This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls
Loueizeh - Baabda

Stage Exam 02

19DEC2022

Do NOT write in this box. Your MARK will be placed here.

Subject :	A Level : Physics 2 : RB
Class :	12A
Teacher :	Dr Ruth Brett
Duration :	1 hour

You should have a physics formula booklet. Write all your answers in this exam paper in black pen. You may use a pencil for diagrams.

Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

- Do not open this paper until the teacher in charge instructs you to do so.
- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

Section A: Multiple Choice. 1 mark each.

1.

In the early 20th century, scattering experiments were carried out by directing high speed alpha particles at thin metal foils.

Which of the following could **not** be concluded from these experiments?

☐ **A** Most of the atom is empty space.

☐ **B** The nucleus of the atom is positively charged.

☐ **C** There is a concentration of charge in the atom.

☐ **D** There is a concentration of mass in the atom.

2.

Which of the following is a fundamental particle?

☐ **A** antiproton

☐ **B** muon

☐ **C** neutron

☐ **D** pion

3.

A nucleus of ${}^{69}_{30}X$ emits a β particle.

Which row of the table shows the proton number and nucleon number of the nucleus after the β particle has been emitted?

	Proton number	Nucleon number
☐ **A**	29	68
☐ **B**	29	69
☐ **C**	31	69
☐ **D**	31	70

4.

A neutron can decay to produce a proton.

Which of the following equations correctly shows neutron decay?

☐ **A** $n \rightarrow p + e^{+} + \bar{\nu}_e$

☐ **B** $n \rightarrow p + e^{+} + \nu_e$

☐ **C** $n \rightarrow p + e^{-} + \bar{\nu}_e$

☐ **D** $n \rightarrow p + e^{-} + \nu_e$

5.

A kaon can decay in several different ways.

Which of the following decays is **not** possible?

☐ **A** $K^0 \rightarrow \pi^{+} + e^{-} + \bar{\nu}_e$

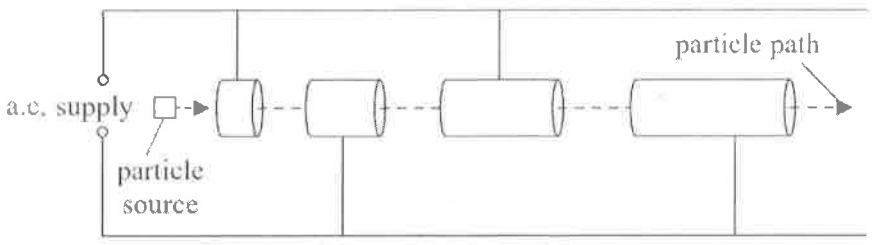
☐ **B** $K^0 \rightarrow \pi^{+} + \pi^{0} + \pi^{-}$

☐ **C** $K^{+} \rightarrow \pi^{0} + e^{+} + \nu_e$

☐ **D** $K^{+} \rightarrow \mu^{+} + \nu_\mu$

6.

The diagram shows the drift tubes at the start of a linear accelerator.



At the end of the linear accelerator the drift tubes are the same length.

Which of the following is the reason for this?

☐ **A** The frequency of the accelerating potential difference is increasing.

☐ **B** The particles are no longer gaining energy.

☐ **C** The rest mass of the particles is increasing.

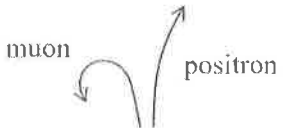
☐ **D** The speed of the particles is no longer increasing.

7.

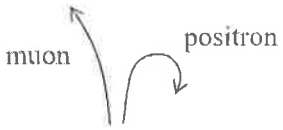
A positron and a muon travel at the same speed through a magnetic field.
The magnetic field is directed into the page.

Which of the following diagrams best represents the motion of the particles?

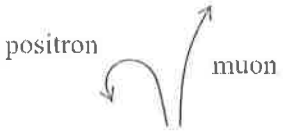
☐ **A**



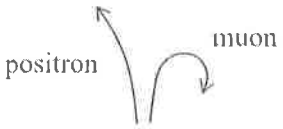
☐ **B**



☐ **C**



☐ **D**

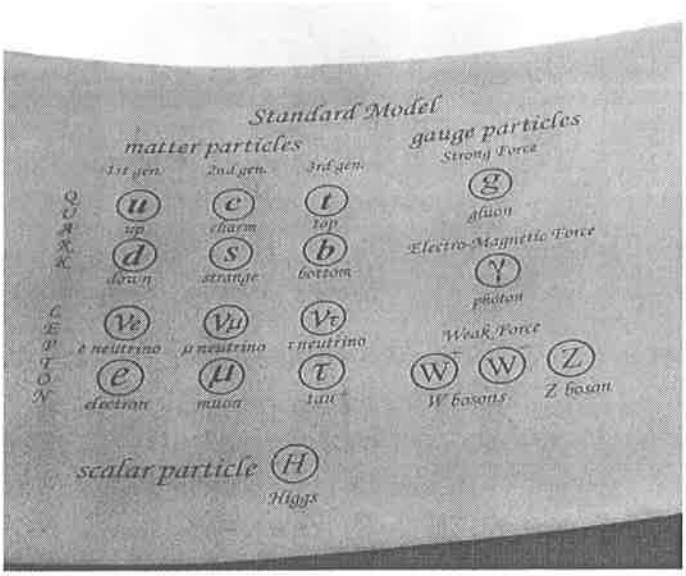


(Total for Section A = 7 marks)

Section B

8.

The photograph shows part of a sculpture at the laboratories of the European Organization for Nuclear Research in Switzerland.



A teacher on a tour says to a group of students, "In fact, nearly all of the matter in that sculpture is made up of the two first generation quarks, in combinations called baryons, and one type of lepton. However, the matter is mostly empty space."

Explain this statement.

(Total for question = 6 marks)

9.

Below are some extracts from the novel "Angels and Demons" by Dan Brown. A discussion about antimatter is taking place between two characters.

(a) Extract 1

A: "So antimatter is real?"

B: "A fact of nature. Everything has its opposite. **Protons have electrons. Up quarks have down quarks.** There is a cosmic symmetry at the subatomic level."

In the context of antimatter, comment on the scientific accuracy of the two statements in bold type.

Protons have electrons. .....

.....

.....

.....

.....

Up quarks have down quarks. .....

.....

.....

.....

.....

(5)

(b) Extract 2

A: "There would be no way to separate the particles from their antiparticles."

B: "He applied a magnetic field. Matter arced right, and antimatter arced left."

Comment on the physics of this method for separating particles from their antiparticles.

.....

.....

.....

.....

(2)

(c) Extract 3

A: "You collected visible amounts of antimatter?"

B: "Five thousand nanograms ... a plasma containing millions of positrons."

Calculate how many positrons there would be in a sample of five thousand nanograms.

.....

.....

Number of positrons = ...

(1)

(d) Extract 4

B: "Antimatter releases pure energy. A one hundred per cent conversion of mass to photons. **So don't look directly at the sample. Shield your eyes.**"

(i) A positron annihilates with an electron to produce two identical photons. Calculate the wavelength of each photon.

.....

.....

.....

.....

.....

Wavelength = ...

(3)

(ii) Comment on the two sentences in bold type in relation to the wavelength you have calculated.

.....

.....

(1)

(Total for question = 12 marks)

10.

Pion radiotherapy is a new form of cancer treatment that has been extensively investigated for tumours of the brain. Pions are short lived sub-atomic particles and belong to a group called mesons.

(a) The following table lists some quarks and their charge.

Quark	Charge / *e*
Up (u)	$+\frac{2}{3}$
Down (d)	$-\frac{1}{3}$
Strange (s)	$-\frac{1}{3}$
Charm (c)	$+\frac{2}{3}$

On the list below circle the combination which could correspond to a π^+ pion.

(1)

uud $\quad$ $\bar{d}\bar{d}\bar{d}$ $\quad$ $u\bar{d}$ $\quad$ $s\bar{c}$

(b) The mass of a pion is 0.14 GeV/c^2. Calculate the mass of a pion in kg.

(3)

Mass = ... kg

(c) Pions can be produced by accelerating protons using a cyclotron. Briefly explain the role of electric and magnetic fields within a cyclotron.

(5)

(d) When pions are used to treat brain tumours they are slowed by the tissue in the brain and cause little damage. When a pion is moving very slowly it may be absorbed by the nucleus of an atom. The atom nucleus then becomes unstable and breaks up into several fragments.

Explain why these fragments shoot out in all directions.

(3)

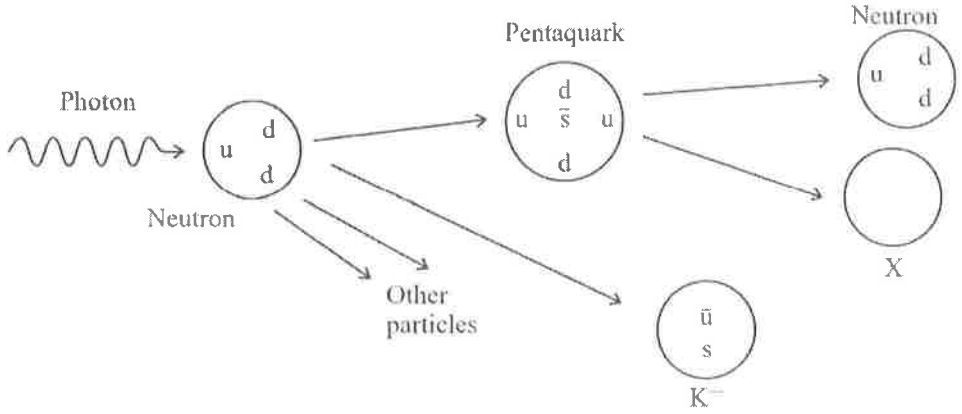
(Total for question = 12 marks)

11.

In July 2003 scientists at the SPring-8 synchrotron in Japan announced the discovery of a pentaquark – a particle made up of 5 quarks.

The pentaquark was produced by firing gamma photons at a target. It decayed very rapidly into other products.

The diagram shows some of the particles involved in the production and decay of the pentaquark, including the quark composition for several of them.



Name three quantities conserved during the decay of the pentaquark.

.....

.....

(2)

The table shows the charges of the six types of quarks as a fraction of the charge on a proton.

Quark type			Charge
up	charm	top	$2/3\ e$
down	strange	bottom	$-1/3\ e$

Find the charge of the pentaquark. Express your answer as a fraction of the charge on a proton.

.....

.....

Charge = ...

(1)

Explain whether particle X must be positive, negative or neutral.

.....

.....

.....

(1)

Suggest a possible quark composition for particle X. Explain your choice of quarks.

.....

.....

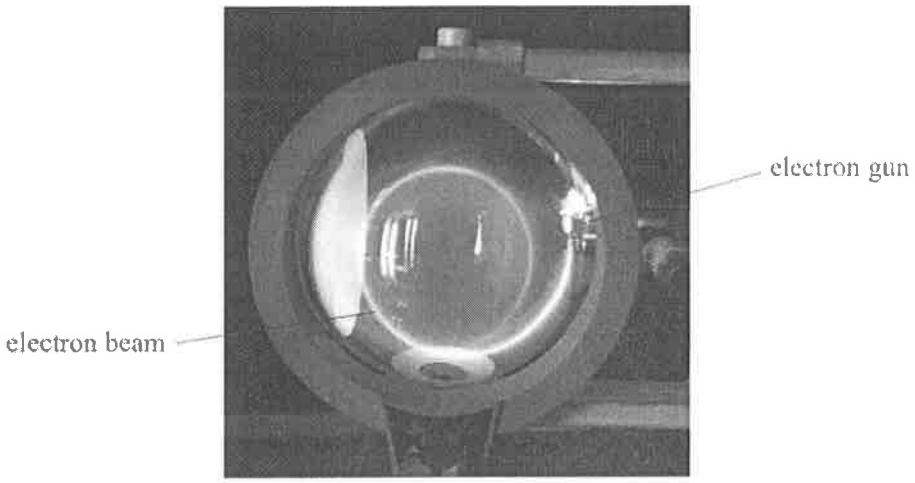
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(2)

(Total for question = 6 marks)

12.

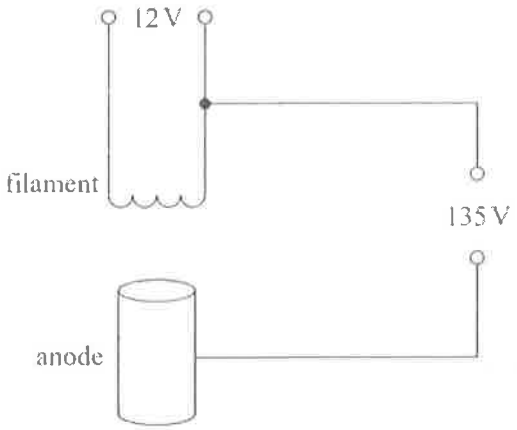
The photograph shows the path of an electron beam in a fine beam tube.



The fine beam tube contains helium gas at very low pressure. When electrons strike the helium atoms the resulting excitation is responsible for the glow tracing the path of the electron beam.

The electron beam is emitted downwards from an electron gun.

(a) The electron gun contains a heated filament above an anode as shown. There is a potential difference of 135 V between the anode and the filament.



(i) Describe how the electron beam is produced.

(2)

(ii) Show that the speed of the electrons leaving the electron gun is about $7 \times 10^6 \text{m s}^{-1}$.

(2)

(b) The electron beam follows the path shown in the photograph. A horizontal magnetic field is applied in the direction into the page.

(i) Show that a particle of momentum p follows a circular path of radius r given by

$$r = p/BQ$$

where Q is the charge on the particle and B is the magnetic flux density.

(2)

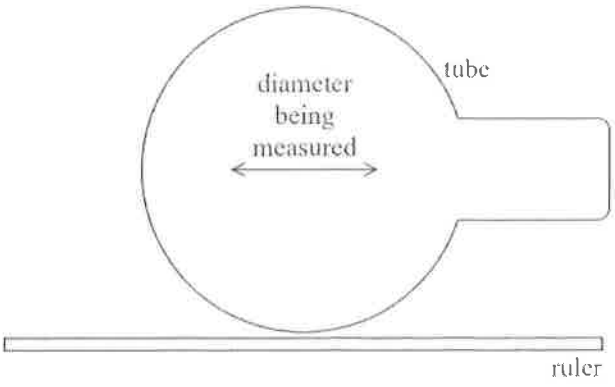
(ii) Calculate B.

diameter of circular path = 7.3 cm

(2)

$B =$

(c) The diameter of the circular path was measured by holding a metre rule in front of the tube and taking a photograph, as shown.



Discuss the suitability of this method.

(2)

(d) Suggest why the electron beam continues along a path of decreasing diameter with decreasing intensity.

(2)

(Total for question = 12 marks)

Section A: Multiple Choice. 1 mark each.

1.

In the early 20th century, scattering experiments were carried out by directing high speed alpha particles at thin metal foils.

Which of the following could **not** be concluded from these experiments?

- ☐ **A** Most of the atom is empty space.
- ☒ **B** The nucleus of the atom is positively charged. (1)
- ☐ **C** There is a concentration of charge in the atom.
- ☐ **D** There is a concentration of mass in the atom.

2.

Which of the following is a fundamental particle?

- ☐ **A** antiproton
- ☒ **B** muon (1)
- ☐ **C** neutron
- ☐ **D** pion

3.

A nucleus of ${}^{69}_{30}X$ emits a β^- particle.

Which row of the table shows the proton number and nucleon number of the nucleus after the β^- particle has been emitted?

	Proton number	Nucleon number
☐ **A**	29	68
☐ **B**	29	69
☒ **C** (1)	31	69
☐ **D**	31	70

4.

A neutron can decay to produce a proton.

Which of the following equations correctly shows neutron decay?

☐ **A** $n \rightarrow p + e^+ + \bar{\nu}_e$

☐ **B** $n \rightarrow p + e^+ + \nu_e$

(1) ☒ **C** $n \rightarrow p + e^- + \bar{\nu}_e$

☐ **D** $n \rightarrow p + e^- + \nu_e$

5.

A kaon can decay in several different ways.

Which of the following decays is **not** possible?

☐ **A** $K^0 \rightarrow \pi^+ + e^- + \bar{\nu}_e$

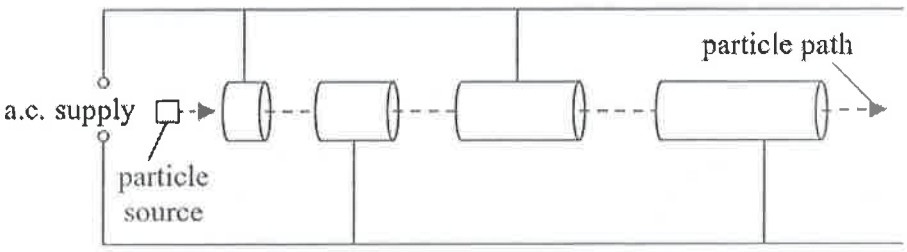
(1) ☒ **B** $K^0 \rightarrow \pi^+ + \pi^0 + \pi^+$

☐ **C** $K^+ \rightarrow \pi^0 + e^+ + \nu_e$

☐ **D** $K^+ \rightarrow \mu^+ + \nu_\mu$

6.

The diagram shows the drift tubes at the start of a linear accelerator.



At the end of the linear accelerator the drift tubes are the same length.

Which of the following is the reason for this?

☐ **A** The frequency of the accelerating potential difference is increasing.

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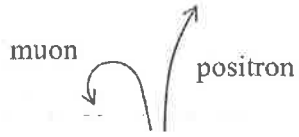
(1) ☒ **D** The speed of the particles is no longer increasing.

7.

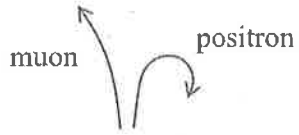
A positron and a muon travel at the same speed through a magnetic field.
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Which of the following diagrams best represents the motion of the particles?

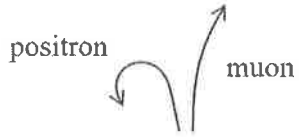
☐ **A**



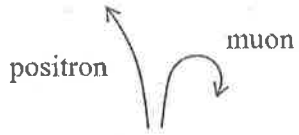
☐ **B**



(1) ☒ **C**



☐ **D**

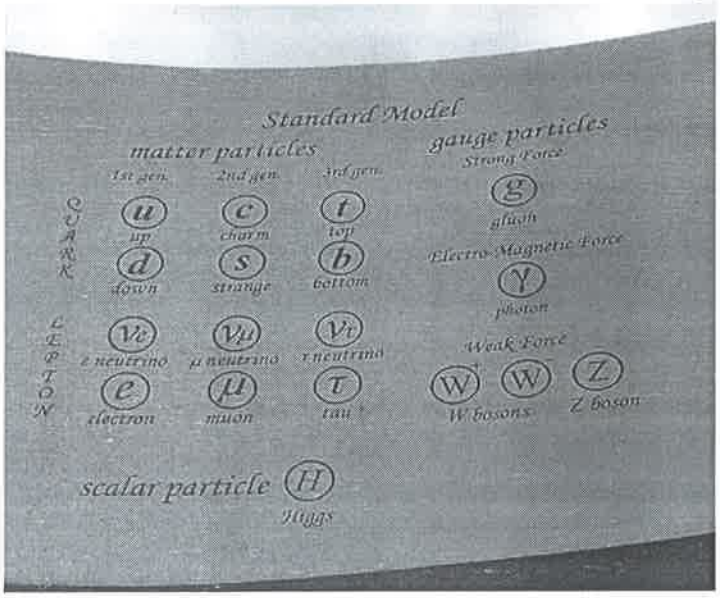


(Total for Section A = 7 marks)

Section B

8.

The photograph shows part of a sculpture at the laboratories of the European Organization for Nuclear Research in Switzerland.



A teacher on a tour says to a group of students, "In fact, nearly all of the matter in that sculpture is made up of the two first generation quarks, in combinations called baryons, and one type of lepton. However, the matter is mostly empty space."

Explain this statement.

(6)

The sculpture is made of atoms which contain protons and neutrons in a nucleus, (1) with electrons orbitting the nucleus. (1) The nucleus is tiny compared to the size of the atom, so matter is mostly empty space. (1)

Electrons are leptons (1) and the only type of lepton in matter. Protons and neutrons are both baryons (1) as they contain 3 quarks (1) each. Protons contain uud quarks while neutrons contain ddu quarks. These up and down quarks are first generation quarks. (1)

MAXIMUM 6

(Total for question = 6 marks)

9.

Below are some extracts from the novel "Angels and Demons" by Dan Brown. A discussion about antimatter is taking place between two characters.

(a) Extract 1

A: "So antimatter is real?"

B: "A fact of nature. Everything has its opposite. **Protons have electrons. Up quarks have down quarks.** There is a cosmic symmetry at the subatomic level."

In the context of antimatter, comment on the scientific accuracy of the two statements in bold type.

Protons have electrons. Electrons are not the antimatter pair of protons. (1) Matter/antimatter pair have opposite charges but the same mass. (1) The antimatter pair of a proton is the antiproton. (1)

ANY 5

Up quarks have down quarks. Up and down quarks do have charges of opposite signs, but they are not equal in magnitude. (1) Up = $+\frac{2}{3}$, down = $-\frac{1}{3}$. Therefore they are not a matter-antimatter pair. (1) The correct pair would be up/anti-up (1) or down/anti-down.

(5)

(b) Extract 2

A: "There would be no way to separate the particles from their antiparticles."

B: "He applied a magnetic field. Matter arced right, and antimatter arced left."

Comment on the physics of this method for separating particles from their antiparticles.

If the magnetic field is perpendicular to the direction of motion (1) then the particles and antiparticles will experience forces in opposite direction (1) because they have opposite charges (1)

MAXIMUM 2

(2)

(c) Extract 3

A: "You collected visible amounts of antimatter?"

B: "Five thousand nanograms ... a plasma containing millions of positrons."

Calculate how many positrons there would be in a sample of five thousand nanograms.

$\frac{5000 \times 10^{-9} \times 10^{-3}}{9.11 \times 10^{-31}} = 5.488 \times 10^{21}$

Number of positrons = 5.5×10^{21} (1)

(1)

(d) Extract 4

B: "Antimatter releases pure energy. A one hundred per cent conversion of mass to photons. So don't look directly at the sample. Shield your eyes."

(i) A positron annihilates with an electron to produce two identical photons. Calculate the wavelength of each photon.

(1)

$\Delta E = \Delta m c^2 = 9.11 \times 10^{-31} \times (3 \times 10^8)^2 = 8.199 \times 10^{-14}$ J for each particle

∴ each photon has 8.199×10^{-14} J

$E = hf = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{8.199 \times 10^{-14}}$ (1)

$\lambda = 2.426 \times 10^{-12}$

Wavelength = 2.43×10^{-12} m (1)

(3)

(ii) Comment on the two sentences in bold type in relation to the wavelength you have calculated.

Shielding is needed as this is a high energy photon (γ or x-ray) (1)

(1)

(Total for question = 12 marks)

10.

Pion radiotherapy is a new form of cancer treatment that has been extensively investigated for tumours of the brain. Pions are short lived sub-atomic particles and belong to a group called mesons.

(a) The following table lists some quarks and their charge.

Quark	Charge / *e*
Up (u)	$+\frac{2}{3}$
Down (d)	$-\frac{1}{3}$
Strange (s)	$-\frac{1}{3}$
Charm (c)	$+\frac{2}{3}$

On the list below circle the combination which could correspond to a π^+ pion.

(1)

uud $\bar{d}\bar{d}\bar{d}$ (ud) (1) $s\bar{c}$

(b) The mass of a pion is 0.14 GeV/c^2. Calculate the mass of a pion in kg.

(3)

$$\frac{0.14 \times 10^{9} \times 1.6 \times 10^{-19}}{(3 \times 10^{8})^2} = 2.5 \times 10^{-28}$$

(1) (1) (1)

(2.489×10^{-28})

ANY TWO OF THESE METHOD MARKS

(1)

Mass = 2.5×10^{-28} kg

(c) Pions can be produced by accelerating protons using a cyclotron. Briefly explain the role of electric and magnetic fields within a cyclotron.

(5)

exert a force ① and therefore
Electric fields accelerate ① charged particles. The polarity reverses every half cycle. ①
The magnetic field exerts a force on the moving charged particles. ① Since the magnetic field is perpendicular to the path of the protons, the force is a centripetal force ① causing circular motion.

(d) When pions are used to treat brain tumours they are slowed by the tissue in the brain and cause little damage. When a pion is moving very slowly it may be absorbed by the nucleus of an atom. The atom nucleus then becomes unstable and breaks up into several fragments.

Explain why these fragments shoot out in all directions.

(3)

Conservation of momentum.
Before the collision, the momentum is negligible, therefore after the collision the total momentum must be zero. Hence the fragments go in all directions.

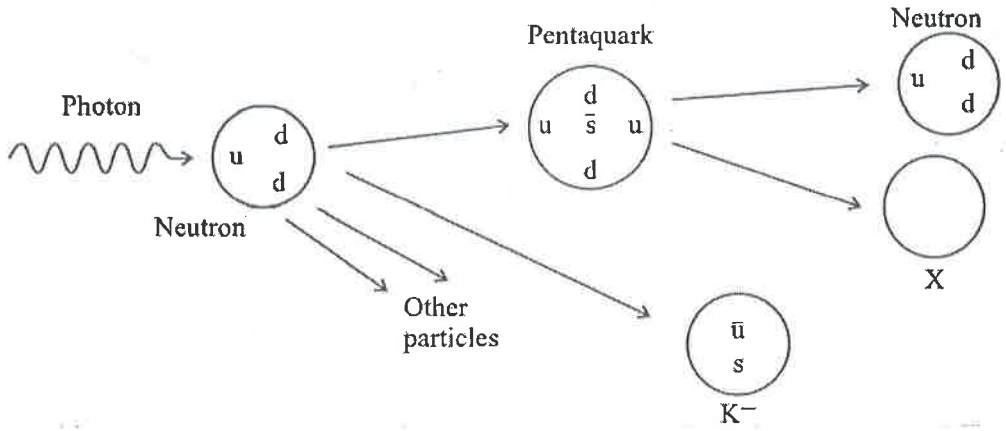
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11.

In July 2003 scientists at the SPring-8 synchrotron in Japan announced the discovery of a pentaquark – a particle made up of 5 quarks.

The pentaquark was produced by firing gamma photons at a target. It decayed very rapidly into other products.

The diagram shows some of the particles involved in the production and decay of the pentaquark, including the quark composition for several of them.



Name three quantities conserved during the decay of the pentaquark.

Momentum, charge, lepton number

All 3 correct = (2)

2 correct = (1)

1 correct = 0

(2)

The table shows the charges of the six types of quarks as a fraction of the charge on a proton.

Quark type			Charge
up	charm	top	2/3 *e*
down	strange	bottom	–1/3 *e*

Find the charge of the pentaquark. Express your answer as a fraction of the charge on a proton.

$u\ u\ d\ d\ \bar{s}$ $\quad +\frac{2}{3}\ +\frac{2}{3}\ -\frac{1}{3}\ -\frac{1}{3}\ +\frac{1}{3}$

Charge = $+1$ (1)

(1)

Explain whether particle X must be positive, negative or neutral.

X must be positive because the pentaquark was positive and the neutron is neutral (1)

(1)

Suggest a possible quark composition for particle X. Explain your choice of quarks.

$u\bar{s}$ (1)

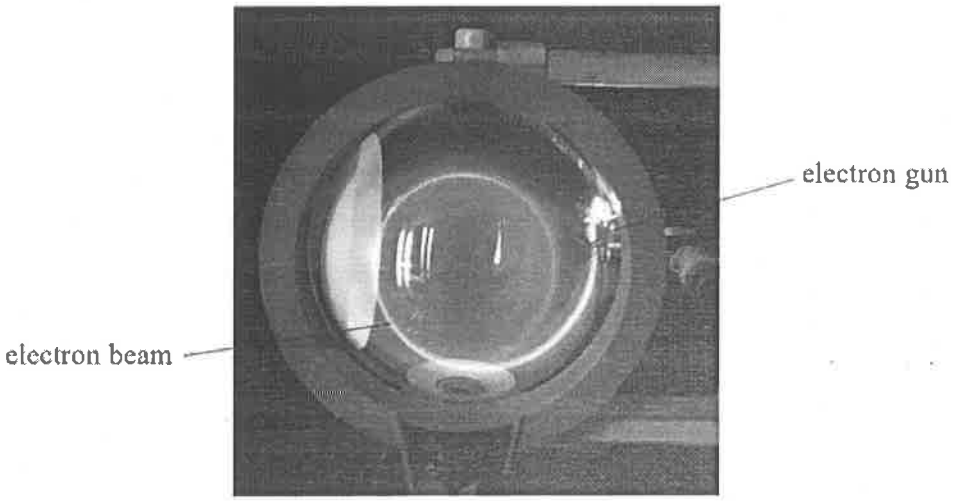
They are the quarks that are left after removing the ddu for the neutron. (1)

(2)

(Total for question = 6 marks)

12.

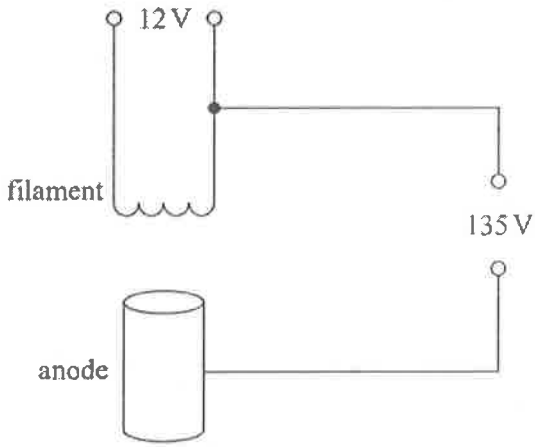
The photograph shows the path of an electron beam in a fine beam tube.



The fine beam tube contains helium gas at very low pressure. When electrons strike the helium atoms the resulting excitation is responsible for the glow tracing the path of the electron beam.

The electron beam is emitted downwards from an electron gun.

(a) The electron gun contains a heated filament above an anode as shown. There is a potential difference of 135 V between the anode and the filament.



(i) Describe how the electron beam is produced.

(2)

Electrons are emitted by thermionic (1) emission and then accelerated (1) by the electric field between the filament and the anode.

(ii) Show that the speed of the electrons leaving the electron gun is about $7 \times 10^6 \text{ m s}^{-1}$.

(2)

$qV = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 135}{9.11 \times 10^{-31}}} = 6.89 \times 10^6 \text{ ms}^{-1}$

(b) The electron beam follows the path shown in the photograph. A horizontal magnetic field is applied in the direction into the page.

(i) Show that a particle of momentum p follows a circular path of radius r given by

$$r = p/BQ$$

where Q is the charge on the particle and B is the magnetic flux density.

(2)

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

$r = \frac{mv^2}{Bqv} = \frac{mv}{Bq}$ but mv = momentum, p and $q = Q$ here, so

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

(ii) Calculate B.

diameter of circular path = 7.3 cm

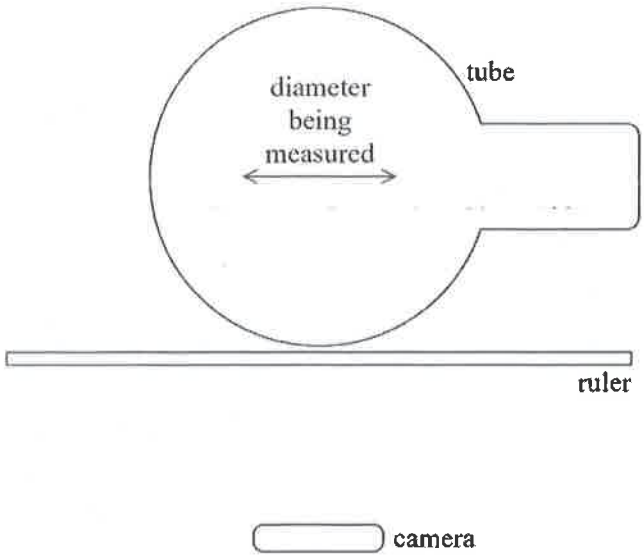
(2)

$B = \frac{p}{rQ} = \frac{9.11 \times 10^{-31} \times 6.89 \times 10^6}{\left(\frac{0.073}{2}\right) \times 1.6 \times 10^{-19}}$ ~~$= 5.32 \times 10^{-4}$ T~~

$= 1.07 \times 10^{-3}$ T

$B = 1.1 \times 10^{-3}$ T

(c) The diameter of the circular path was measured by holding a metre rule in front of the tube and taking a photograph, as shown.



Discuss the suitability of this method.

(2)

Positive - can zoom in (1) or small uncertainty (1) in measured value

Negative - parallax errors (1) or difficult to measure accurately (1) because of thickness of the path

MAXIMUM 2

(d) Suggest why the electron beam continues along a path of decreasing diameter with decreasing intensity.

(2)

Decreasing diameter → loss of energy causes lower speed (1)

Decreasing intensity → fewer electrons in the beam (1)

(Total for question = 12 marks)