Examiners' Report
June 2017

GCE Physics 9PH0 01

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Introduction

This paper consisted of 90 marks and included some familiar formats of questions such as multiple choice, short and longer questions. Types of questions included calculations, short open response and extended writing. The topics covered are Working as a Physicist, Mechanics, Electric circuits, Further Mechanics, Electric and Magnetic Fields, and Nuclear and Particle Physics.

This paper gave candidates the opportunity to demonstrate a wide range of knowledge of different topics on the specification and also demonstrate a range of skills. It included the following new style questions:

Q13(a) tested the principles of a cyclotron and also awarded credit for how well the answer linked the key ideas together - known as a linkage question.

Q17(c) and Q18(c) presented candidates with an opportunity to consider whether a final calculated answer matched information provided within the question. Candidates were expected to make judgements and reach a conclusion.

In addition, Q17(b) and Q18(a) offered a number of alternate routes that candidates could take to calculate or determine the answer to the question. Some of the questions mixed different areas of the specification, such as Q17 with both potential dividers and mechanics featuring within the same scenario.

Well-prepared candidates did well on most questions on this paper. Whilst a few parts of questions such as Q11(b) and Q15(b) provided a challenge for even the most advanced candidates, all the marks were scored at various times. There was no evidence of candidates running out of time and failing to finish.

It was extremely pleasing to see candidates rise to the challenge of problem-solving questions with some particularly innovative approaches being used in Q17. Part (c) offered candidates a variety of methods and led to a range of well-presented answers which reflected an excellent understanding of mechanics.

In question 18(c) many answers successfully combined the use of the word equation with a thorough understanding of moments to predict whether the electrostatic motor might be used for the different applications. These candidates often found different routes through the calculations and made excellent sense of the scenario and demonstrated sophisticated problem-solving skills.

Questions 11(b), 15(b), 17(c) and 18 proved very discriminating and question 13(a) (the linkage question) was frequently well-answered by students who did not necessarily do as well on other sections of the paper. Questions 11(a), 12, 13, 14 and 16 gave all candidates the opportunity to gain accessible marks.

There were some examples of marks lost for trivial reasons such as not including a unit with a calculated answer, not calculating an answer to one further significant figure in a "show that" question, and not including a line in a calculation showing clearly all the substituted values.

Other examples of how to improve performance:

- when answering a question which asks for a judgement, remember to make a final comparative statement when reflecting on the calculated answer

- do not rephrase a question as an answer but look to add to the information already given
- use technical terms correctly.

Some answer spaces had been filled with repeated phrases rather than different points made succinctly. Remember that in open response questions a question total of 3 marks will often mean that three separate points are required.

Section A

Most multiple-choice questions discriminated appropriately with candidates displaying a sound understanding of unit conversion, momentum conservation, parallel combinations of resistors, energy stored on capacitors and the alpha scattering experiment.

In Q4, the use of mgh was surprisingly less convincing with many candidates thinking that a component of height had to be involved.

In Q6, A proved to be a common distractor suggesting that some candidates considered that the resistance of an LDR would decrease significantly in the dark.

In Q7, D was a common distractor with many failing to appreciate the magnetic effect of an iron core within a coil.

In Q9, C was the common distractor, with the invention of a "third" centripetal force.

Q10 proved difficult with C being the most commonly chosen answer suggesting many candidates assumed it was a parallel circuit.

Question 11 (a)

This question examined an understanding of "*F=ma*".

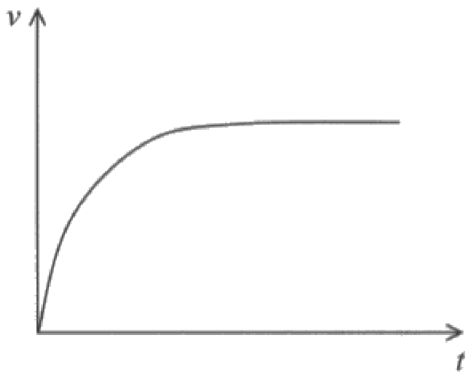
Answers were expected to link the gradient of the graph or acceleration with a comment about the corresponding resultant force.

Candidates could get full credit for an appropriate description of a driving force and its relative magnitude compared with a resistive force but answers following this route were often vague and less convincing.

There were three sections of the graph which deserved comment. The initial section in which acceleration is caused by a resultant force, the middle section in which a decreasing acceleration (some candidates incorrectly referred to this as when the acceleration slows down) is the result of drag forces increasing, and finally a constant velocity when the resultant force is zero.

Many answers only referred to "force".

Many answers did not consider the middle section of the graph, i.e. when the acceleration is decreasing.



(a) Explain the shape of this graph and include a consideration of force as part of your answer.

(3)

First, the gradient of the graph is large. mains the cyclist acted a big force on the bike and had a large acceleration. A little bit late, the gradient of v-t graph is smaller, mains the cyclist reduced the force and had a smaller acceleration. Finally, the v-t graph is a straight, mains the velocity is a constant, no external resultant force acted on the bike. acceleration is 0.

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Examiner Comments

This answer does not make reference to resultant force when discussing acceleration until describing the situation when the acceleration is zero.
It also reveals a common misunderstanding that the acceleration decreases because the (driving) force decreases rather than because the resistive forces increase.
This answer gained 1 mark.

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Examiner Tip

When discussing acceleration link it to resultant force.
Remember the *F* in *F=ma* stands for resultant force.
Try to avoid using phrases that are vague, e.g. "forces are balanced."

At the beginning, the resultant force comes from the cyclist accelerating the bicycle. This causes the bicycle to increase in velocity. As the velocity increases, the air resistance also increases. ~~Eventually the~~ This causes the acceleration to decrease. Eventually the air resistance balances out thrust from the cyclist, causing zero resultant force, thus zero acceleration and constant velocity.

ResultsPlus

Examiner Comments

This answer refers to "resultant force" appropriately and links it with acceleration.
It gained all 3 marks.

Question 11 (b)

This question was about the correct "Physics" meaning of Work done and what happens when kinetic energy becomes constant.

Work done results in the transfer of energy.

Candidates often incorrectly suggested that the work done was a form of energy in itself with answers such as "work done is converted to the kinetic energy".

Not all the energy transferred becomes kinetic energy (and many candidates scored this mark) but when the velocity becomes constant all the energy transferred is to the surroundings as heat etc.

(b) A student makes the following statement.

The work done by the cyclist is converted into the kinetic energy of the cyclist and bicycle.

Criticise this statement.

(3)

Work done is not itself an energy form, but instead the transfer of energy from one form to another. It is instead the chemical energy inside her body that is coverted into kinetic energy in her legs as they move around the pedals., This is the transferred to the kinetic energy of the bicycle
work is done by the cyclist in turning the pedals to get the bicycle to move

(Total for Question 11 = 6 marks)

ResultsPlus
Examiner Comments

This answer reveals a good understanding of the term "work done". It did not explain why the statement does not apply to the different sections of the graph.
It gained 1 out of 3 marks.

ResultsPlus
Examiner Tip

A part (b) of a question will often relate to part (a).
This statement needed to be discussed in relation to the cyclist on the lawn.

(b) A student makes the following statement.

The work done by the cyclist is converted into the kinetic energy of the cyclist and bicycle.

Criticise this statement.

(3)

First of all, ~~w~~ the work done by the cyclist does not convert to kinetic energy completely. Some energy will be dissipated to the surroundings as heat energy. Secondly, ~~it is the bicycle that~~ the student fails to mention that it is the cyclist's chemical energy that is converted to kinetic energy. 'Work done' ~~d~~can not be converted because 'wolk done' itself is the transfer of energy.

(Total for Question 11 = 6 marks)

ResultsPlus
Examiner Comments

This answer begins to explain that the energy transferred is to other forms as well as kinetic energy.
It does not explain that when the kinetic energy becomes constant all the energy transferred is to other forms.
It gained 2 out of 3 marks.

Question 12 (a–b)

This is a projectile question.

Part (a) is a "show that" question. Candidates should calculate their answer to one extra significant figure.

Part (b) was best solved by using $s=ut+1/2at^2$ and taking u as +8.6 and a as -9.8.

Some candidates used a method based on finding the time to the maximum height: whilst quite convoluted, this could still gain full credit.

(a) Show that the vertical component of the initial velocity is about 8.6 m s^{-1}.

(2)

~~the~~ U_v = ~~the~~ initial velocity vertical

$U_v = 14.2 \times \sin(37) = 8.546 \text{ ms}^{-1} \approx 8.6 \text{ ms}^{-1}$

(b) Calculate the height h above the ground from which the shot was thrown.

(3)

~~u = 0~~ ~~v = ?~~ $s = ?$ $v = 0$ $u = 8.546 \text{ ms}^{-1}$ $t = ?$ $a = -9.81$

$V = u + at$ $0 = 8.546 + -9.81t$ $t = 0.8712\text{ s}$ to reach the top of arc.

$1.98\text{ s} - 0.8712 = 1.109\text{ s}$

~~dropping it = 1.109 s~~

dropping it from top of arc = 1.109 s

$s = \frac{1}{2} \times 9.81 \times 1.109^2$

$= 6.03\text{ m}$

$s = 8.546 \times 0.8712 + \frac{1}{2} \times -9.81 \times 0.8712^2$

$= 3.72\text{ m}$

$h = 6.03\text{ m} - 3.72\text{ m}$

$h = 2.313\text{ m}$

$h =$ 2.313 m

ResultsPlus

Examiner Comments

The most popular way to do part (b) was to use $s = ut + 1/2\, at^2$
A common mistake was to ignore the upward initial velocity and downwards value of g.
This illustrates another approach using SUVAT equations which, whilst convoluted, is correct and gained all 3 marks.

Question 12 (c)

This part of the question required candidates to calculate the range - a horizontal distance - and this was emphasized in the question.

This is the product of the horizontal component of velocity and the time of flight as there is no acceleration in this direction.

(c) Calculate the horizontal distance R for this throw.

(3)

$U_h = 14.2 \cos(37) = 11.34 \text{ ms}^{-1}$

$S = U_h - V_h \times t / 2 = 11.34 \times 1.95 / 2 = 11.2266\text{m}$

$R = 11.2266\text{m}$.

ResultsPlus
Examiner Comments

The most common mistake was to use SUVAT and assume there is an acceleration in the horizontal direction as this example shows.
This gained 1 mark for a correct horizontal component of velocity.

ResultsPlus
Examiner Tip

In straightforward projectile questions, remember that the vertical acceleration is *g*, and the horizontal acceleration is 0.

Question 13 (a)

This question tested specification point 133: the role of electric and magnetic fields in particle accelerators. There were marks for recalling an appreciation of the key physics principles and up to 2 marks for linking the principles together sensibly.

The specification makes clear that candidates should understand the role of electric and magnetic fields in the cyclotron.

Some answers did not mention fields but talked about polarity, potential differences or currents. Whilst a degree of tolerance was used in the marking of these answers it is worth noting the emphasis is on the use of fields.

*(a) Explain how the cyclotron produces the high-energy proton beam.

(6)

The protons are accelerated by an alternating voltage when they pass between the dees, being accelerated every half revolution, a magnetic field going perpendicular to the dees ensures the protons stay in a circular path as it exerts a centripetal force on them. As the protons accelerate (so every half revolution) their path radius gets larger, once they are at the maximum energy for this cyclotron they are ejected out of the side as a high energy proton beam.

ResultsPlus

Examiner Comments

The most common marking point that candidates omitted was to say that the time spent in the DEEs is constant (or that the frequency of alternation is fixed) as illustrated by this answer.
This response gained 3 marks for the physics principles + 2 marks for sensibly linking them: a total of 5 out of 6.

ResultsPlus

Examiner Tip

Try to use the correct terminology:
alternates rather than "switches" or "flips"
electric field rather than vague statements about the charges on the DEEs.

Question 13 (b)

This question tested the ability to interpret a graph of information.

There are two aspects of the graph to particularly pick out.

Firstly that more energy is delivered to the tumour by the proton beam compared with X rays.

Secondly that less energy is delivered to surrounding tissue by the proton beam compared with X rays.

Many candidates scored the first mark but omitted the second or phrased the second point in a way that was not absolutely clear.

Deduce why the beam of protons could be a more effective treatment for tumours than a beam of X-rays.

(2)

The beam of protons deliver higher energy than the beam of X-rays at the point where the tumor is ~~78~~ so ~~they may be a more effective treatment~~
(about 12.5 cm below the skin)

ResultsPlus
Examiner Comments

Many candidates correctly pointed out that the energy delivered to the tumour by the proton beam is higher than by the X-rays but often did not discuss the implications for the surrounding healthy tissue. This answer is typical and gains 1 out of 2 marks.

ResultsPlus
Examiner Tip

When answering comparison questions ensure you write an appropriate comparison.
"The proton beam delivers more energy at the tumour than at other depths" is not a comparison that the question asked for.

Question 13 (c)

Part (c) tested specification point 6. This required candidates to use information given in the question to give two general points in favour of this treatment such as "better chances of success" or "fewer side effects".

Some candidates made or implied unreasonable claims such as the proton beam would save all lives, cure cancer, have no side effects etc.

Some candidates gave points repeating the information from part (b) such as "the energy delivered by the proton beam is greater" rather than considering the implication of this advantage.

Some candidates repeated the phrase given in the question "because the proton beam is more effective" rather than interpreting what this actually means.

(c) Developing new cancer treatments is expensive.

Give two possible reasons why money should be provided for the development of this new cancer treatment.

(2)

It is expensive to accelerate protons to high energies so money should be provided.

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Examiner Comments

The idea of this question was to ask candidates to consider why a new technology is worth investing in.
Some answers gave points which were too specific and which in general could not be deduced from the information given in the question.
This answer suggests that the candidate knows something about the different costs of the equipment.

ResultsPlus
Examiner Tip

Give answers to this type of question based on the information given in previous parts and its straightforward interpretation.
Avoid rephrasing the question.

- Reduces time spent under treatment.
- Increases success rate at removing tumours.
- Could save money in the long run as it would be quicker.

ResultsPlus
Examiner Comments

This answer gave the reasons that would lead to funding discussions and gains 2 out of 2 marks.

ResultsPlus
Examiner Tip

Convoluted sentences get in the way of making an argument.

Question 14 (a)

Question 14 is about the use of Force on a current-carrying conductor in a magnetic field to produce a pumping effect.

Part (a) required the use of Flemings left hand rule which gives the direction of the arrow as "out of the page".

Question 14 (b)

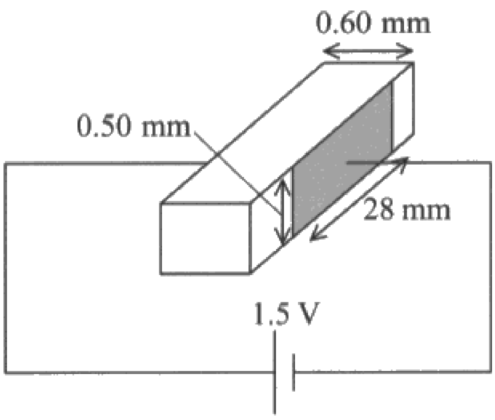
Part (i) tested the use of the resistivity equation coupled with the use of $V=IR$ to predict a current across a conducting liquid.

Part (ii) tested the use of $F=BIL$.

The cross-sectional area was shaded in the diagram to help candidates; the length being 0.60 mm.

However, some candidates took the 28 mm as the length in either the resistivity calculation or in (ii) $F=Bll$ or both. These answers lost some marks.

The electrodes were connected to a 1.5 V cell. Salt water was pumped using a magnetic field of magnetic flux density 0.40 T.



(i) Show that the current through the salt water is about 20 mA.

resistivity of salt water = 1.6 Ω m

(4)

$R = \frac{\rho L}{A}$

$A = 0.50\,mm \times 28\,mm$ $\quad l = 0.6\,mm = 6\times10^{-4}\,m$

$= 1.4\times10^{-5}\,m^2$

$R = \frac{(1.6\,\Omega m)(6\times10^{-4}\,m)}{(1.4\times10^{-5}\,m^2)} = 68.6\,\Omega$ $\quad V = 1.5\,V$

$I = \frac{V}{R}$ $\quad I = 0.021875\,A \approx 20\,mA$

(ii) Hence calculate the force on the salt water.

(2)

$F = BIL$ Perpendicular

$F = 0.4\ (0.021875)(6 \times 10^{-4})$

$F = 5.25 \times 10^{-6}$ N

Force = 5.25×10^{-6} N

ResultsPlus
Examiner Comments

Look carefully at the diagram to decide which is the length and what dimensions contribute to the cross-sectional area.
Some answers suggested that the 28 mm was the length of the conductor rather than the 0.6 mm.
This answer has the correct dimensions for *A* and *L* but does not convert their unrounded answer into mA.

ResultsPlus
Examiner Tip

If the "show that" answer is required in mA ensure you show the conversion to mA before rounding to the value given.
This answer gained 3 out of 4 marks; had it stated 22mA it would have gained full credit.

Question 15 (a)

This question started with a circuit in which a capacitor is charged through a resistor.

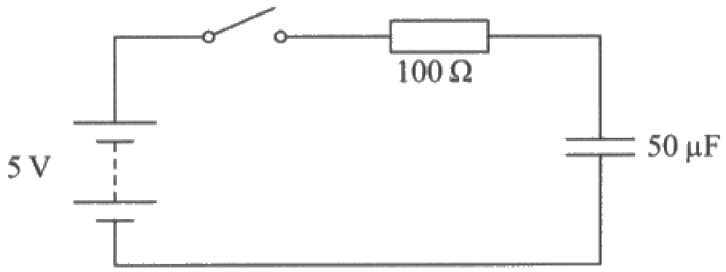
The question asked candidates to describe the potential differences across both the capacitor and the resistor as the capacitor charged.

It was pleasing to note the vast majority of candidates described a charging rather than a discharging process.

However a significant number of answers discussed the capacitor and omitted the resistor.

Some candidates correctly commented that the p.d. across the capacitor would increase but omitted that it starts at 0 V and ends at 5 V, or similarly missed the starting and end points for the resistor.

15 A circuit consists of a battery of e.m.f. 5 V and negligible internal resistance, a switch, a 100 Ω resistor and an uncharged 50 μF capacitor.



(a) Describe what happens to the potential difference across the resistor and the potential difference across the capacitor after the switch is closed.

(4)

When the switch closes, current is allowed to flow. The P.d is instantly up to its max value across the resistor. ~~Current it he~~

The p.d across the capacitor is exponential. It increases quickly at first but then slows down. The time constant $= 100 \times 50 \times 10^{-6} = 0.005$ sec. This means at 0.005 seconds it is at about 63% capacity. After about 0.025 seconds it is fully charged.

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Examiner Comments

The question required a description of the way the potential difference across both the capacitor and the resistor will change when the switch is closed.
Some answers discussed one or the other. While most answers revealed that candidates knew that the p.d. across the capacitor would reach 5 V, the initial and final values for the p.d. across the resistor were less commonly stated.
This answer does not state that the capacitor p.d. will reach 5 V and omits similar start and end points for the p.d. across the resistor. It gains 2 out of 4 marks.

Question 15 (b)

This part discussed the way a capacitor resistor circuit responds to an applied p.d. which switches on and off. It follows on from part (a).

The answer required adding a scale to the time axis. This can be achieved by using $T=1/f$ to show that the time period of the wave is 50 ms. Some candidates omitted to note the time axis units as ms and wrote 0.1 next to the two full waves point.

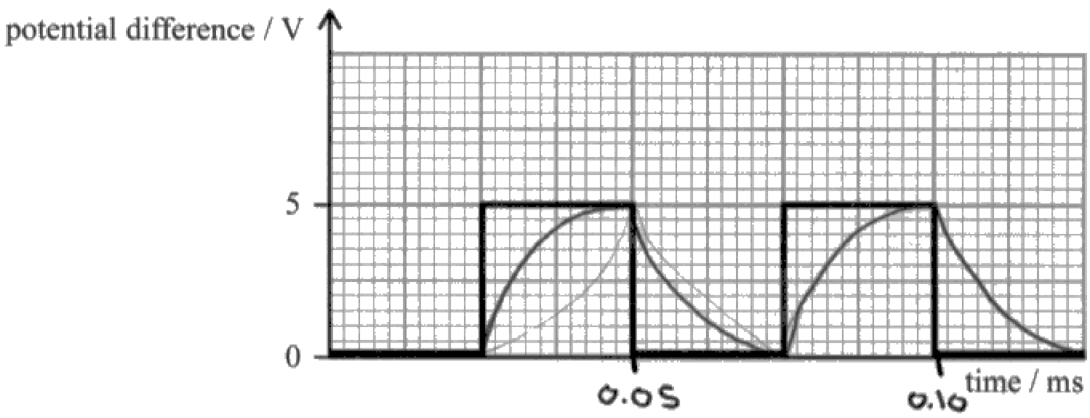
Candidates then needed to have some idea of how long the capacitor would take to charge/ discharge by using the time constant equation.

This reveals that the time (half of a full wave ie 25 ms) is just sufficient to fully charge and discharge.

Finally, the exponential sketch of charging the capacitor should fit within a "square" and the discharge curves to the right hand side when the applied p.d. is off. Some credit was awarded if the charging and discharging curves were swapped over so that the charging curve corresponded to when the applied p.d. was off.

Some candidates did not use the time constant equation and therefore did not know how long the process would take.

Some candidates thought that the question was about alternating potential differences and attempted to calculate an r.m.s. value of some description.



On the graph add values to the time axis and sketch a graph of the potential difference, V_{out}, across the capacitor for two cycles of the square wave. Assume the capacitor is initially uncharged.

(5)

$f = 20 \therefore T = \frac{1}{f} = \frac{1}{20} = 0.05$ sec.

$RC = 100 \times 50 \times 10^{-6} = 0.005 \therefore T \gg RC$

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Examiner Comments

This answer reveals a common mistake to write 0.1 rather than realise the scale for time is in ms.
In all other respects it is a good answer and shows the capacitor charging and discharging as the voltage applied is switched on and off and gained 4 out 5 marks.

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Examiner Tip

When dealing with resistor-capacitor questions calculate the time constant *RC* if you are given the values. It is likely to be helpful.

Question 16 (a)

Question 16 is about particle physics. Although the question is about a lambda particle the candidates are not required to know any details about different particles other than those stated in the specification.

It was pleasing to note the vast majority of candidates understood that a baryon was comprised of three quarks whose charge must, in this case, total zero.

Quark	Charge / *e*
u	+2/3
d	−1/3
s	−1/3

State, with justification, the quark content of a Λ^0 particle.

(2)

uds . This is because Λ^0 particle is neutrally charged. Therefore the total charge of the quarks together should sum up to zero.

ResultsPlus
Examiner Comments

The word neutral was used in the stem of the question. Answers were expected to state that this means 0 charge, or more usefully to show the three charges on the u, d and s quarks adding to 0.
This answer makes the point clear.

ResultsPlus
Examiner Tip

If a question says "with justification" ensure you have fully explained your thinking.

Question 16 (b)

This part involved a unit conversion from MeV/c^2 to kg.

The vast majority of answers were fully correct but some did not take the M into account - this resulted in a one-mark penalty.

Part (b) is a standard conversion of units.

(b) Calculate the mass of the Λ^0 particle in kg.

(3)

$E = mc^2$ ~~$1116 \times 10^6 \times (3 \times 10^8)^2$~~

$1116 \text{ MeV}/c^2 = 1116 \text{ MeV} = 1116 \times 10^6 \text{ eV} \times 1.6 \times 10^{-19}$

$= 1.79 \times 10^{-10}$ kg

Mass of Λ^0 particle = 1.79×10^{-10} kg

ResultsPlus
Examiner Comments

The most common error was to forget to square the speed of light *c* - although this answer omits *c* completely. It gains 1 out of 3 marks for multiplying by the charge on the electron.

Question 16 (c)

Part (c) tests whether candidates are familiar with the conservation laws in points 135 and 142 of the specification.

The fifth process was named correctly by almost all candidates because the conservation of charge does not hold.

The second process was named by many because baryon number is not conserved.

Some candidates did correctly identify the fourth process but often cited that strangeness is not conserved.

There are some particle interactions and decays in which strangeness is not always conserved so this is not a conservation law to rely on.

Momentum has to be conserved in all particle interactions and two particles produced by the decay are required to conserve momentum with one particle recoiling from the other. For this reason the lambda particle cannot decay into one particle (the neutron) alone.

(c) A student suggests five ways a Λ^0 particle might decay. These are

$\Lambda^0 \rightarrow p + \pi^-$ Q = 0
~~Λ^0~~ $\rightarrow e^+ + e^-$ Q = 0
$\Lambda^0 \rightarrow n + \pi^0$ Q = 0
$\Lambda^0 \rightarrow n$ Q = 0
~~Λ^0~~ $\rightarrow p + \pi^0$ Q = +1

Deduce which of these decay processes are **not** possible.

(6)

• $\Lambda^0 \rightarrow p + \pi^0$ is not possible as charge is not conserved. ~~the π p~~ p the proton and π^0 have a total charge of +1e.

• $\Lambda^0 \rightarrow e^+ + e^-$ is not possible as the baryon number is not conserved. The left side has a baryon number of 1 while the right has a baryon number of 0.

• $\Lambda^0 \rightarrow n$ not possible as strangeness isn't conserved as the left side has -1 strangeness but the right has 0 and it is a weak interaction as quark flavour

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Examiner Comments

The application of the conservation of charge and baryon number were well understood by most candidates as this answer shows.
Many answers suggested that the fourth example Λ^{o} □ n was not possible (which is correct) but gave the wrong reason - conservation of strangeness. Conservation of strangeness is not always observed in particle interactions and therefore cannot be an automatic assumption.
However momentum will not be conserved unless at least two particles are produced from the decay of a single particle.
This answer gained 5 out of 6 marks.

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Examiner Tip

With these questions, remember there is conservation of charge, energy, momentum, baryon and lepton number to consider.

Question 16 (d)

Part (d) is concerned with energy - matter conversion.

Large-mass particles can be created from high energy collisions as a result of $\Delta E = \Delta mc^2$.

Some candidates incorrectly suggested that a collision between two particles was required to produce a particle more massive than either of the two initial particles; the implication being that the two particles collide and stick together.

Some candidates incorrectly suggested that particles were created when particles disintegrate, like a billiard ball splintering into pieces.

(d) Lambda particles were first detected in experiments which made use of cosmic rays entering the atmosphere. Cosmic rays are mainly high-energy protons which have a mass less than that of a lambda particle.

Explain why a cosmic ray could lead to the creation of a lambda particle.

(2)

the cosmic rays are travelling at relativistic speeds this causes them to slow down and some of the energy is converted into ~~[illegible]~~ a ~~[illegible]~~ mass. This mass ~~is~~ is greater than it was before.

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Examiner Comments

Answers frequently omitted a reference to the equation $\Delta E = \Delta mc^2$ as in this example. It therefore gained 1 out of 2 marks.

ResultsPlus
Examiner Tip

If possible use a relevant equation which can be quoted and is useful to the argument.

Question 16 (e)

The question firstly required candidates to point out why a neutral particle will not be observed for one mark. It then required a connection between conservation laws and what information is already known and not known about the lambda particle.

Some candidates referred to charge and whilst this gained some credit this would already be known due to the lack of a track rather than by studying the decay particles.

The momentum of the particle can be determined by adding the vector values of momenta of the two decay particles. The curvature of the tracks lead to values of momenta.

In general, an answer referring to momentum often leads to full credit of two marks.

This part tested specification point 135.

(e) The Λ^0 particle cannot be directly observed in particle experiments, however some of the decay products can.

Explain why the Λ^0 particle cannot be directly observed but information about it can be obtained by studying its decay particles.

(3)

As the Λ^0 particle has no charge it cannot be detected in experiments. However, as it decays in can produce particles with equal opposing charges which can be observed via cloud and bubble chambers which map the particles path via the ionisation of the particle. The paths can be used to determine what each particle is via its momentum distinguished by spirals formed and the shape/type of path it makes.

(Total for Question 16 = 16 marks)

ResultsPlus
Examiner Comments

Many answers rephrased or quoted the question and started by saying neutral particles cannot be observed in detectors, rather than explaining why, as in this example.
The momenta and charge of the decay particles can be obtained by studying the curvature of their tracks.
The question asked what information could be obtained for the lambda particle. The charge of the lambda particle is already confirmed by the lack of a track; however its momentum can be determined by conservation of momentum. The sum of the momenta of its decay particles will equal the momentum of the lambda particle.
This answer states that the momenta of the decay particles can be determined but omits to describe how this can lead to the momentum of the lambda particle. It gained 1 out of 3 marks.

ResultsPlus
Examiner Tip

Try to add to the information already given in a question. The curvature of a track in a bubble chamber can be used to determine the charge and the momentum of the particle.

Question 17 (a)

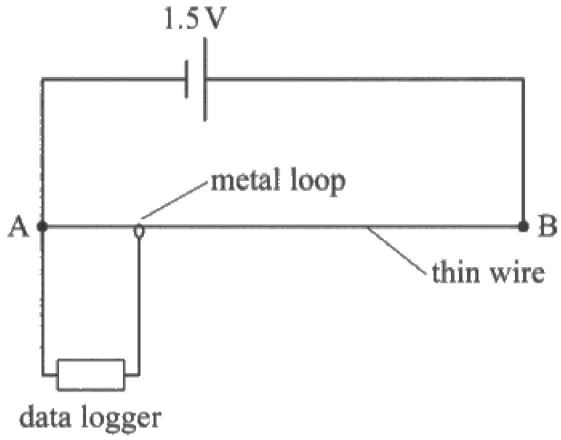
This question is based on a demonstration of motion on an inclined plane. It combines the topics of potential dividers and mechanics. Part (a) required an explanation of a potential divider in this particular context.

Many candidates appreciated the essential idea of a potential divider but often did not express their ideas well enough to gain full credit. There are different ways to explain a potential divider and different approaches were rewarded. The most common one was to describe the wire as two series resistors either side of the metal loop and this is a sensible way to answer this question.

The final mark point that the potential difference is proportional to length in this case was rarely seen.

Part (a) tested specification point 43: potential divider circuits.

(a) The two ends of the wire are connected to a 1.5 V cell. A data logger, set to measure potential difference, is connected to the metal loop and to the negative terminal of the cell.



Explain how the potential difference recorded by the data logger will vary as the loop moves along the length of the wire AB.

(3)

The trolley loop and thin wire effectively acts as a potentiometer / potential divider. The greater the distance the loop moves along AB, the ~~greater~~ smaller the resistance on the right hand side of the loop, the p.d ~~across the~~ that the datalogger measures therefore increases with the distance along AB.

ResultsPlus
Examiner Comments

Most answers showed an appreciation that the p.d. would increase; however, significantly fewer answers could explain why.
This answer reveals an understanding that the wire can be treated as two series resistors: the two lengths of wire either side of the metal loop act as two series resistors. This gains 2 out of 3 marks.

ResultsPlus
Examiner Tip

The resistivity equation was a useful way to help answer this question, essentially stating that resistance is proportional to length of wire.

Question 17 (b–c)

Part (b) was ideally answered by taking the gradient of the graph and converting the potential difference to a distance.

This would give the instantaneous value of velocity at the time required.

Some candidates read off the value of potential difference at this time and converted this to distance and then used a SUVAT equation to predict the velocity. This gained credit but does make the assumption that the initial velocity is zero at the start of the graph which is not quite true.

Some answers assumed the speed of the trolley was constant down the slope which is not correct.

Part (c) was pleasingly answered by a significant number of candidates. It is an example of a new style of question which expected candidates to reflect on their calculated answer and make a comment.

There are a number of approaches that could gain full credit. The most popular was to calculate the acceleration using $v=u+at$. Candidates could take their previous value of velocity and use either the 1.5 given in the question or were permitted to use $u = 0$ at $t=0$.

The equation $a = g\sin\theta$ could then be used to predict the angle of slope θ.

Answers to questions which require a comparison to be made with data given in the question such as this part and Q18(c) should include a numerical comparison.

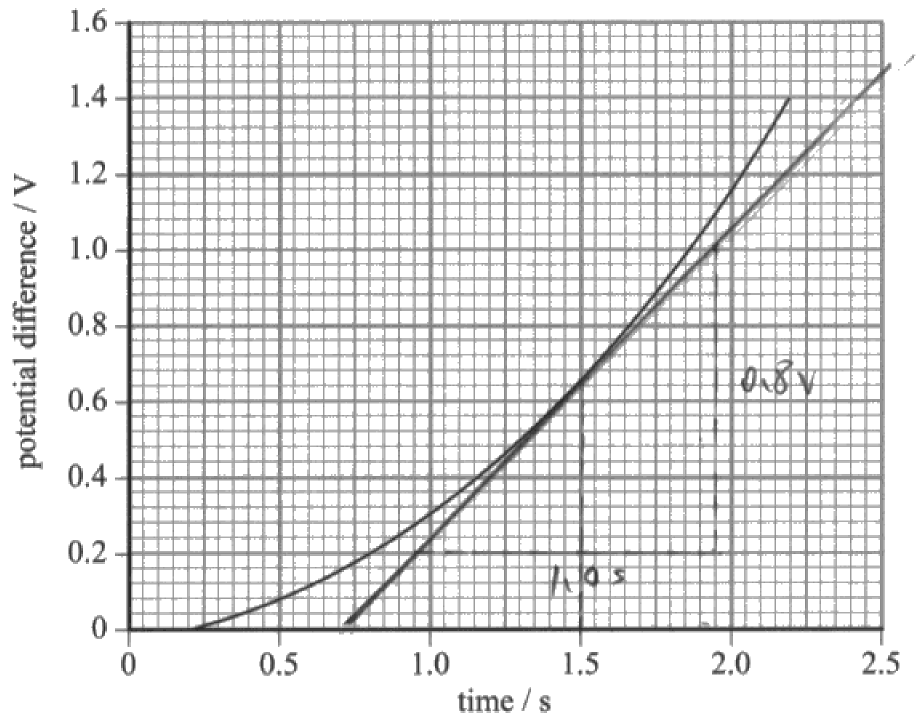
It is not enough to simply say "the angle is 4.3° and this is within the uncertainty".

Part (b) offered a number of ways to reach a value of velocity - however, some methods made the assumption that the trolley was at rest at t=0 seconds.

These methods, using SUVAT, could be given a maximum of 3 marks, as this was not stated explicitly in the question.

Part (c) again offered several different approaches but the question asked candidates to consider acceleration and make a decision about the angle of slope. This was a new style of question.

(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

1.5 V represents a distance of 2.00 m.

(4)

$\frac{dV_{(p.d.)}}{dR} = I\frac{\rho}{A}\frac{dl}{dt} = I\frac{\rho}{A}v$ $\therefore \frac{dV_{(p.d)}}{dR} \propto v$

also $V \propto l$ Scale $= \frac{1.5}{2.0} = 0.75\,V/m$

$\frac{0.8}{0.75 \times 1.0} = 1.07\,m\,s^{-1} \approx 1.1\,m\,s^{-1}$

Velocity = $1.1\,m\,s^{-1}$

(c) The student calculated the velocity of the trolley at 2.0 s to be 1.5 m s^{-1}.

By considering the acceleration of the trolley, determine whether the student's measurement of θ was within the uncertainty quoted.

(4)

let mass of trolley be m

$F = ma \therefore w \sin\theta = m a \quad mg \sin\theta = ma$

$\sin\theta = \frac{a}{g}$

$a = \frac{1.5 - 1.1}{2.0 - 1.5} = 0.8 m.s^{-2}$

$\sin\theta = \frac{0.8}{9.81} = \frac{80}{981}$

$\theta = \sin^{-1}\frac{0.8}{9.81} = 4.68° \approx 4.7°$

4.7° is with range of 3° – 5° (±1° around 4°)

∴ The measurement of θ was within uncertainty quoted.

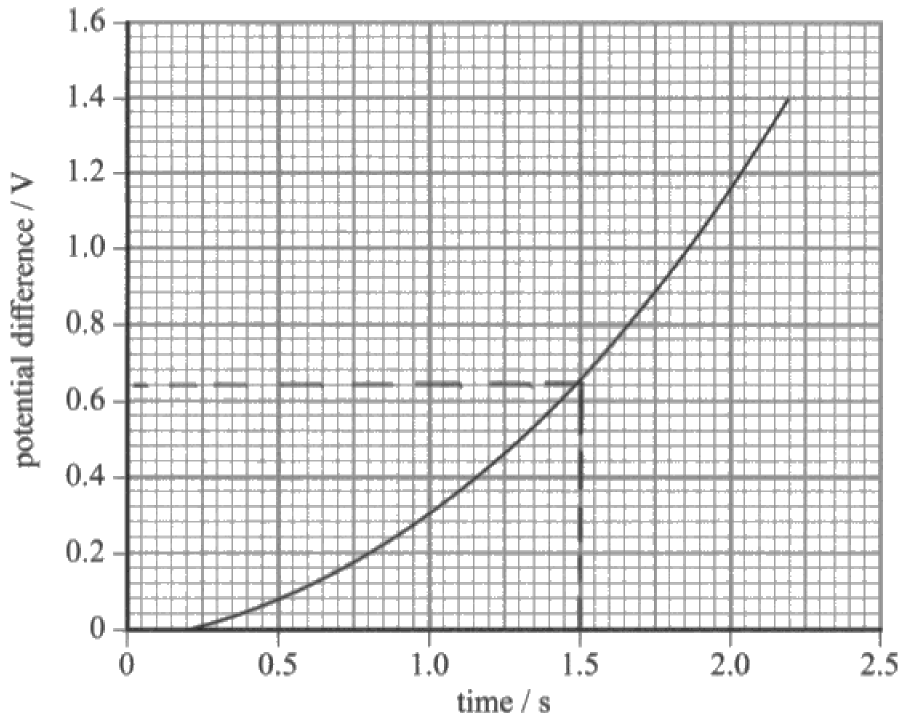
ResultsPlus
Examiner Comments

This answer illustrates a model answer to (b) and (c) and makes use of the gradient of the graph at the relevant time.

ResultsPlus
Examiner Tip

When asked to consider whether a quantity (in this case an angle) lies within a certain range ensure you use a numerical argument within your conclusion.

(b) The graph shows the data obtained from the data logger.



Determine the velocity of the trolley at 1.5 s.

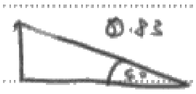
1.5 V represents a distance of 2.00 m.

(4)

~~1.5 V = 2 m~~   1.5 V   2 m

0.62 V × ?

At 0.62, d = 0.83 m



$v = \frac{d}{t}$ 0.83 cos(4) = 0.83

$v = 0.83 / 1.5$

$v = 0.55\ ms^{-1}$

Velocity = $0.55\ ms^{-1}$

ResultsPlus
Examiner Comments

This answer reveals an alternate method.
The candidate has taken an (incorrect) value of V from the graph, then scaled it correctly to distance.
However, a common mistake was to assume that the velocity was constant as illustrated here.

Question 18 (a)

Question 18 examined electrostatic forces, moments of forces and a knowledge of electric field line and equipotential diagrams.

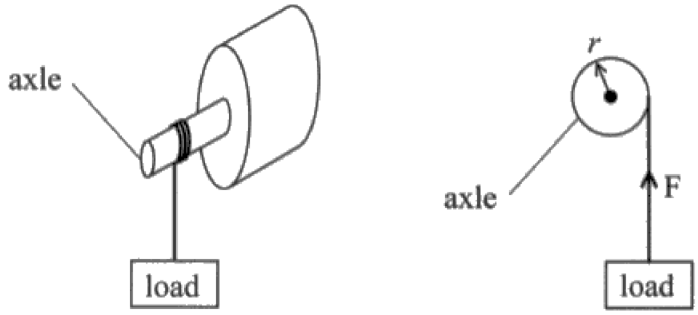
Part (a) required a derivation of an unfamiliar equation. The individual steps are all standard topics and there were three common approaches all of which could gain full credit.

Almost all candidates gained one mark for using work = force × distance but a number of derivations then went wrong because this distance was confused with perpendicular distance in order to try and introduce the moment of a force equation.

This part concerns the derivation of an equation using individual steps that candidates should be familiar with.

18 Motors usually have a rotating component which can do work W.

(a) A motor lifts a load in a time t. The axle of the motor has a radius r and exerts a force F.



The power produced by a motor can be calculated by using the following word equation.

Power = moment of the force exerted by the rotating axle × angular velocity

Derive this equation, starting with power $P = \dfrac{W}{t}$.

(4)

$W = Fd \quad \therefore \quad P = \dfrac{F \cdot d}{t} \xrightarrow{v = \frac{d}{t}} P = Fv \xrightarrow{v = \omega r} P = Fr\omega$

$\downarrow F \cdot r = \text{moment}$

Power = moment of force exerted by rotating axle × angular velocity.

ResultsPlus
Examiner Comments

The derivation of the formula in part (a) involved four steps.
This answer shows one route that candidates could take. It is clear and the equations the candidate used have been neatly itemised. It would gain 4 out of 4 marks.

ResultsPlus
Examiner Tip

You can explain things clearly without using long-winded sentences.

$P = W/t$

$= F \times d/t$

$= F \times r \times r\theta/t$

$= F \times r \times r\theta/t$

$= F \times r \times \omega$

= moment of force × angular velocity

ResultsPlus

Examiner Comments

A number of answers confused distance as in distance moved by a force with perpendicular distance as in a moment calculation.
This answer appears to invent an extra radius *r*. It would gain 1 out of 4 marks.

Question 18 (b)(i)

This part required candidates to indicate the direction of the electric field by adding an arrow to the field lines which should be the direction of force on a positive charge. The question also required the addition of equipotential lines. These should be perpendicular to the field lines and should not cross or touch.

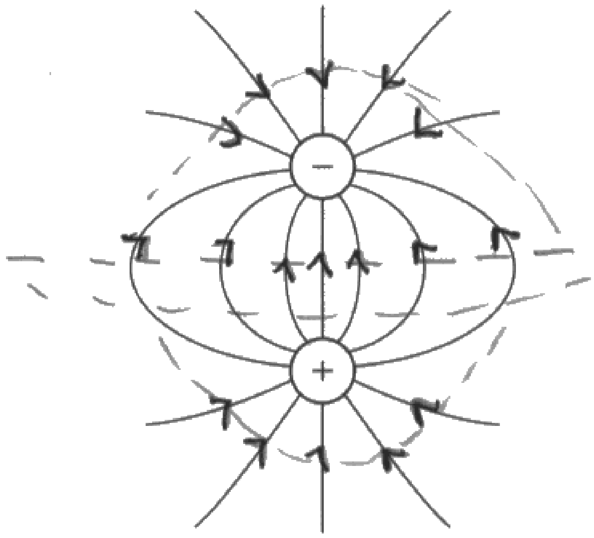
The mark scheme required a minimum of three lines. A sensible line to start with was horizontal, central, and straight. Two approximate circles above and below this line were acceptable for full credit.

(i) In the diagram below, electric field lines have been drawn around one pair of these spheres.

Add to the diagram to show

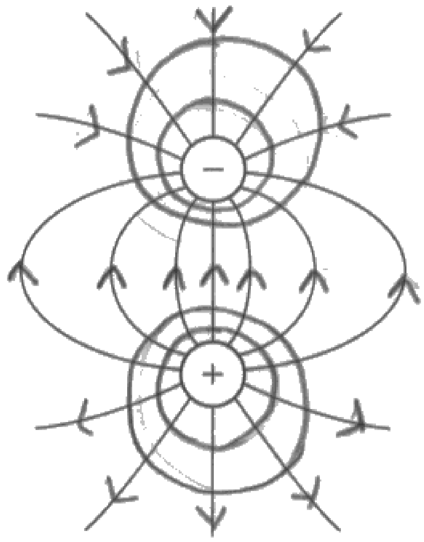
- the directions of the field lines
- the lines of equipotential.

(3)



ResultsPlus
Examiner Comments

This answer has the correct arrows pointing towards the negative charge but the arrows underneath the positive charge point in the wrong direction.
The central horizontal equipotential line is a sensible line to start with. The other two lines are not continuous and become parallel with the field strength lines rather than perpendicular. Two full "circles" would have been adequate.
The response gained no marks.



ResultsPlus

Examiner Comments

This answer is much better. The arrows are correct.
The equipotential lines are continuous and largely perpendicular to the field lines.
The diagram has a reasonable degree of symmetry. It would gain 3 out of 3 marks.

Question 18 (b)(ii) – (c)

Part (b)(ii) is a standard calculation of force between two charged particles using the equation in specification point 110. The question is a "show that" so the answer needs to be given to at least one further significant figure.

A few answers did not calculate a value of Force or calculated an incorrect value. If the substitutions of charge, a distance and the constant were shown this could gain one mark of credit.

Part (c) was another new style question in which candidates were invited to make some calculations and, using a table of data, make a recommendation of which applications could use this type of motor. Many candidates did well and a number of approaches were rewarded with full credit.

Some answers predicted the force required by using

moment of force = Force × perpendicular distance = power ÷ angular velocity

then compared the value with that obtained in (b)(ii) for full credit.

Another approach was to use the value of force from (b)(ii) to predict a power required for each application. Then compare this value with that stated in the table.

The most common mistake was take the distance as 0.04 m rather than 0.08 m between the two forces on either end of the 8 cm rod.

Part (b)(ii) is a "show that" question. The answer should be given to, at least, two significant figures (0.036 N).

Part (c) asked candidates to consider some data and decide whether the electrostatic motor could be used for any of the applications. It is an example of a new style of question.

(ii) The distance between the centres of each charged sphere in this pair is 5.0 cm.

Show that the force between this pair of charged spheres is about 0.04 N.

charge on each sphere = 0.10 μC

(2)

$F = k\frac{Q_1 Q_2}{r^2} = \frac{8.99 \times 10^9 \times 0.1 \times 10^{-6} \times 0.1 \times 10^{-6}}{(5 \times 10^{-2})^2}$

$= 0.03596$

$0.036 = 0.04 N.$

(c) The table shows the typical power and the corresponding angular velocity required for three different appliances.

	Power / W	**Angular velocity / rad s^{-1}**
Electric car	2.0×10^4	300
Vacuum cleaner	1.4×10^3	1000
Small pond pump	0.5	200

Deduce which of these appliances, in principle, could use the electrostatic motor in (b).

You should use the word equation in (a) and assume that the length of the rod in the electrostatic motor is 8.0 cm.

Assume that the electrostatic motor would deliver a constant force throughout one complete rotation.

(4)

P = moment of force by rotating axle x Ang v.

0.864 | $0.036 \times 8 \times 10^{-2} \times 300$

2.88. | $0.036 \times 8 \times 10^{-2} \times 1000$

0.576 | $0.036 \times 8 \times 10^{-2} \times 200$

Small pond pump as power = 0.576 = 0.5 W

ResultsPlus
Examiner Comments

The two popular ways to answer part (c) were either to predict the force required for each application or to predict the power produced by the electrostatic motor. Either way the answer should include a final quantitative comparison, e.g. the force required in a small pond pump is 0.031 N so this is smaller than 0.036 N. (This was calculated above in part (b)(ii) so it could be used in this application.)

This answer makes an effort to compare power required with power generated by the electrostatic motor for each example and so gains full credit.

ResultsPlus
Examiner Tip

When you have been asked to make a decision based on calculated values you should refer to them when making your final statement.

Paper Summary

Based on their performance on this paper, candidates could improve on the following points:

- An understanding of the concept of "work done";
- How particle tracks can be used to determine momentum and the use of its conservation law;
- The use of a gradient of a graph to find an instantaneous value of rate of change;
- A general appreciation of potential divider circuits;
- The behaviour of a capacitor-resistor circuit when being charged and discharged.

Grade Boundaries

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

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