1 The number of neutrons in a nucleus of $^{197}_{79}Au$ is

☐ **A** 276

☐ **B** 197

☒ **C** 118

☐ **D** 79

$^{197}_{79}Au$ $197 = A = p + n$ $79 = Z = p$

$79 + n = 197$

$n = 118$

(Total for Question 1 = 1 mark)

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2 Which of the following is a possible unit for rate of change of momentum?

☐ **A** kg m s

☐ **B** kg m s^{-1}

☒ **C** kg m s^{-2}

☐ **D** kg m s^{-3}

$F = \frac{\Delta mv}{t}$ $\frac{kgms^{-1}}{s}$ $kgms^{-2}$

(Total for Question 2 = 1 mark)

---

3 A positron enters a particle accelerator. As it emerges from the accelerator its mass is measured to be 3.8×10^{-29} kg.

$m_0 = 9.11 \times 10^{-31}$ kg

It can be concluded that the positron

☐ **A** has become a different particle.

☐ **B** is travelling in a circle.

☒ **C** is travelling at close to the speed of light.

☐ **D** is travelling at a non-relativistic speed.

4 Particles of mass m, each carrying a charge q, are travelling with a speed v. They enter a magnetic field of flux density B at right angles to the field. This causes the particles to move in a circular path.

Which of the following changes would decrease the radius of the path of the particles?

- ☐ **A** an increase in m
- ☒ **B** an increase in q
- ☐ **C** a decrease in B
- ☐ **D** an increase in v

$r = \frac{mv}{BQ}$ if increase in q larger denominator so smaller r

(Total for Question 4 = 1 mark)

5 A 500 μF capacitor (C_1) is charged to a potential difference V_1. A second capacitor of capacitance 50 μF (C_2) is charged to a potential difference V_2 so that the two capacitors store the same amount of energy.

The value of $\left(\frac{V_1}{V_2}\right)^2$ is

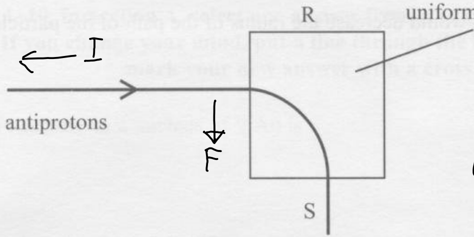
- ☐ **A** 100
- ☐ **B** 10
- ☒ **C** 0.1
- ☐ **D** 0.01

$W = \frac{1}{2}QV = \frac{1}{2}CV^2$ $\quad W_1 = W_2$

$\frac{1}{2}C_1V_1^2 = \frac{1}{2}C_2V_2^2$

$\left(\frac{V_1}{V_2}\right)^2 = \frac{C_2}{C_1}$ $\quad \frac{50\mu F}{500\mu F} = \frac{1}{10}$ $\quad 0.1$

6 A beam of antiprotons enters a uniform magnetic field, causing the beam to change direction as shown in the diagram.



Fleming's Left Had Rule

What is the direction of the magnetic field?

- ☐ **A** perpendicularly out of the page
- ☒ **B** perpendicularly into the page
- ☐ **C** towards R
- ☐ **D** towards S

(Total for Question 6 = 1 mark)

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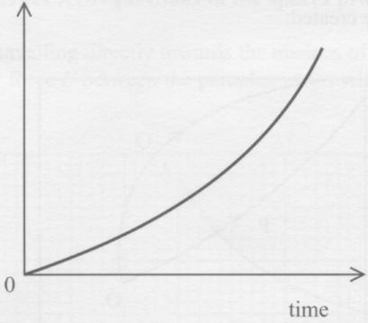
7 A student suggests that two colliding protons could undergo the interaction

$$p + p = p + n + \pi^{+}$$

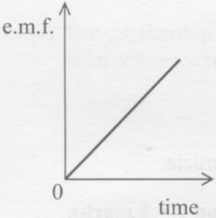
Which of the following statements is true?

- ☐ **A** The interaction is not possible because charge is not conserved. 1+1 = 1+0+1
- ☐ **B** The interaction is not possible because the number of particles is not conserved. X
- ☒ **C** The colliding protons must have a very high value of kinetic energy. mass created
- ☐ **D** The resulting particles must have a very high value of kinetic energy.

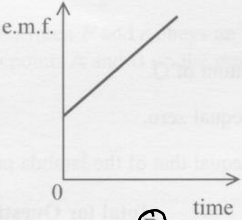
8 The graph shows how the magnetic flux passing through a coil varies with time.



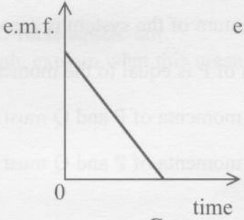
Which of the following graphs could show how the magnitude of the e.m.f. induced in the coil varies with time?



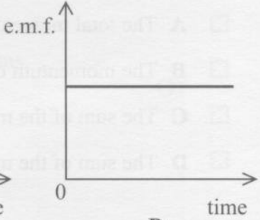
A



B



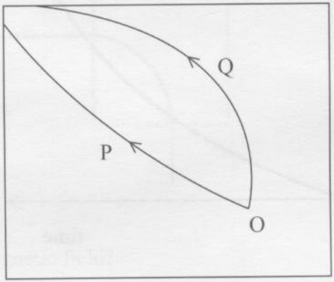
C



D

Questions 9 and 10 refer to the diagram below.

The diagram shows the tracks in a particle detector. A lambda particle has decayed at O and two particles P and Q were created.



9 Which of the following is a correct statement about momentum in this decay?

☐ **A** The total momentum of the system is zero.

☐ **B** The momentum of P is equal to the momentum of Q.

☐ **C** The sum of the momenta of P and Q must equal zero.

☒ **D** The sum of the momenta of P and Q must equal that of the lambda particle.

(Total for Question 9 = 1 mark)

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10 Which of the following must be a correct statement about energy in this decay?

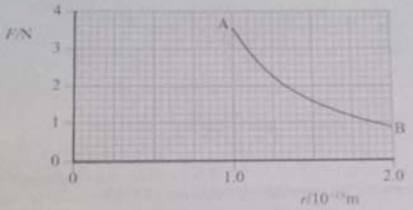
☐ **A** total energy of P and Q < total energy of the lambda particle

☒ **B** total energy of P and Q = total energy of the lambda particle

☐ **C** total energy of P and Q > total energy of the lambda particle

☐ **D** total energy of P > total energy of Q

11 An alpha particle $^{4}_{2}He$ is travelling directly towards the nucleus of a gold atom $^{197}_{79}Au$.
The graph shows how the force F between the particles varies with their separation r over a short distance.



(a) The relationship between F and r obeys an inverse square law.
With reference to points A and B on the graph, explain what this means.

(2)

the Force is inversely proportional to the square of the seperation. $F = \frac{k}{r^2}$. So the factor by which the Force is changed, is the inverse square of the factor r is changed.
at A F = 3.5 N r = 1 × 10^{-13} m when r is doubled to 2 × 10^{-13} m, F is decreased by a factor 4 (0.875) as shown at point B.

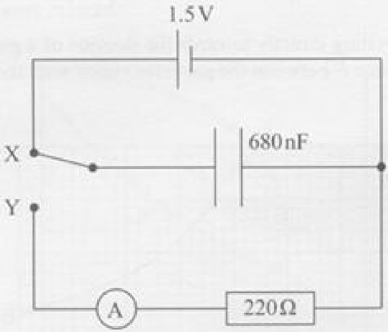
(b) Calculate the force between the alpha particle and the gold nucleus when their separation is at its minimum value of 4.5×10^{-14} m.

(3)

$$F = \frac{Q_1 Q_2}{4\pi \varepsilon_0 r^2} \qquad F = \frac{2(1.6\times10^{-19}) \times 79(1.6\times10^{-19})}{4\pi(8.85\times10^{-12})(4.5\times10^{-14})^2}$$

17.96.. N

12 A capacitor can be charged and discharged using the following circuit. It can be assumed that the ammeter has zero resistance.



(a) Initially the switch makes contact at X.
Calculate the charge stored by the capacitor when it is fully charged. **(2)**

$Q = CV = 680 \times 10^{-9} \times 1.5$

$= 1.02 \times 10^{-6}\,C$

Charge = ...

(b) The switch is moved to make contact at Y so that the fully charged capacitor is discharged through the 220 Ω resistor.

Calculate the charge remaining on the capacitor after it has been discharging for 1.0 ms and comment on your answer. **(4)**

$Q = Q_0 e^{-t/RC}$

$= 1.02 \times 10^{-6} e^{-\frac{1 \times 10^{-3}}{220 \times 680 \times 10^{-9}}}$

$= 1.28 \times 10^{-9}\,C$

Charge = ...

Comment Almost fully dischaged

(c) The capacitor is charged and discharged 500 times per second.

Calculate the average current through the ammeter.

(2)

$$I = \frac{\Delta Q}{\Delta t} = \frac{500 \times 1.02 \times 10^{-6}}{1}$$

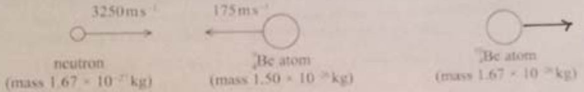
$$= 6.0 \times 10^{-4}\,A$$

13 (a) State the principle of conservation of momentum.

(2)

the total momentum before a collision is equal to the total momentum after a collision (or explosion). as long as no external forces are acting

(b) A head-on collision occurs between a neutron and a beryllium atom $^{9}_{4}Be$. The nucleus of the beryllium atom absorbs the neutron to form the isotope $^{10}_{4}Be$.



(i) Calculate the velocity of the $^{10}_{4}Be$ atom, indicating its direction by adding an arrow to the diagram.

(4)

momentum before = momentum after

$1.67\times10^{-27}(3250) + 1.50\times10^{-26}(-175) = 1.67\times10^{-26}\,V$

$V = +167.81\ ms^{-1}$

$168\ ms^{-1}$

Velocity = $168\ ms^{-1}$

(ii) Using a suitable calculation, determine whether the collision was elastic or inelastic.

(2)

an elastic collision KE is conserved where as in an inelastic collision KE is not conserved: $\frac{1}{2}mv^2 \neq \frac{1}{2}mv^2$

Before

$\frac{1}{2}\times(1.67\times10^{-27})\times(3250)^2 + \frac{1}{2}(1.5\times10^{-26})\times(175)^2 \neq \frac{1}{2}\times(1.67\times10^{-26})\times(167.81)^2$

$9.05\times10^{-21}\ J$ $\qquad$ $2.35\times10^{-22}\ J$

so inelastic

(Total for Question 13 = 8 marks)

14 (a) State Faraday's law of electromagnetic induction.

(2)

Induced e.m.f. is equal to the rate of change of magnetic flux linkage

(b) Vehicles such as buses may be powered by electric motors. The motors on these buses use batteries which need to be charged often. This is normally done by connecting to a fixed electrical supply whilst the bus is parked.

The photograph shows a bus on a road in South Korea. This road enables the batteries to charge whilst the bus is in motion.

Under the road there are electric cables, connected to a 440V 60 Hz supply. These generate magnetic fields. There is a coil inside the charging device which is located below the floor of the bus. This enables the batteries on the bus to charge.

*(i) Explain how this system works.

(3)

- 60Hz supply generates a varying magnetic field
- Coil in the bus cuts through the magnetic field.
- There's a change in magnetic flux linkage
- e.m.f. is induced in the coil, creating a current which charges battery

(ii) It is not necessary for the cable to be installed under the entire length of the road. The batteries used to power these buses can be much smaller than those used in other electric buses.

Explain why the cables do not need to be installed under the entire length of the road and why the batteries can be smaller.

(3)

- Battery doesn't need to be chaged constantly
- Size of battery determines range between recharges
- Bus doesn't need to reach a fixed charging station so battery can be small

15 Hammer Throwing is an Olympic sport. The sport uses a metal sphere attached to a chain. The athlete holds the chain and spins around to give the sphere a large angular velocity.

When the sphere is released it travels in a parabolic path through the air and lands on the ground.

(a) Explain why, at the instant of release, the sphere stops travelling in a circular path.

(2)

There is no longer a centripetal force acting on the sphere so it would not follow a circular path.

(b) The sphere has a mass of 7.3 kg. The athlete moves the sphere through a circle of radius 1.7 m. The speed of the sphere, at the instant of release, is 18 m s^{-1}.

(i) Calculate the angular velocity of the sphere.

(2)

$\omega = \frac{v}{r}$ $\quad \frac{18}{1.7}$ $\quad 10.6$

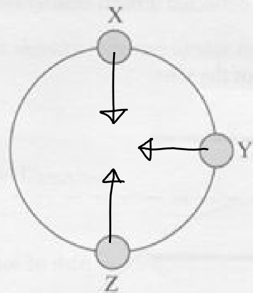
Angular velocity = 10.6 rads^{-1}

(ii) Assuming that both the circle and chain are horizontal, calculate the force that the athlete exerts on the chain just before its release.

(2)

$F = \frac{mv^2}{r}$ $\quad \frac{7.3 \times 18^2}{1.7}$ $\quad 1390N$

(c) The diagram below shows the sphere moving in a vertical circle.



(i) Draw arrows on the diagram to show the direction of the centripetal force on the sphere at each of the positions X, Y and Z.

(1)

*(ii) The tension in the chain varies as the sphere moves in the vertical circle.

State the position, X, Y or Z, at which the tension will be a maximum and the position, X, Y or Z, where it will be a minimum. Explain your answers.

(4)

At X: ↓ $T + mg = \frac{mv^2}{r}$

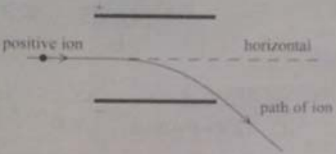
$T = \frac{mv^2}{r} - mg$ (minimum)

AT Z: ↑ $T - mg = \frac{mv^2}{r}$

$T = \frac{mv^2}{r} + mg$ (maximum)

16 A beam of identical positive ions travels horizontally in a vacuum. The ions pass between two charged plates and are deflected downwards by the electric field between the plates.

The diagram shows the path of one of the ions.



*(a) Explain the path of the ion both between the plates and when it has left the plates.

(4)

the Positive ion is repelled from the positive plate and attracted to the negative plate. Charged particles move in parabolas if projected into an electric field in a direction at right angles to the field. the ion moves at a constant velocity at right angles to the field but accelerate along the direction of the field.
The path is straight outside the field as no force acts on the ions

(b) Whilst the electric field is still acting, the path of the ions can be returned to the horizontal by applying a magnetic field over the same region as the electric field acts.

(i) Explain the conditions under which the ions have no overall deflection as they pass between the plates.

(2)

the magnetic force is equal to the force from the electric field so there is a resultant force of zero and it moves at a constant velocity

$260 \times 10^3\, ms^{-1}$ $0.045\, m$

(ii) The ions have a velocity of 260 km s^{-1}. The plate separation is 4.5 cm and the potential difference across the plates is 60 V.

Calculate the magnetic flux density required so that there is no overall deflection of the ions.

(4)

$BQv = EQ$ $E = \frac{V_P}{d}$

$B = \frac{E}{v}$ $\frac{V_P}{dv}$ $\frac{60}{0.045 \times 260 \times 10^3}$ $= 5.1 \times 10^{-3}$

Magnetic flux density = 5.1×10^{-3} T

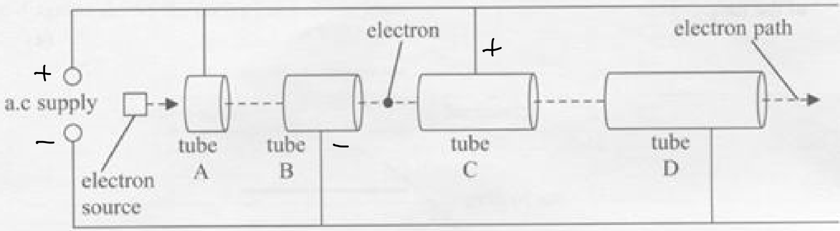
(c) State and explain how the path of the ions in just the magnetic field would be different from the path in just the electric field.

(3)

the ions would move in a circular path in just the magnetic field as opposed to a parabolic motion in the electric field.

so $F = \frac{mv^2}{r} = BQv$ giving a radius of $r = \frac{mv}{BQ}$

17 (a) High energy particles used to investigate the structure of matter are produced in particle accelerators. The diagram shows the main features of a linear accelerator (linac).



(i) An electron is shown between tubes B and C.

The circles on the diagram indicate the terminals of the a.c. supply. Indicate on the diagram their polarity when the electron is between tubes B and C.

Explain your answer.

(2)

Electron must be attracted to tube C and repelled from tube B

(ii) Explain why it is necessary for the tubes to increase in length along the linac.

(1)

So that particles can spend the same time in them as they accelerate

(iii) The peak voltage of the a.c. supply is 250 kV.

Calculate the increase in electron kinetic energy, in joules, as the electron moves from tube A to tube D.

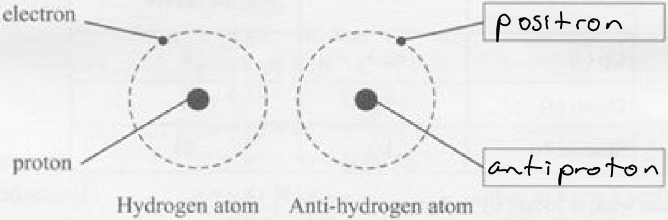
(3)

$WD = QV = 1.6 \times 10^{-19} \times 250 \times 10^{3} = 0.4 \times 10^{-13}$ J

Increase in KE $= 3 \times 0.4 \times 10^{-13} = 1.2 \times 10^{-13}$ J

(b) The Antiproton Decelerator at CERN slows down very high energy antiprotons to produce anti-atoms such as anti-hydrogen.

The diagram is a representation of a hydrogen atom and an anti-hydrogen atom.



(i) Use the boxes in the diagram to identify the particles in the anti-hydrogen atom.

(1)

(ii) State one difference and one similarity between the electron and its corresponding particle in the anti-hydrogen atom.

(2)

Opposite charge

Same mass

(iii) State what would happen if a hydrogen atom collided with an anti-hydrogen atom.

(1)

annihilate to give off energy

(c) In the early 1960s Murray Gell-Mann proposed a quark model that consisted of three quarks. The table gives some of the properties of these quarks.

Quark	Charge	Predicted mass in MeV/c^2
Up (u)	+2/3	4
Down (d)	−1/3	4
Strange (s)	−1/3	80

(i) Explain what is meant by a charge of +2/3. **(2)**

2/3 of charge of a positron

$+\frac{2}{3} \times 1.6 \times 10^{-19}$ C

(ii) State the predicted mass and charge of the ū quark. **(2)**

4 meV/c^2 $E = mc^2$

(iii) Calculate the mass of the s̄ quark in kg. **(3)**

$\frac{80 \times 10^6}{(3 \times 10^8)^2} = 8.9 \times 10^{-10}$ kg