 24933.75$

$T =$ 25000 N

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Examiner Comments

This answer is completely correct for full credit. It is also well laid out and clear.

Question 13 (b)

This question involved an energy (or power) efficiency calculation and because it was a "deduce" question required learners to make a numerical comparison.

Some answers used a wrong factor for time, e.g. multiplying by 3600 to convert minutes into seconds.

This answer writes down a correct expression for *mgh* but forgets to use *g*.

(b) The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10%.

Deduce whether this claim for efficiency was correct.

(5)

Energy used:

$1250 \times 22.3\ \text{MJ} = 27875\ \text{MJ} = 2.7875 \times 10^{10}\ \text{J}.$

work done

→ per minute: W_m = [crossed out] = $Fx = 2500 \times g \times 12$

$W_m = 30000g$

→ per day: minutes in a day $= 60 \times 24 = 1440.$

$W_d = 30{,}000 \times 1440 = 2{,}073{,}600$

Efficiency $= 100 \times \dfrac{\text{work done}}{\text{total energy}} = \dfrac{2073600(100)}{2.7875 \times 10^{10}}$

$= 7.44 \times 10^{-3}\,\%$ = [crossed out]

ResultsPlus
Examiner Comments

They also make an arithmetical error multiplying 30000 x 1440.

The answer shows the correct method but makes two errors.

It achieves 3 out of 5 marks.

ResultsPlus
Examiner Tip

A number of formulae require the use of *g*. Don't forget to multiply by 9.81 at some stage in your calculation.

This learner decides to calculate transfer of energy per second or power.

(b) The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10%.

Deduce whether this claim for efficiency was correct.

(5)

$E = mgh$ $\quad P_w = \frac{mgh}{t_w} = \frac{2500 \times 12 \times 9.81}{60}$

$P_c = \frac{1250 \times 22.3 \times 10^3}{t_c}$ $\quad = 4905\ W$

$= \frac{1250 \times 22.3 \times 10^3}{60 \times 60 \times 24} = 322.63\ W$

$\frac{P_c}{P_w} = 0.06577 = 6.58\%$ Efficient

10% is over the actual efficiency by 3.42% (overestimate)

ResultsPlus Examiner Comments

The calculation of power input from coal has an error interpreting MJ correctly.

This answer achieves 3 out of 5 marks.

ResultsPlus Examiner Tip

Ensure you know the meaning of all unit prefixes: kJ, MJ, GJ etc

This answer incorrectly converts an amount per minute to per day.

(b) The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10%.

Deduce whether this claim for efficiency was correct.

(5)

$E = mgh \quad E = 2500 \times 9.81 \times 12$

$= 294300$ ×60 Useful energy

$= 1.765800$

Energy in $= (1250 \times 22.3 \times 10^6 = 2.757 \times 10^{10}$ J

Efficiency $= \frac{\text{Useful energy}}{\text{Total}} \times 100$

$= \frac{294300 \times 60 \times 24}{2.7875 \times 10^{10}} \times 100$

$= 91.2\%$ $\quad 100 - 91.2\%$

$= 9\%$ ∴ correct

ResultsPlus
Examiner Comments

It should have multiplied by 60 x 24 to convert from per minute to per day.

This answer achieves 3 out of 5 marks.

(b) The engine, which ran continuously, could lift a mass of 2500 kg of water through 12 m each minute.
The engine used 1250 kg of coal a day. 1 kg of coal can release 22.3 MJ of energy.
The beam engine was said to have an efficiency of 10%.

Deduce whether this claim for efficiency was correct.

(5)

Energy per minute = mgh = 2500 x 9.81 x 12 = 294300 J a minute

Per day = 294300 x 60 x 24 = 4.24×10^8 J

Coal energy per day = 1250 x (22.3×10^6) = 2.79×10^{10} J

Efficiency % = $\frac{\text{useful energy output}}{\text{total energy input}} \times 100 = \frac{4.24 \times 10^8}{2.79 \times 10^{10}} \times 100$ = ~~1.525~~ 1.52%

Claim is incorrect, ~~at~~ only 1.52% efficient

ResultsPlus
Examiner Comments

This answer shows all the stages of the calculation with an appropriate conclusion for full credit.

Question 14 (a)

The rocket is travelling upwards for the first 1.9 s. The simplest method of finding the height was to calculate the area in the triangle of height 20 m and base 1.9 s.

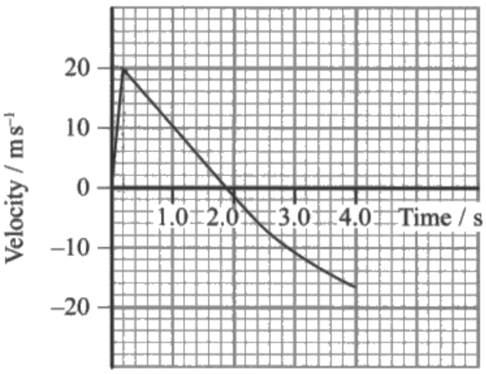
A number of learners attempted to use SUVAT equations, almost always unsuccessfully.

A significant number of answers assumed the rocket was travelling upwards in the first 0.2 s only.

Answers that tried to use SUVAT equations were over-complicated and often had more than one error.

14 A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.

A velocity-time graph for the bottle for the first 4 s after take-off is shown.



(a) Determine the height to which the rocket travelled. **(2)**

s ? u 0 v 20 a t 0.2

$s = \frac{v-u}{t}$ $\frac{(u+v)t}{2} = s$

$= \frac{20(0.2)}{2} = s$

$s = 10(0.2)$

Height = 2m

ResultsPlus
Examiner Comments

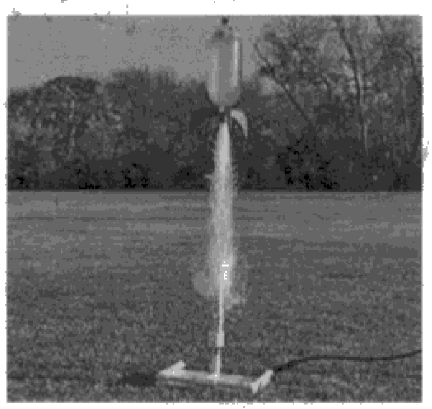
This answer only calculates the distance moved in the first 0.2 s. It gained a mark of 0 out of 2.

ResultsPlus
Examiner Tip

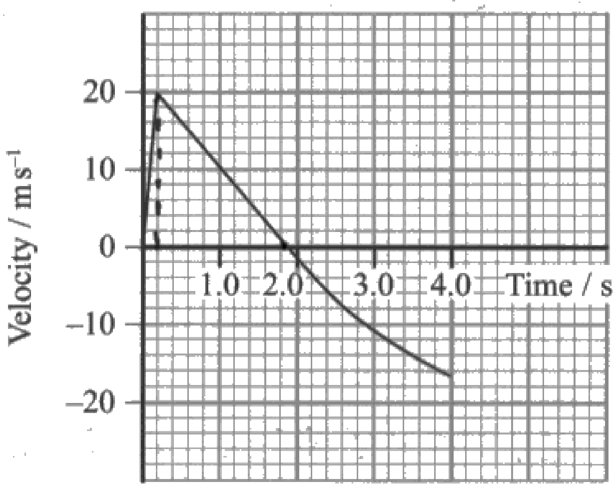
When given a velocity-time graph it is usually a good idea to use gradient = acceleration and area = displacement.

This answer uses a correct "area under the line method" but misreads the value on the time axis.

14 A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.



A velocity-time graph for the bottle for the first 4 s after take-off is shown.



$v = \frac{d}{t}$

$v \times t = d.$

(a) Determine the height to which the rocket travelled.

(2)

$\frac{1}{2}bh$ $\quad \frac{1}{2} \times 0.2 \times 20 + \frac{1}{2} \times 1.6 \times 20$

$2 + 16 = 18$ m.

[illegible]

Height = 18 m.

ResultsPlus
Examiner Comments

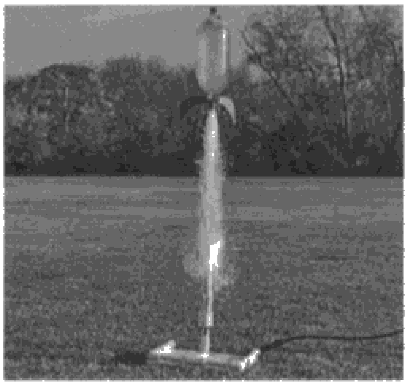
This gains MP1 only.

ResultsPlus
Examiner Tip

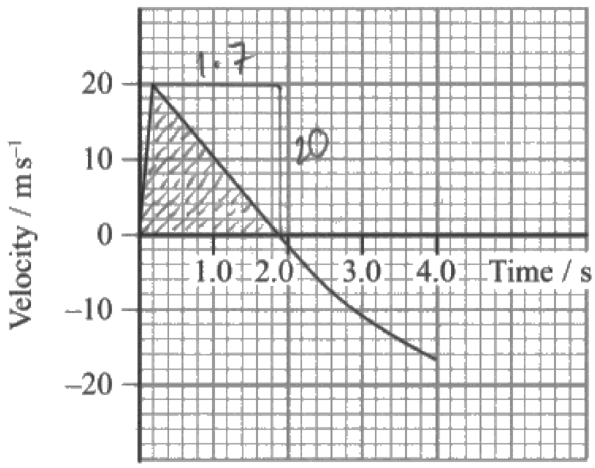
Take care when reading values off graphs.

This method is over-complicated and results in an approximate value.

14 A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.

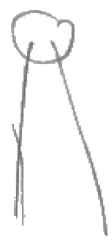


A velocity-time graph for the bottle for the first 4 s after take-off is shown.



$V = \frac{D}{T}$

$D = VT$



1 box = 0.4

(a) Determine the height to which the rocket travelled.

(2)

1.9s 40 boxes

Distance = Area under the graph

40×0.4 = 16 5×0.4 = 2

16 + 2 = 18 m

Height = 18m

ResultsPlus
Examiner Comments

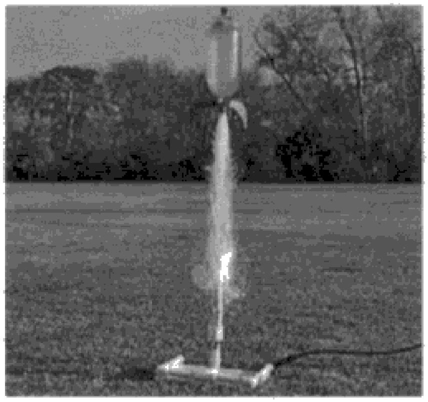
The difficulty of counting squares is that some are not full squares.

This gains MP1 only.

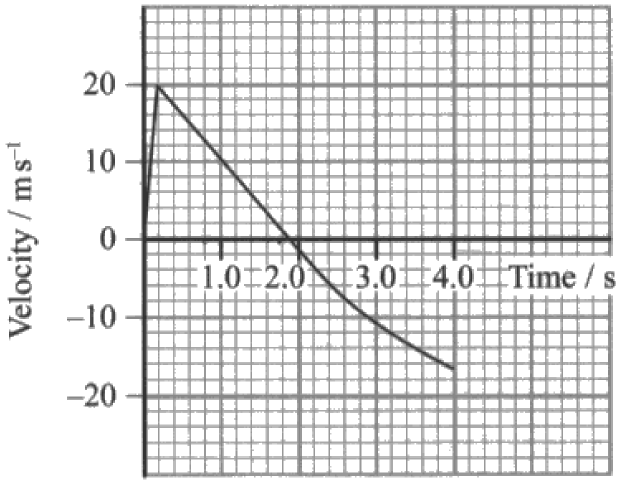
ResultsPlus
Examiner Tip

When the graph is a straight line (or combination of straight lines) use area of rectangle (and triangle) formulas.

14 A physics class made a toy rocket. A drinks bottle was partially filled with water and inverted over a valve. An air pump delivered air to the bottle until the pressure forced the bottle from the valve and the water was ejected from the bottle at high speed.



A velocity-time graph for the bottle for the first 4 s after take-off is shown.



(a) Determine the height to which the rocket travelled.

(2)

Distance travelled = area under v-t graph.

height = $\frac{1}{2} \times 20 \times 1.9$ = 19m

Height = 19m

ResultsPlus
Examiner Comments

This answer shows the simplest method of calculation, for full credit.

Question 14 (b)

This question examined whether learners could interpret a velocity-time graph. The acceleration is given by the gradient.

The acceleration is 100 m s^{-2} for the first 0.2 s.

It then becomes -12 m s^{-2} to about 2.2 s.

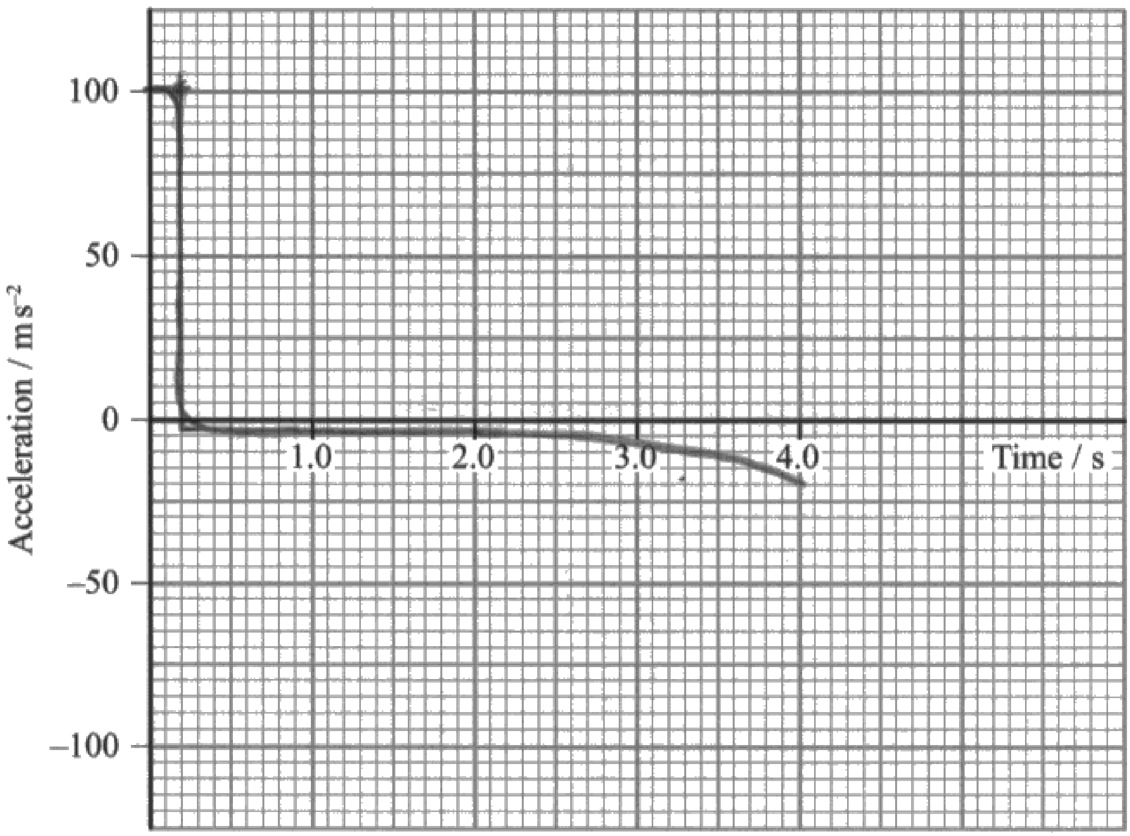
It then decreases in magnitude.

Many answers had the right general shape of graph but had little mistakes such as misreading the time axis, incorrectly calculating the negative gradient or leaving the negative acceleration as constant up to 4 s.

The ability to interpret a velocity-time graph was patchy with some learners unable to grasp the meaning of a negative gradient. This meant that they often gained the first two marks but confused their response to the second part of the acceleration-time graph.

(b) Sketch the corresponding acceleration-time graph on the axes below.

(5)



ResultsPlus
Examiner Comments

This answer achieves the first two mark points.

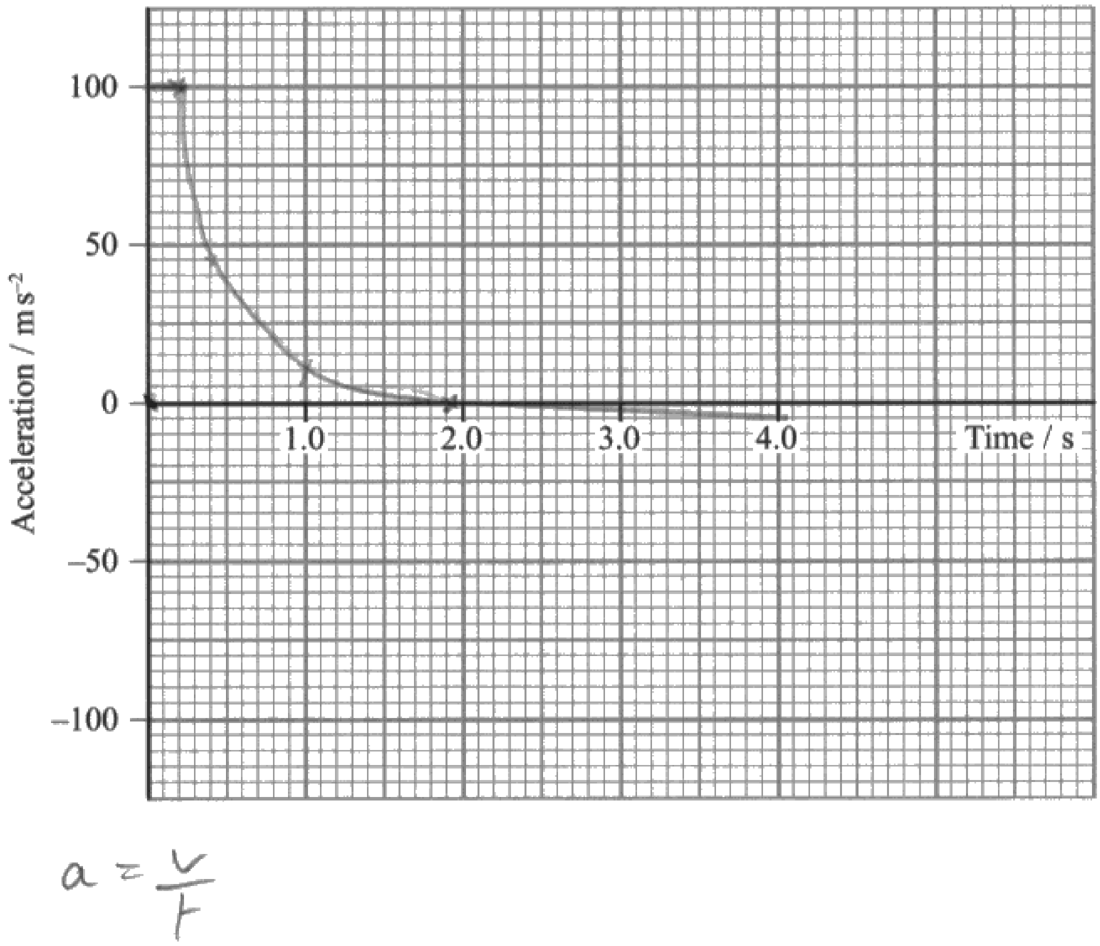
It does show a negative value of acceleration between 0.4 and 4 s so collects mark point 3.

The initial negative acceleration is incorrectly judged to be about -5 m s^{-2} and it shows the gradient increasing in magnitude in the last 1.5 s or so.

This answer has the correct initial acceleration for the right time period.

(b) Sketch the corresponding acceleration-time graph on the axes below.

(5)



ResultsPlus
Examiner Comments

The answer achieves the first two marks.

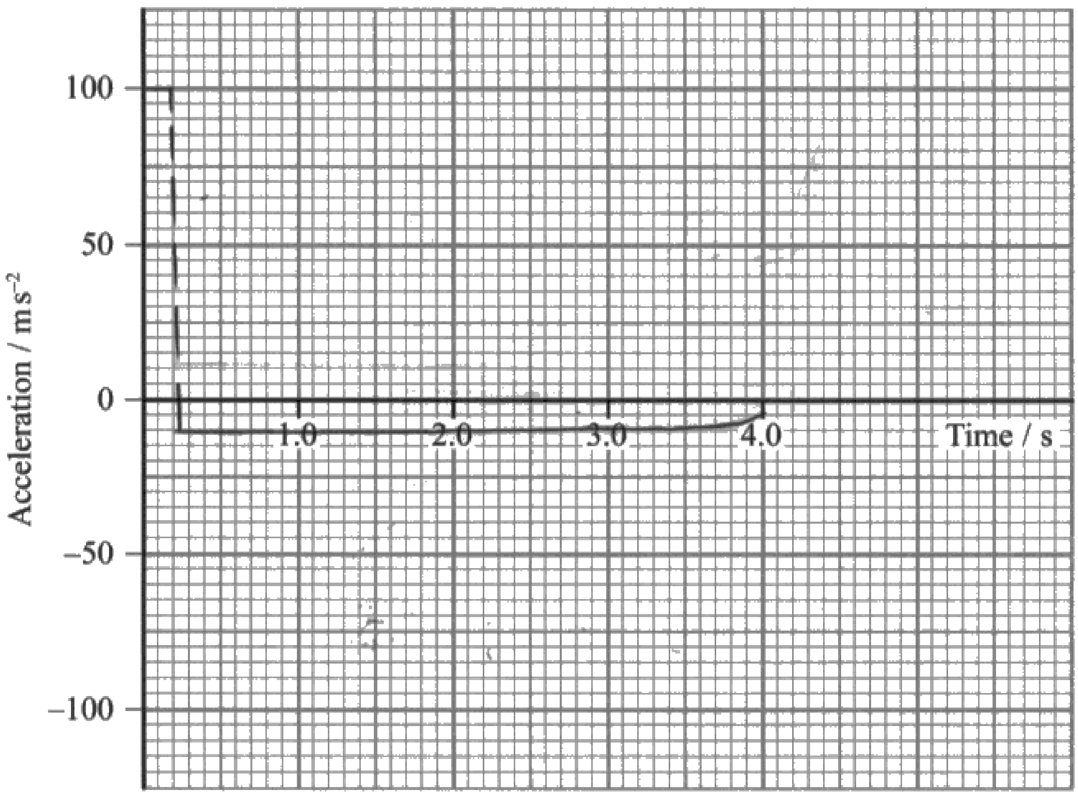
The learner hasn't correctly interpreted the negative gradient.

ResultsPlus
Examiner Tip

Ensure you understand how to interpret the gradient of a graph.

(b) Sketch the corresponding acceleration-time graph on the axes below.

(5)



$a = \frac{\Delta v}{t}$.

① : $a = 100 ms^{-2}$

② : $a = -12 ms^{-2}$

③ : $a = -10 ms^{-2}$.

? at $t = 4$ $a = 0$.

final $-5 ms^{-2}$

(Total for Question 14 = 7 marks)

ResultsPlus
Examiner Comments

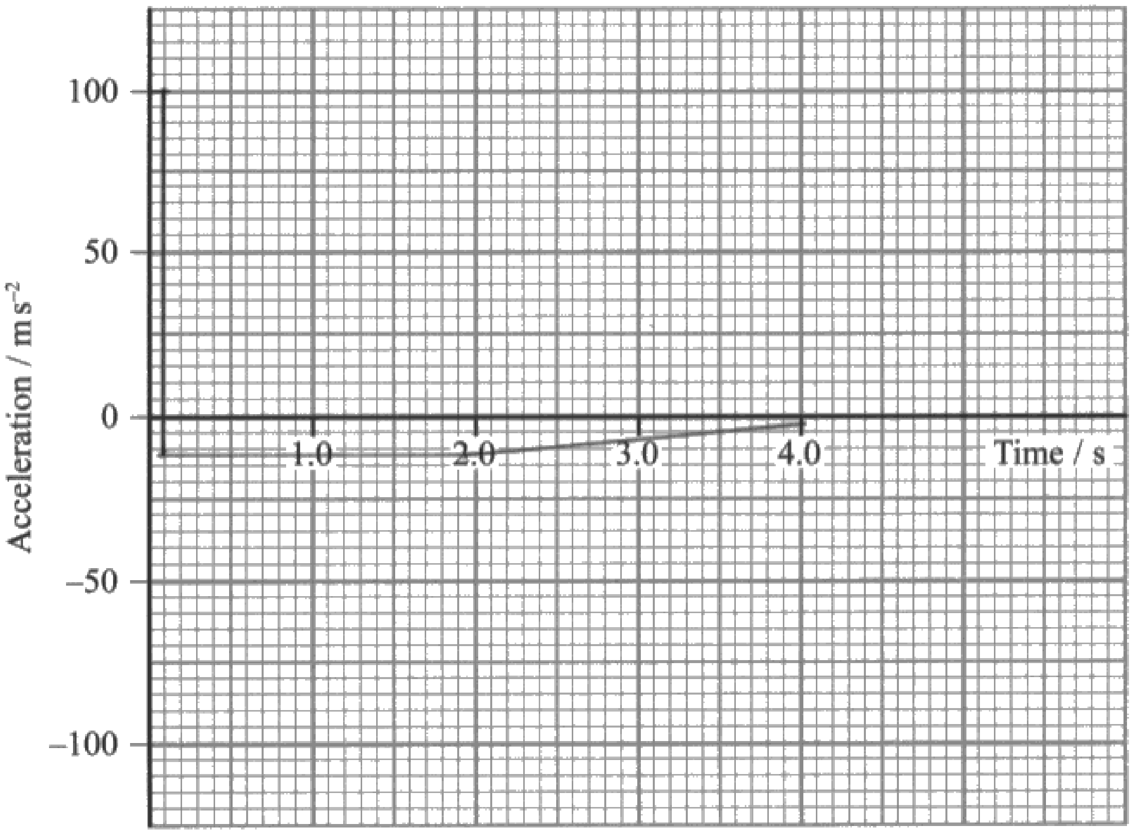
This answer achieves all the first four marks.

It shows the magnitude of the acceleration decreasing but only in the last 0.5s whereas the gradient of the velocity-time graph started to change at about 2.2s. It therefore does not achieve the final mark point.

The scales on the acceleration - time graph are different to those on the velocity - time graph.

(b) Sketch the corresponding acceleration-time graph on the axes below.

(5)



ResultsPlus
Examiner Comments

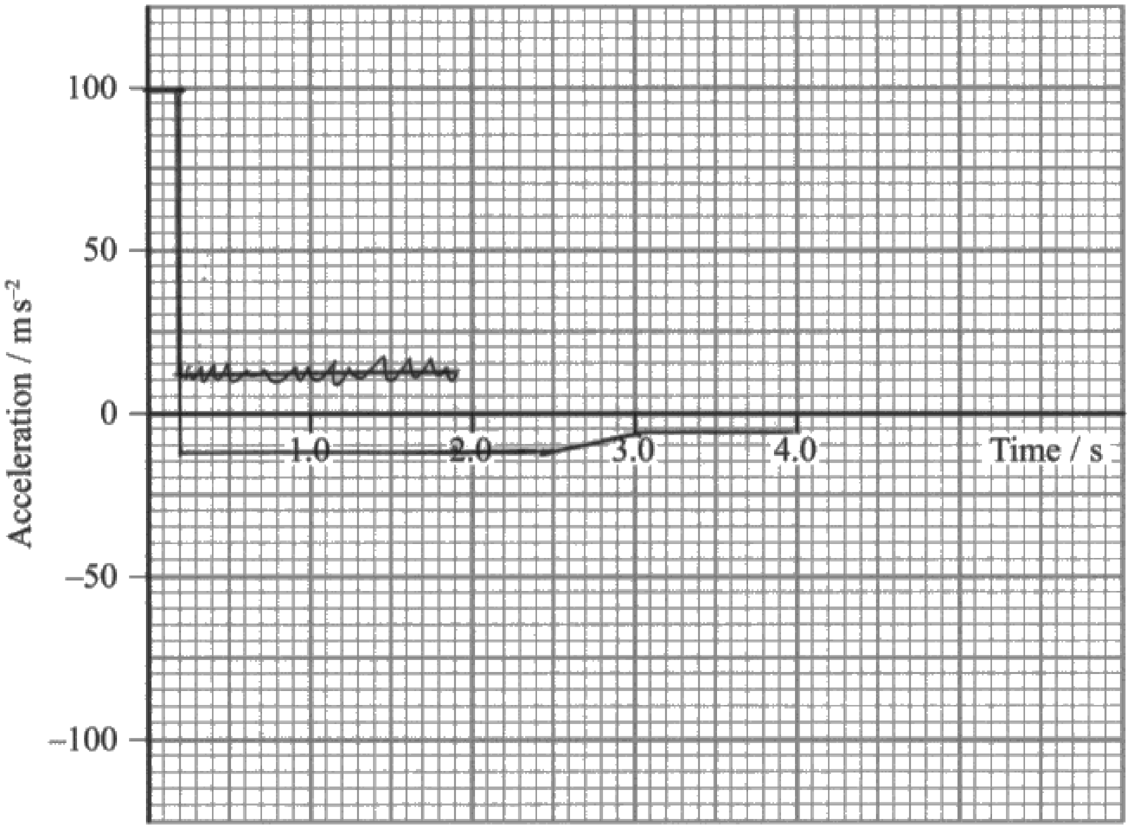
This shows the acceleration of 100 m s^{-2} but only for 0.1 s. It doesn't gain mark point 1.

ResultsPlus
Examiner Tip

Take care with graph scales.

(b) Sketch the corresponding acceleration-time graph on the axes below.

(5)



ResultsPlus
Examiner Comments

This shows an answer awarded all five marks.

Some students chose to show a step change in the magnitude of the acceleration in the last 1.5 s whilst others showed a gradual decrease in magnitude. Either approach was acceptable.

Question 15 (a)

The five marking points are taken from the specification.

Learners often listed hadrons as fundamental particles rather than quarks or omitted to mention any particles as fundamental.

Mark points 2 and 3 were usually present for a description of baryons and mesons as was mark point four for either stating or listing 6 quarks or leptons.

Few learners explicitly stated that each fundamental particle has an antiparticle.

This answer mentions leptons as an example of a fundamental particle but does not include quarks.

15 The discovery of the Higgs particle was an important contribution to our understanding of particle physics.

(a) Describe the standard model for subatomic particles. You should identify the fundamental particles and the composition of the particles we can observe.

(5)

Fundamental particles are particles not composed of particles. Fundamental particles are Leptons such as electrons which are subatomic particles. Electrons are also light.

Neutrons and protons are both subatomic particles are are baryons that are made up of 3 quarks. For instance, neutrons have a quark composition of dud. Neutrons and baryons are not Fundamental particles. All baryons decay into protons (apart from protons)

ResultsPlus
Examiner Comments

The answer goes on to give a description of a baryon but not a meson so achieving mark point 2.

ResultsPlus
Examiner Tip

Ensure you take note of exactly what the specification expects you to know.

This answer does not make clear which particles are fundamental.

15 The discovery of the Higgs particle was an important contribution to our understanding of particle physics.

(a) Describe the standard model for subatomic particles. You should identify the fundamental particles and the composition of the particles we can observe.

(5)

- Hadrons: - Mesons : made up of a quark and an antiquark: $q\bar{q}$
  - Baryons : made up of 3 quarks or 3 antiquarks: qqq or $\bar{q}\bar{q}\bar{q}$
- Quarks : - 6 different types of quarks ~~...~~ paired up in 3 families
  - every quark has an ~~...~~ antiquark pair with equal mass energy, opposite ~~...~~ charge, baryon number of $-\frac{1}{3}$
  - every quark has a baryon number of $+\frac{1}{3}$
- Leptons : - baryon number 0
  - include electrons, muons, tauons and neutrinos ν_e, ν_μ, ν_τ
- Bosons: - force carriers
  - W, Z bosons and Gluons carry the strong and weak force
  - Higgs boson ~~...~~

ResultsPlus
Examiner Comments

It does achieve mark points 2, 3 and 4 but does not state that each fundamental particle has an antiparticle equivalent.

15 The discovery of the Higgs particle was an important contribution to our understanding of particle physics.

(a) Describe the standard model for subatomic particles. You should identify the fundamental particles and the composition of the particles we can observe.

(5)

The fundamental particles are leptons and quarks. Quarks make up mesons & baryons which are collectively called hadrons. We cannot observe individual quarks, only mesons, which are made from a quark + anti-quark pair, and baryons e.g. the proton, which are made from 3 quarks or 3 anti quarks. There are 6 classes of both quarks and leptons and ~~each lepton & quark~~ for each matter particle, there is the corresponding anti-matter particle which has same mass but opposite charge, e.g. electron & a positron. This arrangement shows symmetry in the particles. There are also the particles that carry the fundamental force, photons for EM radiations, Higgs boson for mass. gluon for strong nuclear

ResultsPlus
Examiner Comments

This answer has all five mark points.

Question 15 (b)

This question is a conversion from kg to GeV/c^2.

Note that if the calculation is divided into stages then the first stage should be to multiply by c^2, this is converting kg to J. The second stage should be a division by 1.6×10^{-19} , this is converting J to eV.

If the division by 1.6×10^{-19} is carried out first this is not a conversion from J to eV. This was only penalised if the final numerical answer was incorrect and the method was then reviewed.

Many answers combined both in one single staged calculation which was given full credit.

(b) The mass of the Higgs particle is 2.2×10^{-25} kg.

Calculate this mass in GeV/c^2.

(3)

$$\frac{2.2 \times 10^{-25}}{1.6 \times 10^{-19}} \times 3 \times 10^{8} = 412.5$$

Mass = 412.5 GeV/c^2

ResultsPlus
Examiner Comments

This answer omits the square for the speed of light. MP2 cannot be awarded as it is not a conversion from J to eV. This answer gets 0 out of 3 marks.

ResultsPlus
Examiner Tip

Write down the equation you are using before substituting the numbers.

This answer was seen a number of times. The learner correctly multiplies by c^2 but then goes on to divide by c^2.

antibaryons B = -1, and all other particles B = 0.

(b) The mass of the Higgs particle is 2.2×10^{-25} kg.

Calculate this mass in GeV/c^2.

(3)

~~$E = mc^2$ 2.2×10^{-25} Kg = 2.2×10^{-25}~~

$E = mc^2$ 2.2×10^{-25} Kg $= (2.2 \times 10^{-25})(3 \times 10^8)^2$ J

$= 1.98 \times 10^{-8}$ J

$= \frac{1.98 \times 10^{-8}}{1.60 \times 10^{-19}}$ eV $= 1.24 \times 10^{11}$ eV $= 1.24 \times 10^2$ GeV

$1.24 \times 10^2 \div (3 \times 10^8)^2 = 1.38 \times 10^{-15}$

Mass = 1.38×10^{-15} GeV/c^2

ResultsPlus
Examiner Comments

The answer gains both MP1 and 2.

ResultsPlus
Examiner Tip

Learn to convert these units as it is a specification requirement.

(b) The mass of the Higgs particle is 2.2×10^{-25} kg.

Calculate this mass in GeV/c².

(3)

$2.2 \times 10^{-25} \times (3 \times 10^{8})^2 = 1.98 \times 10^{-8}$

$\frac{1.98 \times 10^{-8}}{1.6 \times 10^{-19}} = 1.2375 \times 10^{11}$ eV $\approx 1.24 \times 10^{2}$ GeV

≈ 124 GeV

Mass = 124 GeV/c²

ResultsPlus
Examiner Comments

This answer is laid out clearly in one stage and achieves full credit.

This is an example of an incorrect answer.

When the method is looked at the order of the stages of conversion is incorrect.

(b) The mass of the Higgs particle is 2.2×10^{-25} kg.

Calculate this mass in GeV/c².

(3)

$2.2 \times 10^{-25} \div 1.6 \times 10^{-19} = 1.375 \times 10^{-6} = 1.375$ GeV

$1.375 \times (3 \times 10^{8})^2 = 1.2 \times 10^{20}$ GeV/c²

(2 s.f.)

Mass = 1.2×10^{20} GeV/c²

ResultsPlus
Examiner Comments

The division by 1.6×10^{-19} does not convert J to eV.

This does not gain MP2.

The calculation does gain MP1 for multiplying by c^2

Giga is incorrectly interpreted.

ResultsPlus
Examiner Tip

Learn to do this conversion with a single stage calculation.

Question 15 (c) (i)

This question was about the high energy required in particle collisions so that new particles can be created. The Higgs particle has a relatively high mass, so a particularly high energy will be required according to $\Delta E = \Delta mc^2$.

The mark scheme also rewarded the point that energy is required to overcome the electrostatic forces of repulsion between the two accelerated protons. However, this energy is a much smaller scale than that required to produce new particles.

This answer confuses the strong nuclear force with the electrostatic repulsion force between the protons.

(c) The Higgs particle was discovered using the Large Hadron Collider (LHC) in 2012. Two beams of very high energy protons, moving in opposite directions, were made to collide.

(i) Explain the need for such high energy collisions.

(3)

The high energy is needed in order to overcome the strong nuclear force between the protons so that they collide instead of repelling eachother. Also the high energy enable us to slow the reaction down so that data can be collected about the experiment

ResultsPlus
Examiner Comments

It doesn't achieve mark point 1. Answers of this type were often vague about the type of force between the protons.

This answer achieves mark point 1 both ways.

(c) The Higgs particle was discovered using the Large Hadron Collider (LHC) in 2012. Two beams of very high energy protons, moving in opposite directions, were made to collide.

(i) Explain the need for such high energy collisions.

(3)

The protons needed to be high energy so that their speeds would be high enough to overcome the electrostatic forces of repulsion between them due to both protons being positively charged. They also needed to have enough energy that it would be sufficient to be converted into the mass of a new particle ($\Delta m = \frac{\Delta E}{c^2}$).

ResultsPlus
Examiner Comments

This answer gives both arguments for mark point 1 and also quotes $E = mc^2$ in an appropriate context so achieves MP2.

It doesn't specifically state that the Higgs particle has a relatively high mass so doesn't achieve MP3.

ResultsPlus
Examiner Tip

Note that the energies required to overcome the electrostatic force of repulsion between the protons is relatively small compared to the energy required to create new particles.

(c) The Higgs particle was discovered using the Large Hadron Collider (LHC) in 2012. Two beams of very high energy protons, moving in opposite directions, were made to collide.

(i) Explain the need for such high energy collisions.

(3)

The higgs particle has a very large mass in comparison to the two protons, and so to create this extra mass needed to form the Higgs, ~~the~~ extra energy is needed ~~as~~ that can be converted to mass using $E = mc^2$. Hence the protons must have very large energy.

ResultsPlus
Examiner Comments

This answer expresses all three mark points well and achieves full credit.

Question 15 (c) (ii)

This question was best approached using the equation at the back of the exam paper $r = p / BQ$

Some learners overcomplicated this question by first deriving the equation. Some confused the circumference for the radius, and some substituted the charge on a proton as 1.

This example shows the circumference being substituted for radius.

(ii) The beams of protons are contained within a ring of superconducting magnets.

Calculate the momentum of a proton in a beam.

(3)

magnetic field strength = 8.3 T
circumference of the ring = 27 km

$r = \frac{p}{BQ}$

$27 \times 10^{3} \times 8.3 \times 1.6 \times 10^{-19} = 3.59 \times 10^{-14}$

Momentum = 3.59×10^{-14} kg m s^{-1}

ResultsPlus
Examiner Comments

The dimensions for the substitutions in *r=p/BQ* are dimensionally correct so this answer achieves MP2 for the use of the equation.

ResultsPlus
Examiner Tip

Also note that the circumference is in km. This needs to be changed to m when calculating the radius using 2*πr*.

The calculations are correct.

The units for momentum are incorrect.

(ii) The beams of protons are contained within a ring of superconducting magnets.

Calculate the momentum of a proton in a beam. **(3)**

magnetic field strength = 8.3 T
circumference of the ring = 27 km

$p = mv$
$= m\ ms^{-1}$

$r = \frac{p}{Bq}$

Circumference = πd

1.6×10^{-19} = charge

$\frac{27000}{\pi} = d$

$4297.183 = \frac{p}{8.3 \times 1.6 \times 10^{-19}}$

$d = 8594.366$

$r = 4297.183\ m$

$p = 4297.183 \times 8.3 \times 1.6 \times 10^{-19}$
$= 5.71 \times 10^{-15}$

Momentum = $5.71 \times 10^{-15}\ m^2 s^{-1}$

ResultsPlus
Examiner Comments

This cannot be awarded MP3 so gains 2 out of 3 marks.

ResultsPlus
Examiner Tip

Make sure you use the correct units.

(ii) The beams of protons are contained within a ring of superconducting magnets.

Calculate the momentum of a proton in a beam.

(3)

B magnetic field strength = 8.3 T

$2\pi r$ circumference of the ring = 27 km

$P = mv$ $m_p = 1.67 \times 10^{-27}$ kg $B = 8.3$ T $2\pi r = 27000$ m

$Q_p = 1.6 \times 10^{-19}$ $r = 4297.18$ m

$r = \frac{P}{BQ}$ $P = rBQ$ $P = 4297.18 \times 8.3 \times 1.6 \times 10^{-19}$

$P = 5.71 \times 10^{-15}$ kg ms^{-1}

Momentum = 5.71×10^{-15} kg ms^{-1}

ResultsPlus
Examiner Comments

This shows a clearly laid out answer with correct units for full credit.

Question 15 (c) (iii)

The protons have equal momentum but are travelling in opposite directions, so the total momentum is zero.

A number of learners multiplied their answer to (c)(ii) by 2. i.e. forgetting the directions are opposite.

An example of forgetting the direction of the two momenta are opposite.

(iii) State the total momentum of the products of the collision between the two beams of protons.

(2 x above answer) **(1)**

Total momentum = 1.14×10^{-14} kg m s^{-1}

ResultsPlus
Examiner Comments

This answer was awarded 0 marks.

Question 15 (d)

This question examined the idea that at speeds close to the speed of light relativistic effects occur. The mass of the protons will no longer be the rest mass - the equation quoted would no longer be valid at these speeds.

Some answers simply stated that energy would be converted to mass. They were not clear that the mass of the proton increases.

(ii) The beams of protons are contained within a ring of superconducting magnets.

Calculate the momentum of a proton in a beam.

(3)

magnetic field strength = 8.3 T
circumference of the ring = 27 km

$F = Bev$

$p = mv$

$p = (1.67 \times 10^{-27}) v$

$F = \frac{mv^2}{r}$

(d) The LHC accelerates protons until they gain energies of about 7 TeV.

A student used the equation $E_k = \frac{p^2}{2m}$ to predict the energy of a proton in the beam, using the momentum calculated in (c)(ii), but found the energy was far higher than 7 TeV.

Explain why.

(2)

as the proton beams gain mass as they accelerate.

ResultsPlus
Examiner Comments

This answer achieves the proton gaining mass mark.

This answer initially suggests that the protons reach the speed of light which is incorrect.

(ii) The beams of protons are contained within a ring of superconducting magnets.

Calculate the momentum of a proton in a beam.

magnetic field strength = 8.3 T
circumference of the ring = 27 km

(3)

$F = BIl$
$F = BqV$
$p = mv$ $r = \frac{p}{Bq}$ $E_k = \frac{p^2}{2m}$ $\Phi = B \times A$
$F = \frac{mv^2}{r} = \frac{p^2}{r}$ $p = \sqrt{Fr}$
$F = \frac{mv^2}{r}$

(d) The LHC accelerates protons until they gain energies of about 7 TeV.

A student used the equation $E_k = \frac{p^2}{2m}$ to predict the energy of a proton in the beam, using the momentum calculated in (c)(ii), but found the energy was far higher than 7 TeV.

Explain why.

(2)

The energy is far higher as when the protons reach the speed of light or close to it you get relativistic effects $\Delta E = c^2 \Delta m$. As the proton gets faster it converts its energy into mass meaning that its value is lower in reality. When you calculate using $\frac{p^2}{2m}$ you don't take into account energy being converted to mass.

(Total for Question 15 = 17 marks)

ResultsPlus
Examiner Comments

It then correctly states that the velocity approaches the speed of light and gains mark point 1.

The answer then becomes unclear - vaguely stating that energy changes into mass - but suggesting that the mass will be lower as a result.

(ii) The beams of protons are contained within a ring of superconducting magnets.

Calculate the momentum of a proton in a beam.

(3)

magnetic field strength = 8.3 T   B $Q = 1.6 \times 10^{-19}$ C
circumference of the ring = 27 km

$r = \frac{p}{BQ}$ ∴ $p = BQr$ as $2\pi r = 27 \times 10^3$

$r = \frac{27 \times 10^3}{2\pi} = 4297$ m

$p = 8.3 \times 1.6 \times 10^{-19} \times 4297$

$= 5.71 \times 10^{-15}$ kgms^{-1}

Momentum = 5.7×10^{-15} kgms^{-1}

(d) The LHC accelerates protons until they gain energies of about 7 TeV.

A student used the equation $E_k = \frac{p^2}{2m}$ to predict the energy of a proton in the beam, using the momentum calculated in (c)(ii), but found the energy was far higher than 7 TeV.

Explain why.

(2)

In the LHC, protons approach the speed of light, so their mass increases greatly so as $E_k = \frac{m^2v^2}{2m}$ $E_k = \frac{1}{2}mv^2$, ~~as~~ energy will greatly increase. Relativistic equations must be used instead as relativistic effect is occuring at such speeds.

(Total for Question 15 = 17 marks)

ResultsPlus
Examiner Comments

This answer achieves full credit.

Question 16 (a)

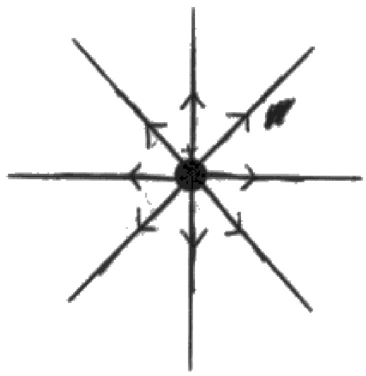
There were three marks for this question. The first two marks were for lines representing a field which is radial in nature and an arrow pointing outwards.

The last mark was for using a ruler and making sure the lines were equally separated by angle.

The third point was the most difficult with many answers showing lines that were not equally spaced.

16 (a) Sketch the electric field around a positive point charge.

(3)



ResultsPlus
Examiner Comments

This diagram was judged to be on the border and the mark MP3 was given.

The answer was awarded a total of 3 marks.

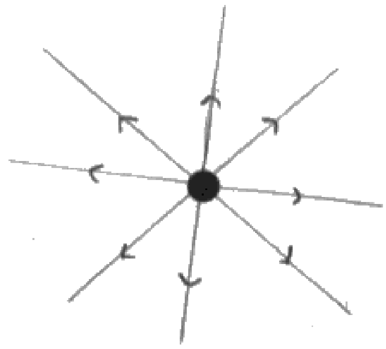
ResultsPlus
Examiner Tip

Use a ruler when drawing field lines which should be straight.

The radial lines had to be equally spaced and this diagram does not show equally spaced lines.

16 (a) Sketch the electric field around a positive point charge.

(3)



ResultsPlus
Examiner Comments

This gains 2 out of 3 marks.

ResultsPlus
Examiner Tip

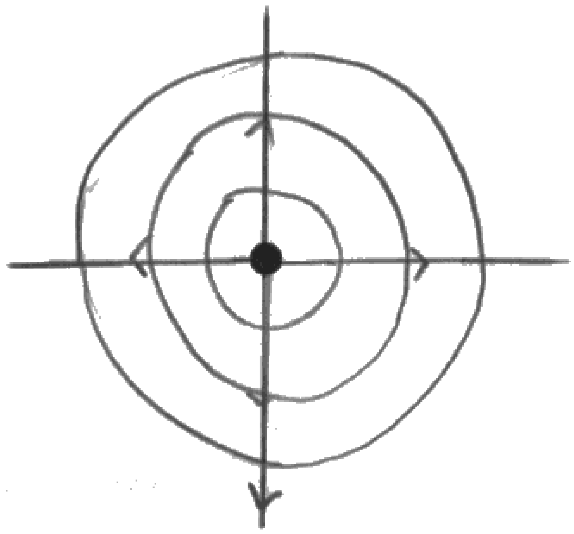
Take care when drawing field diagrams

This answer shows both equipotential lines and electric field lines.

It was possible to ignore equipotential lines if they were dotted or labelled.

16 (a) Sketch the electric field around a positive point charge.

(3)



ResultsPlus
Examiner Comments

In this case the examiner has been given a choice and therefore marked it incorrect.

ResultsPlus
Examiner Tip

Answer the question and keep the diagram as simple as possible.

Question 16 (b)

The question provided a graph of potential against distance.

The most appropriate method to calculate field strength at a point is to use the gradient of the potential-distance graph.

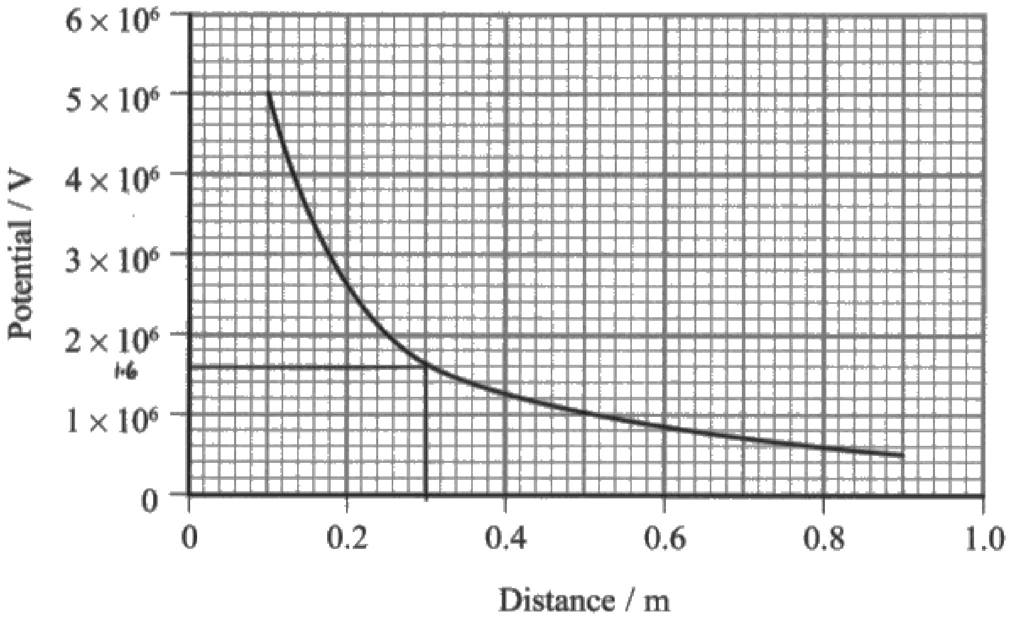
Another way is to use both equations for *E* and *V* in a radial field.

Once learners had a numerical value for *E* they had to compare this with the given value from the question.

This answer does not use a correct method.

It also does not compare the calculated value with the value given in the question.

(b) The graph shows how potential varies with distance from the centre of a charged sphere.



Air molecules will be ionised if the electric field strength exceeds 3×10^6 V m^{-1}.

Deduce whether air molecules will be ionised at a distance of 30 cm from the centre of this sphere.

(4)

At distance 0.3, potential = 1.6×10^6 V

$E = \frac{V}{d} = \frac{1.6 \times 10^6}{0.3} = 5338333.3$ Yes, the air molecules will

$\approx 5 \times 10^6$ V m^{-1} be ionised.

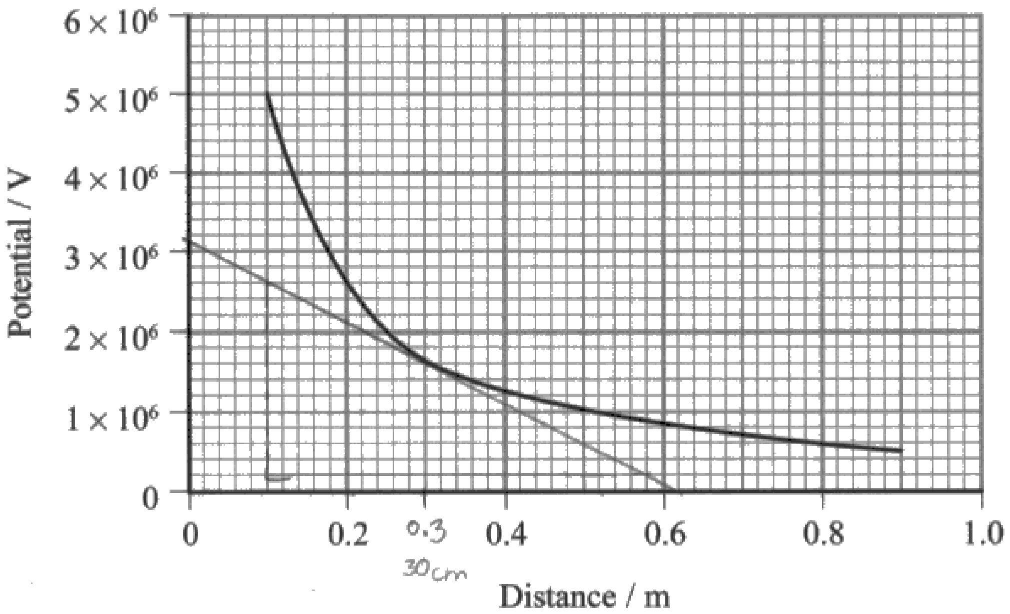
ResultsPlus
Examiner Comments

This gained 1 mark for using the graph to find a correct value of *V*.

MP3 for the answer so achieves 2 out of 4 marks.

This shows a tangent and correctly calculates the gradient.

(b) The graph shows how potential varies with distance from the centre of a charged sphere.



Air molecules will be ionised if the electric field strength exceeds $3 \times 10^6\,\mathrm{V\,m^{-1}}$.

Deduce whether air molecules will be ionised at a distance of 30 cm from the centre of this sphere.

(4)

$E = \frac{V}{d}$ $\quad E = \frac{\Delta V}{\Delta d} = \frac{2.4 \times 10^6}{0.48} = 5 \times 10^6\,\mathrm{V\,m^{-1}}$

Yes they would be ionized

ResultsPlus
Examiner Comments

The learner does not compare their value explicitly with the value of *E* given in the question.

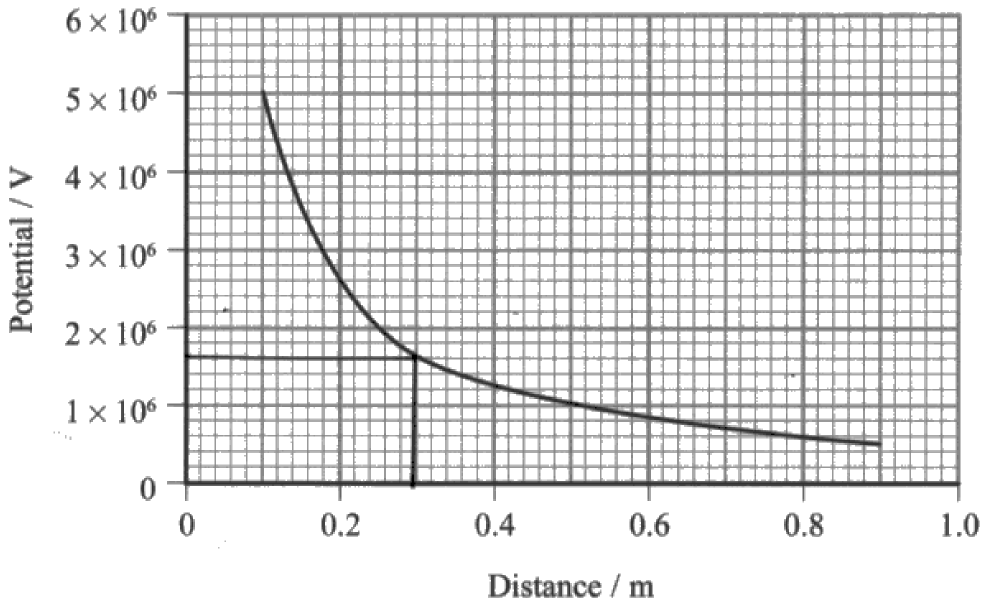
This answer achieves the first 3 marks.

ResultsPlus
Examiner Tip

In "deduce" questions remember to compare your answer with that given in the question explicitly.

This method includes the use of both radial field equations.

(b) The graph shows how potential varies with distance from the centre of a charged sphere.



Air molecules will be ionised if the electric field strength exceeds 3×10^6 V m^{-1}.

Deduce whether air molecules will be ionised at a distance of 30 cm from the centre of this sphere.

$V = k\frac{Q}{r}$ $Q = kVr$ $V = k \times \frac{Q}{r}$ $\frac{Vr}{k} = Q$

(4)

$E = k\frac{Q}{r^2}$ = $V = 1.6\times10^6$ $k = 8.99\times10^9$

$E = 8.99\times10^9 \times \frac{5.339\times10^5}{0.3^2}$ $Q = \frac{Vr}{k} = \frac{(1.6\times10^6) \times (0.3)}{8.99\times10^9} = 5.339\times10^5$

≈ 5333067

≈ 5.34×10^6 V m^{-1}

The air molecules will be ionised.

ResultsPlus
Examiner Comments

It does not explicitly compare their value of *E* with that given in the question.

This answer gains the first 3 marks.

Question 16 (c)

This question was set to test the idea that there must be zero potential gradient within the suit, therefore the field strength within the suit is also zero. However, very few learners gave this answer.

The two examples below were common and gained some credit.

(c) A magician did a trick which he claimed was the most dangerous ever. He positioned himself midway between two charged spheres which were separated by a distance of about two metres. Each sphere was charged to a potential that would cause ionisation at a distance of one metre. He wore a protective suit of chain mail and a helmet consisting of a metal cage. The protective suit and helmet were earthed to a potential of 0 V.

A scientist said "there is no danger in this and I would happily do it tomorrow".

Explain whether this statement is justified.

(3)

the scientist is justified. The suit acts as a faraday cage and protects the magician from the electricity. The current enters the magicians' suit and travels straight to earth, leaving the magician unharmed.

(Total for Question 16 = 10 marks)

ResultsPlus
Examiner Comments

This answer gains MP2 and MP4 for 2 marks.

ResultsPlus
Examiner Tip

When there are 3 marks there will be 3 distinct mark points.

"Explain" questions at the end of a question are often based on the topics previously tested within the question. In this case on electric field strength related to potential gradient.

Scientist is correct. ~~Magician~~ The protection is earthed, if he is struck by high voltage the charge can flow into the ground/earth so he would not be harmed. No charge will flow through him, only through his protection.

ResultsPlus
Examiner Comments

This answer gains MP4 for 1 mark.

Question 17 (a)

Three methods for proving this equation were commonly seen.

Two approaches appear in the mark scheme.

A neat use of similar triangles simplifies this proof as shown in the first example below.

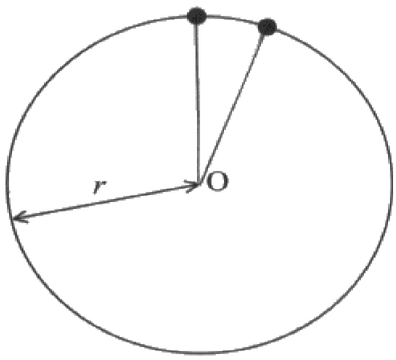
All proofs require a trigonometrical approximation to be made. This wasn't always pointed out in the answer.

This shows another method for this proof in addition to the two given in the mark scheme but it contains one error and one omission.

17 A centrifuge is a machine which rotates.

(a) A particle in a centrifuge moves in a circle of radius r, centre O, with a constant speed v.

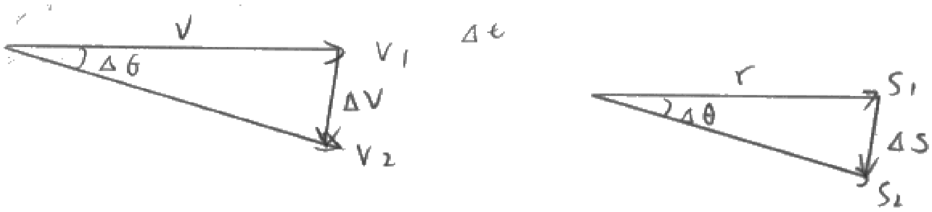
The diagram represents two positions of the particle.



Derive the equation for centripetal acceleration $a = \frac{v^2}{r}$ by considering the velocity at these two positions.

Your answer should include a vector diagram.

(5)



~~$\Delta v = r\Delta\theta$~~

~~$a = \frac{r\Delta\theta}{\Delta t}$~~

~~$a = r.\omega$~~

~~$a = \omega = v$~~ $\Delta v = \omega r$ $a = r\omega^2$

~~$\frac{\Delta v}{\Delta t} = a = \frac{\omega r}{\Delta t}$~~ $\Rightarrow a = \frac{v^2}{r}$.

$\Delta S = r\Delta\theta$ $\Delta v = \Delta\theta . v$

$v = \frac{\Delta S}{\Delta t} = r \cdot \frac{\Delta\theta}{\Delta t} = r\omega$. $a = \frac{\Delta v}{\Delta t} = \frac{\Delta\theta}{\Delta t} \cdot v$

$a = \omega \cdot v = \frac{v}{r} \cdot v = \frac{v^2}{r}$

$(\omega = \frac{v}{r})$ $\Rightarrow a = \frac{v^2}{r}$.

ResultsPlus
Examiner Comments

There is an assumption being made that the circular arc of the motion is approximately the same as the straight line representing change of velocity.

This is true for small angles and needed to be indicated for the fifth mark.

Also note that the direction of the arrows on the velocity vectors is incorrect. This was not penalised on this paper and the answer gains 4 out of 5 marks.

Δv is the difference between the two velocities so the arrow on v_2 should be reversed.

ResultsPlus
Examiner Tip

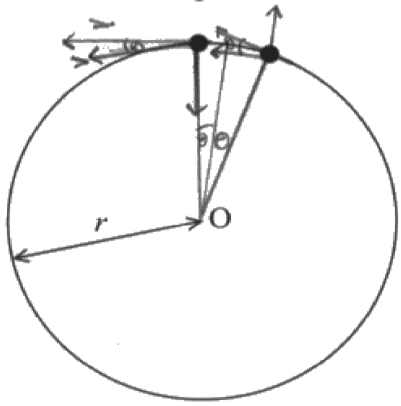
Be careful about the direction of vectors. Reverse the arrow indicating direction to show a negative of a vector .

This proof uses components of velocity at the two positions.

17 A centrifuge is a machine which rotates.

(a) A particle in a centrifuge moves in a circle of radius r, centre O, with a constant speed v.

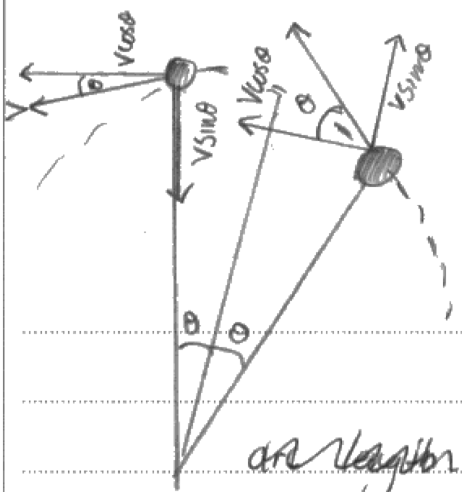
The diagram represents two positions of the particle.



Derive the equation for centripetal acceleration $a = \frac{v^2}{r}$ by considering the velocity at these two positions.

Your answer should include a vector diagram.

(5)



y - direction $\Delta V = 0$ x - direction $\Delta V = 2V\sin\theta$

arc length: $V = \frac{d}{t} = r\omega$

$= r\frac{2\theta}{t}$

$\Rightarrow t = \frac{2\theta r}{V}$

$a = \frac{\Delta V}{t}$

$= \frac{2V\sin\theta \times V}{2\theta r} = \frac{V^2 \sin\theta}{\theta r}$

$\sin\theta \approx \theta$ since θ is small

$\Rightarrow \frac{\sin\theta}{\theta} \approx 1 \quad \therefore \quad a = \frac{V^2}{r}$

ResultsPlus
Examiner Comments

This includes a reference to the small angle approximation and gains full credit.

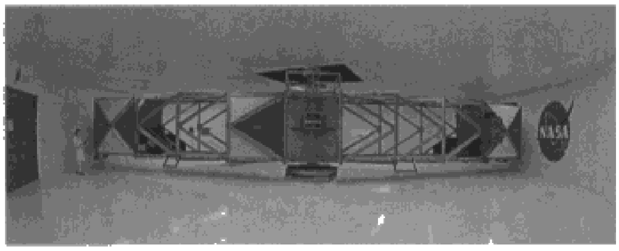
ResultsPlus
Examiner Tip

Use a labelled diagram to illustrate your working - this is an excellent example.

Question 17 (b) (i)

The following two examples show two alternative correct approaches.

(b) The United States' space agency, NASA, uses a centrifuge to test whether equipment will operate when experiencing large forces. The equipment to be tested is attached to the end of the frame of the centrifuge, which rotates around a vertical axis at its centre.



The centrifuge rotates at 50 revolutions per minute with a radius of 8.8 m.

(i) Show that the angular velocity of the centrifuge is about 5 rad s^{-1}.

(2)

$\omega = \frac{2\pi}{T}$, $T = \frac{60}{50} = 1.2$

$\omega = \frac{2\pi}{1.2} = 5.2$ rad s^{-1}

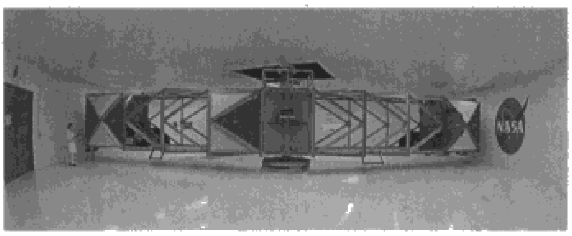
ResultsPlus
Examiner Comments

This correctly calculates time period *T* and then substitutes it in

ω = 2π/*T*

The answer gains full credit.

(b) The United States' space agency, NASA, uses a centrifuge to test whether equipment will operate when experiencing large forces. The equipment to be tested is attached to the end of the frame of the centrifuge, which rotates around a vertical axis at its centre.



The centrifuge rotates at 50 revolutions per minute with a radius of 8.8 m.

(i) Show that the angular velocity of the centrifuge is about 5 rad s^{-1}.

(2)

$\omega = 2\pi f \rightarrow f$ $50 : 60$ $\frac{50}{60} : 1$ $f = \frac{5}{6}\ s^{-1}$

$\omega = 2\pi \times \frac{5}{6} = 5.2\ rad\ s^{-1}$

ResultsPlus
Examiner Comments

This example calculates frequency and uses $\omega = 2\pi f$ for full credit.

Question 17 (b) (ii)

This question was about this centrifuge. The angular velocity of this centrifuge is small whilst its radius is large.

The best approach was to use $F = mr\omega^2$ to explain that the force is large as the radius at which the equipment is placed is large.

The use of the equation $F=mv^2/r$ does not help with the argument unless the student makes it very clear that they are discussing linear velocities being large because the radius is large (from $v = r\omega$).

This answer uses the right circular motion equation and refers to a large radius for full credit.

1·2

(ii) Explain how the centrifuge applies large forces to the equipment under test.

(2)

Greater force applied through ~~greater~~ extending the range of the end of the centrifuge fuses, thus increasing the diameter, increased r

$a = r\omega^2$ greater r → greater a → greater F

$F = ma$

ResultsPlus
Examiner Comments

The answer refers to the end of the centrifuge having a large radius for the second marking point.

This answer illustrates how using the other circular motion equation leads to confusion.

(ii) Explain how the centrifuge applies large forces to the equipment under test.

(2)

$F = \frac{mv^2}{r}$

Mass and velocity remains constant, decrease the radius to increase centripetal force.

ResultsPlus
Examiner Comments

The radius is actually large and this leads to the linear velocity of the equipment under test being large.

This answer was awarded 0 marks.

ResultsPlus
Examiner Tip

Look at whether the previous question has helped to guide you in thinking a particular way about a situation. The previous question was about angular velocity and was a prompt to use $F=mr\omega^2$

This answer uses the right equation for MP1.

(ii) Explain how the centrifuge applies large forces to the equipment under test.

(2)

In order for the equipment to move in a circle, there must be a centripetal force acting on it. The force is given by $F = m\omega^2 r$ ← radius. As the object is moving at a very high angular velocity, large mass forces are applied on it.

ResultsPlus
Examiner Comments

The answer refers to a large angular velocity rather than to the large radius so does not score the second mark.

Question 17 (b) (iii)

This question was best solved using the formula $a = r\omega^2$

If the student used their calculated value from (b)(i) they should arrive at a value of about 25*g* and therefore suggest the claim is correct.

If they use the "show that" from (b)(i) then they arrive at an answer which is significantly less than 25*g* so they should state that the claim was incorrect.

This shows a fully correct example.

(iii) The NASA website says the centrifuge can be used to test whether the equipment can withstand accelerations of up to about 25*g*.

Deduce whether this claim is correct.

(2)

$25 \times 9.81 = 245.25\ m/s^2$ $\quad a = r\omega^2$

$= 8.8 \times 5.24^2$

$= 241.26\ m/s^2$

The claim is correct as $245.25 \approx 241.26$

ResultsPlus
Examiner Comments

This gains full credit.

ResultsPlus
Examiner Tip

You should show a comparison of your value with that given in the question, as this does.

This example shows an incorrect conclusion from a correct calculation.

(iii) The NASA website says the centrifuge can be used to test whether the equipment can withstand accelerations of up to about 25*g*.

Deduce whether this claim is correct.

(2)

$a = \frac{v^2}{r}$

$= r\omega^2 = 8.8 \times 5.2^2 = 237.952 \approx 238$

$25g = 245.25 \approx 245 \qquad 245 > 238$

∴ The equipment can not withstand up to 25g

ResultsPlus
Examiner Comments

The learner has calculated a numerical value of 25*g* - this should strictly have the units of acceleration.

This gained MP1.

ResultsPlus
Examiner Tip

Note the word "about" and use common sense to consider its meaning. These two values are only 2% different.

This answer calculates the acceleration in terms of *g*.

(iii) The NASA website says the centrifuge can be used to test whether the equipment can withstand accelerations of up to about 25*g*.

Deduce whether this claim is correct.

(2)

$a = r\omega^2$ $8.8 \times 5.24^2 = 241.256966$

$\frac{241}{9.81} = 24.592966g$. This is close to 25g

So the claim is correct.

ResultsPlus
Examiner Comments

This shows that the answer rounds to 25*g* and this approach tends to lead to a sensible conclusion. Both marks awarded.

This answer uses the "show that" value from Q17(b)(i).

(iii) The NASA website says the centrifuge can be used to test whether the equipment can withstand accelerations of up to about 25*g*.

Deduce whether this claim is correct.

(2)

$a = r\omega^2$ $8.8 \times 5^2 = 220\ ms^{-2}$ so

$g = 9.81\ ms^{-2}$ $220 \div 9.81 = 22.4$

Hence only 22.4g, claim incorrect as can only withstand 22.4g.

ResultsPlus
Examiner Comments

This leads to a significantly smaller value compared to 25*g*.

This answer then draws the correct the conclusion for full credit.

Question 18 (a)

This question was about

(i) the acceleration caused by a magnetic force on a ball bearing

(ii) momentum conservation at a collision

(iii) the nature of elastic collisions.

These three points of increasing difficulty were expected for full credit.

This learner does not clearly identify which ball bearings are being discussed.

The answer is vague about the term energy and does not clearly identify kinetic energy until the last few words.

18 A 'Gauss gun' can be made from five ball bearings of equal mass and two magnets, as shown.

Pairs of ball bearings are placed to the right of two strong magnets. A single ball bearing is released from the left, as shown. The ball bearing is attracted to, and collides with, the first magnet. This and all subsequent collisions can be assumed to be elastic.

(a) Explain what happens to make the last ball bearing on the right subsequently move off with a large velocity.

(3)

The energy from each collision is transferred to the next object along, be it ball or magnet. Therefore, because the collisions are elastic, the last ball will have the same energy as the first ball as kinetic energy, and will move quickly.

ResultsPlus
Examiner Comments

This answer was close to being awarded mark point 3. The answer states that all the kinetic energy is transferred to the last ball but should have said from the third ball.

There is an acceleration and therefore increase in kinetic energy as the third ball is attracted to the second magnet.

This answer did not collect any of the mark points.

ResultsPlus
Examiner Tip

When discussing elastic collisions be clear that it is all the kinetic energy that is conserved.

This answer leaves some confusion about which balls are being discussed.

In every collision momentum is conserved so when the 1st ball bearing collides with the magnet, its momentum must be transfered to something else. In this case it momentum is transfered to the 3rd ball bearing in the picture. The same then happens as the 3rd ball bearing hits the second magnet. It causes the one furthest right to move off with a large velocity

As all of the collisions are elastic KE is conserved so the final ball bearing will move off with the same KE as the first one had.

ResultsPlus
Examiner Comments

This answer covers momentum conservation well.

It also looks to discuss conservation of kinetic energy but compares the final ball bearing with the kinetic energy of the "first" ball bearing. It isn't clear whether the student means the original ball bearing which was released or what is in effect the third ball bearing which left the first magnet.

The final ball bearing will have more kinetic energy than the first because work is done by the second magnet.

This doubt means that the answer gains 1 mark.

ResultsPlus
Examiner Tip

Some students labelled the ball bearings in the diagram to help their explanation.

18 A 'Gauss gun' can be made from five ball bearings of equal mass and two magnets, as shown.

Pairs of ball bearings are placed to the right of two strong magnets. A single ball bearing is released from the left, as shown. The ball bearing is attracted to, and collides with, the first magnet. This and all subsequent collisions can be assumed to be elastic.

(a) Explain what happens to make the last ball bearing on the right subsequently move off with a large velocity.

(3)

When the first ball hits the first magnet the ball A moves off with the same kinetic energy as the first ball had when they collided and the first ball and magnet remain stationary. Ball a is accelerated towards the second magnet and when it collides with the magnet ball B moves away with the kinetic energy ball A had before the collision. Because of conservation of momentum and E_k ball B ends up with the combined E_k of A and the first ball

ResultsPlus
Examiner Comments

This is a good answer with all three points.

ResultsPlus
Examiner Tip

This avoids the confusion of discussing different balls by labelling them on the diagram.

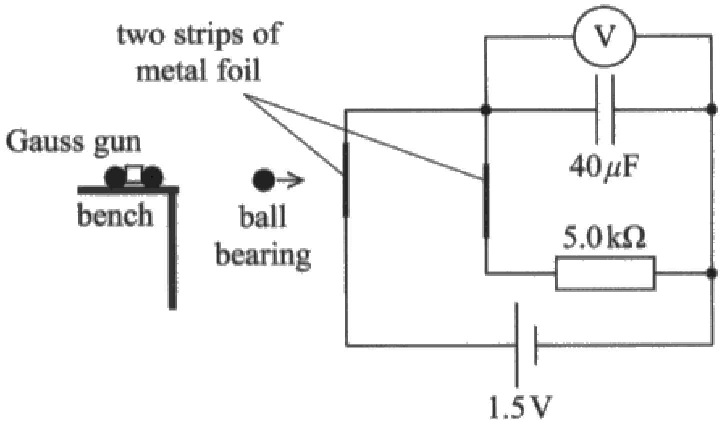
Question 18 (b) (i)

The answer could be calculated either using $W = 1/2\ CV^2$

or a combination of $Q = CV$ followed by $W = 1/2\ QV$.

Learners could use $Q = CV$ and then subsequently $1/2\ QV$.

(b) A student set up the apparatus shown to measure the speed of the last ball bearing. The 'Gauss gun' was placed at the end of a bench, so that the ball bearing left the gun and broke two strips of metal foil which formed part of an electric circuit.



As the ball bearing left the gun, it broke the first foil strip at its centre so that the capacitor started to discharge. When the ball bearing broke the second foil strip the capacitor discharge stopped.

(i) Calculate the energy stored in the capacitor when it was fully charged.

(2)

~~$C = \frac{Q}{V}$ $\frac{40 \times 10^{-6}}{1.5V}$ $Q = CV$~~

~~$(40 \times 10^{-6}) \times 1.5 = 6 \times 10^{-5}$~~

$W = \frac{1}{2} QV$ $(0.5 \times 1.5 \times (40 \times 10^{-6})) = 3 \times 10^{-5}$ J

Energy stored = 3×10^{-5} J

ResultsPlus
Examiner Comments

This answer shows a confusion between capacitance *C* and charge *Q*.

It was awarded 0 marks.

ResultsPlus
Examiner Tip

Be careful with capacitor questions not to confuse Q with C.

This shows the approach using *Q* = *CV* followed by 1/2 *QV*.

$Q = CV = 40 \times 10^{-4} \times 1.5$

$Q = 6 \times 10^{-3}$

$W = \frac{1}{2} QV$

$= 0.5 \times 6 \times 10^{-3} \times 1.5$

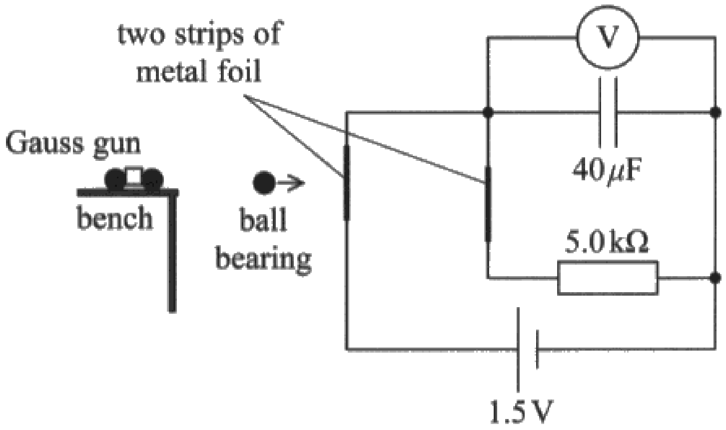
$= 4.5 \times 10^{-3}$

Energy stored = 4.5×10^{-3} ~~6×10^{-3}~~ J

ResultsPlus
Examiner Comments

Note that the learner incorrectly interprets the meaning of the prefix μ and achieves 1 mark.

(b) A student set up the apparatus shown to measure the speed of the last ball bearing. The 'Gauss gun' was placed at the end of a bench, so that the ball bearing left the gun and broke two strips of metal foil which formed part of an electric circuit.



As the ball bearing left the gun, it broke the first foil strip at its centre so that the capacitor started to discharge. When the ball bearing broke the second foil strip the capacitor discharge stopped.

(i) Calculate the energy stored in the capacitor when it was fully charged.

(2)

$W = \frac{1}{2}QV \quad W = \frac{1}{2}CV^2 = \frac{40 \times 10^{-6} \times (1.5)^2}{2} = 4.5 \times 10^{-5}\,J$

ResultsPlus
Examiner Comments

This shows the approach using $W = 1/2\ CV^2$ and achieves full credit.

Question 18 (b) (ii) - (iv)

The first part of this question required the use of the exponential discharge equation.

The other two parts tested an understanding of projectile motion.

Learners should show all their substitutions when carrying out a "show that" question as in (b)(ii).

A number of answers to b(iv) substituted a value for initial velocity in $s = ut + 1/2\ at^2$ and did not achieve the 2 marks.

A number of answers to (ii) showed a calculation of time constant only.

(ii) The voltmeter reading halved in the time taken for the ball bearing to travel between the two foil strips.

Show that the time taken for the ball bearing to travel between the two foil strips was about 0.1 s.

(2)

$RC = \tau = 40 \times 10^{-6} \times 5 \times 10^{3} = 0.2s$

(iii) The two foil strips were 0.50 m apart.

Calculate the horizontal velocity of the ball bearing.

(2)

$E_k = \frac{1}{2}mv^2$ $\frac{0.5}{0.31}$ = [illegible] $5 ms^{-1}$

Horizontal velocity = [illegible] $5 ms^{-1}$

(iv) The student positioned the second foil strip with its centre 8.0 cm lower than the centre of the first foil strip.

Deduce whether the ball bearing broke the second foil strip at its centre.

Assume the ball bearing was travelling horizontally as it broke the first foil strip.

(2)

0.5m

8.0×10^{-2}

t = 0.1

t = 0.1

a = 9.81

u = 0

s

$s = ut + \frac{1}{2}at^2$

s = 0.04m

it did not break it in its centre.

ResultsPlus
Examiner Comments

In part (iv) the candidate has rounded the answer too far - to just one significant figure. It isn't clear how they arrived at this answer as they do not show the values of s and t substituted into the equation.

The marks were awarded as follows:
(ii) 0 (iii) 2 (iv) 0

ResultsPlus
Examiner Tip

In general, write answers to at least two significant figures.

This shows a fully correct example.

(ii) The voltmeter reading halved in the time taken for the ball bearing to travel between the two foil strips.

Show that the time taken for the ball bearing to travel between the two foil strips was about 0.1 s.

(2)

time taken to half = ln 2 RC

= ln 2 × 5×10³ × 40×10⁻⁶ = 0.1386 s

≈ 0.14 s

(iii) The two foil strips were 0.50 m apart.

Calculate the horizontal velocity of the ball bearing.

(2)

$v = d/t$ $v = \frac{0.5}{0.138629} = 3.6067 \text{ ms}^{-1}$

≈ 3.61

Horizontal velocity = 3.61 ms^{-1}

(iv) The student positioned the second foil strip with its centre 8.0 cm lower than the centre of the first foil strip.

Deduce whether the ball bearing broke the second foil strip at its centre.

Assume the ball bearing was travelling horizontally as it broke the first foil strip.

(2)

vertical distance travelled. u=0 s=? t=0.1386 a=9.81

$s = ut + \frac{1}{2}at^2$

$s = 0 + \frac{1}{2} \times 9.81 \times 0.1386^2$

s = 0.094 m

= 9.4 cm

So No, it did not break it at it's centre.

ResultsPlus
Examiner Comments

The marks were awarded as follows:
(ii) 2 (iii) 2 (iv) 2

ResultsPlus
Examiner Tip

Show all the values substituted into the formula.

Paper Summary

Based on their performance on this paper, students are offered the following advice:

- when carrying out a calculation write down the equation, substitute the values then calculate the answer
- ensure unit prefixes are understood - this particularly affected Q15(b) prefix G and Q18 prefix μ
- the answer to a "show that" question (e.g. Q18(b)(ii)) should be written to at least one more significant figure
- a "deduce" question will usually require a numerical comparison of the student's answer with a value given in the question.

New topics on the specification such as the application of moments in Q13 and the proof of the circular motion equation in Q17(a) presented difficulties. Ensure your revision covers every specification point.

Many answers to Q15(a) demonstrated a very sound knowledge of the standard model. However some students appear to have learnt considerably more than the specification requires and this sometimes led to a confusing answer. Take note of exactly what the specification requires you to know on this topic.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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