This is a Class 1 exam

Lebanon Evangelical School for Boys and Girls

Lebanon Evangelical School
for Boys and Girls Loueizeh - Baabda

Stage Exam 02

08DEC2023

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

Write your answers in the spaces provided on this question paper. Give your final answers to an appropriate number of significant figures and write the unit if there is one. You should have a physics formula booklet.

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.

Q1. At the beginning of the 20th century, Rutherford carried out large-angle alpha particle scattering experiments using gold ($^{197}_{79}$Au) foil.

The vast majority of the alpha particles went straight through the foil whilst a few were deflected straight back.

Describe how the model of the atom **changed**, as a consequence of these experiments.

(4)

.....

.....

.....

.....

.....

.....

.....

.....

(Total for question = 4 marks)

Q2.

A series of experiments was carried out in the 1970s to investigate the structure of protons using the linac at Stanford, USA.

* Explain how an electron is accelerated in a linac.

(6)

.....

.....

.....

.....

.....

.....

.....

.....

Continue on the next page if necessary.

.....

.....

.....

.....

.....

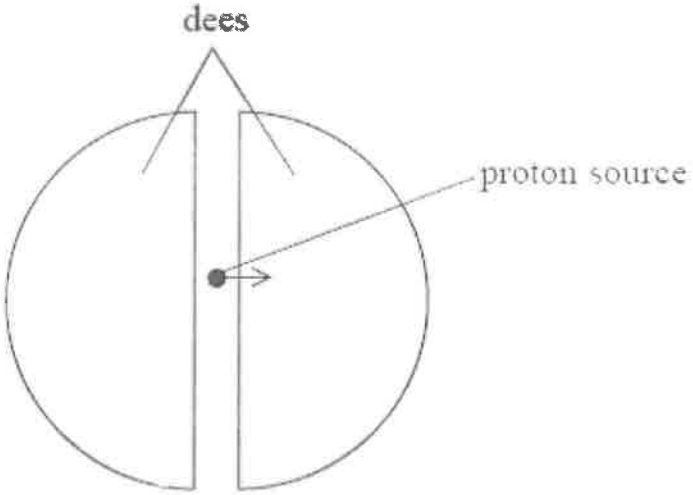
.....

.....

.....

(Total for question = 6 marks)

Q3. A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



a) (i) Complete the diagram to show the path of the protons.

(1)

(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

(1)

.....

(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

.....

.....

.....

.....

.....

.....

.....

b) (i) Show that the magnetic flux density B of the applied magnetic field is given by

$$B = \frac{2\pi f m}{e}$$

where f is the frequency of the alternating potential difference, m is the mass of the proton and e is the charge on the proton.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

(ii) In a particular cyclotron B is 1.2 mT.
Calculate the frequency f of the alternating potential difference.

(2)

.....

.....

.....

.....

f = ...

(iii) In a cyclotron, in which this expression applies, protons were accelerated to a speed of 1.2×10^7 m s^{-1}.

Determine the time taken to accelerate a proton to this speed from rest.
magnetic flux density = 1.2 mT
accelerating potential difference = 8 kV

(5)

(Note: you have seen a similar question before, but it was not exactly the same and the numbers are different.)

Time = ...

(Total for question = 15 marks)

Q4. Which of the following particle equations is correct for the decay of a proton within a nucleus?

☒ **A** $p \rightarrow n + \beta^+$

☒ **B** $p \rightarrow p + \beta^+$

☒ **C** $p \rightarrow n + \beta^+ + \nu$

☒ **D** $p \rightarrow p + \beta^+ + \nu$

(Total for question = 1 mark)

Q5. A high-energy proton can interact with a photon to produce two particles.

Which of the following could be the two particles produced?

☒ **A** $n + \pi^0$

☒ **B** $n + \pi^+$

☒ **C** $\pi^0 + \pi^+$

☒ **D** $\pi^- + \pi^+$

(Total for question = 1 mark)

Q6. The neutral lambda Λ^0 particle is a baryon that contains one strange quark.

The table shows quarks and their relative charge.

Quark	Charge / e
u	+2/3
d	−1/3
s	−1/3

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

(2)

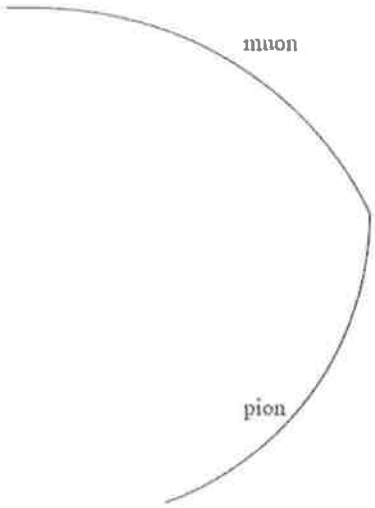
.....

.....

.....

(Total for question = 2 marks)

Q7. A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



a) Deduce whether the antineutrino is charged, giving two reasons for your decision.

(2)

.....

.....

.....

.....

b) According to the standard model, the pion and muon are classified within two different groups of particles.

State which group each particle belongs to and describe the two groups.

(4)

.....

.....

.....

.....

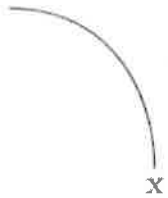
.....

.....

(Total for question = 4 marks)

Q8. Scientists studying anti-matter recently observed the creation of a nucleus of anti-helium 4, which consists of two anti-protons and two anti-neutrons.

The diagram represents the path of a proton through a magnetic field starting at point X.



Add to the diagram the path of an anti-helium 4 nucleus also starting at point X and initially travelling at the same velocity as the proton.

Explain any differences between the paths.

(5)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

(Total for Question = 5 marks)

Q9. Hadrons are a group of particles. Hadrons can be either baryons or mesons.

(a) (i) State the quark structure of a baryon.

(1)

.....

(ii) State the quark structure of a meson.

(1)

.....

(b) State **one** similarity and **one** difference between a particle and its antiparticle.

(2)

Similarity

.....

.....

Difference

.....

.....

(c) (i) The table gives some of the properties of up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	−1/3	0
s	−1/3	−1

One or more of these quarks combine to form a K^+, a meson with a strangeness of +1.

Write down the quark combination of the K^+.

(1)

.....

(Total for Question = 5 marks)

Q10. The table gives some of the properties of the up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	−1/3	0
s	−1/3	−1

There are nine possible ways of combining u, d and s quarks and their antiquarks to make nine different mesons. These are listed below:

$u\bar{u}$ $u\bar{d}$ $u\bar{s}$ $d\bar{d}$ $d\bar{u}$ $d\bar{s}$ $s\bar{s}$ $s\bar{u}$ $s\bar{d}$

(a) From the list select the four strange mesons and state the charge and strangeness of each of them.

(4)

Meson	Charge/*e*	Strangeness

(b) Some of the mesons in the list have zero charge and zero strangeness.

Suggest what might distinguish these mesons from each other.

(1)

.....

.....

.....

(Total for Question = 5 marks)

Q1. At the beginning of the 20th century, Rutherford carried out large-angle alpha particle scattering experiments using gold ($^{197}_{79}$Au) foil.

The vast majority of the alpha particles went straight through the foil whilst a few were deflected straight back.

Describe how the model of the atom **changed**, as a consequence of these experiments.

(4)

Before the α-particle scattering experiments, the plum pudding model (1) was used to explain what was inside an atom. It was considered to contain mass and charge that were evenly distributed. [alternative to 1st mark] (1)

After the experiment, the nuclear model was developed :-

- most of the atom is empty space (1)
- most of the mass of the atom is in a tiny nucleus. (1)
- the nucleus is charged. (1)

(Total for question = 4 marks)

Q2.

A series of experiments was carried out in the 1970s to investigate the structure of protons using the linac at Stanford, USA.

* Explain how an electron is accelerated in a linac.

(6)

Electrons are accelerated by electric fields (1) across the gaps (1) between the drift tubes. (1)

Adjacent tubes have opposite polarity, (1) and this switches while the electrons are in the tubes so they will always be accelerated towards an oppositely (+ve) charged tube. (1)

The length of the tubes increases (1) along the linac so the time spent in each tube is constant even though the speed is increasing.

Continue on the next page if necessary.

.....

.....

.....

.....

.....

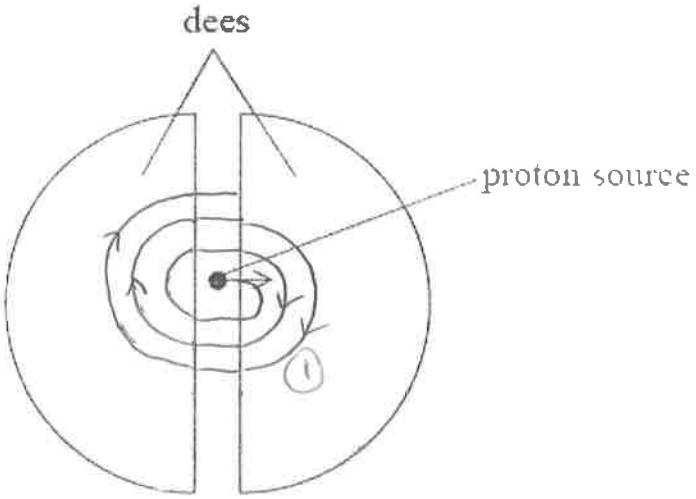
.....

.....

.....

(Total for question = 6 marks)

Q3. A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



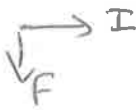
a) (i) Complete the diagram to show the path of the protons.

(1)

(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

(1)

Out of the page (1)



(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

There is an electric field across the gap between the dees which accelerates the protons (1), thus increasing their speed and kinetic energy. (1)
While the protons are in the dees, the pd reverses so the protons will always be accelerated towards the negative dee on the other side of the gap. (1)

b) (i) Show that the magnetic flux density B of the applied magnetic field is given by

$$B = \frac{2\pi f m}{e}$$

where f is the frequency of the alternating potential difference, m is the mass of the proton and e is the charge on the proton.

(3)

$F = Bqv = \frac{mv^2}{r}$ (1) $\quad q = e \quad v = \frac{2\pi r}{T}$ (1)

$B = \frac{mv}{er} = \frac{m}{er}\left(\frac{2\pi r}{T}\right) = \frac{2\pi m}{eT}$

$T = \frac{1}{f}$ (1) $\quad B = \frac{2\pi m f}{e}$

(ii) In a particular cyclotron B is 1.2 mT.
Calculate the frequency f of the alternating potential difference.

(2)

$f = \frac{eB}{2\pi m} = \frac{1.6 \times 10^{-19}\ (1.2 \times 10^{-3})}{2\pi\ (1.67 \times 10^{-27})} = 18298$ (1)

$f =$ 18.3 kHz (1)

(iii) In a cyclotron, in which this expression applies, protons were accelerated to a speed of 1.2×10^7 m s^{-1}.

Determine the time taken to accelerate a proton to this speed from rest.
magnetic flux density = 1.2 mT
accelerating potential difference = 8 kV

(5)

Kinetic energy of each proton after acceleration

$E_K = \frac{1}{2}mv^2 = \frac{1}{2}(1.67 \times 10^{-27})(1.2 \times 10^7)^2 = 1.202 \times 10^{-13}$ J (1)

After each acceleration, the energy gained is

$\Delta E = qV = 1.6 \times 10^{-19}(8000) = 1.28 \times 10^{-15}$ J (1)

No. accelerations needed $= \frac{1.202 \times 10^{-13}}{1.28 \times 10^{-15}} = 94$ (1)

$\therefore \frac{94}{2} = 47$ complete orbits are needed.

$f = 18.3$ kHz $\quad T = \frac{1}{f} = 5.46 \times 10^{-5}$ s (1) each complete cycle.

$\therefore$ total time needed $= 47 \times 5.46 \times 10^{-5} = 2.57 \times 10^{-3}$ s (1)

Time = 2.57 ms

(Total for question = 15 marks)

Q4. Which of the following particle equations is correct for the decay of a proton within a nucleus?

- ☐ **A** $p \rightarrow n + \beta^+$
- ☐ **B** $p \rightarrow p + \beta^+$
- (1) ☒ **C** $p \rightarrow n + \beta^+ + \nu$
- ☐ **D** $p \rightarrow p + \beta^+ + \nu$

(Total for question = 1 mark)

Q5. A high-energy proton can interact with a photon to produce two particles.

Which of the following could be the two particles produced?

- ☐ **A** $n + \pi^0$
- (1) ☒ **B** $n + \pi^+$
- ☐ **C** $\pi^0 + \pi^+$
- ☐ **D** $\pi^- + \pi^+$

(Total for question = 1 mark)

Q6. The neutral lambda Λ^0 particle is a baryon of mass 1116 MeV/c^2 and contains one strange quark.

The table shows quarks and their relative charge.

Quark	Charge / e
u	+2/3
d	−1/3
s	−1/3

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

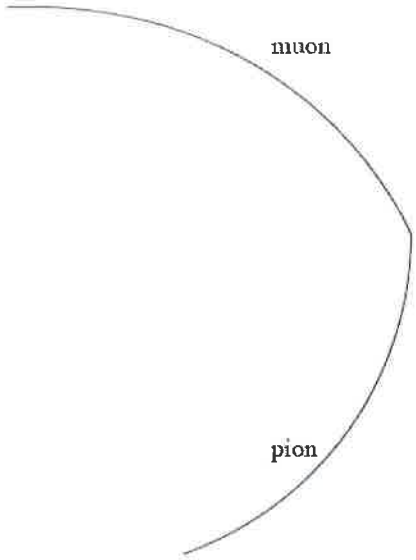
(2)

uds (1)

$+\frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0$ makes charge = 0 (1)

(Total for question = 2 marks)

Q7. A negatively charged pion decays into a muon and an antineutrino. The diagram shows tracks in a particle detector formed in such an event.



a) Deduce whether the antineutrino is charged, giving two reasons for your decision.

(2)

The antineutrino is not charged because there is no track (1)
The muon and pion have the same charge because the paths curve the same way. Therefore charge is conserved
So the antineutrino isn't charged (1)

b) According to the standard model, the pion and muon are classified within two different groups of particles.

State which group each particle belongs to and describe the two groups.

(4)

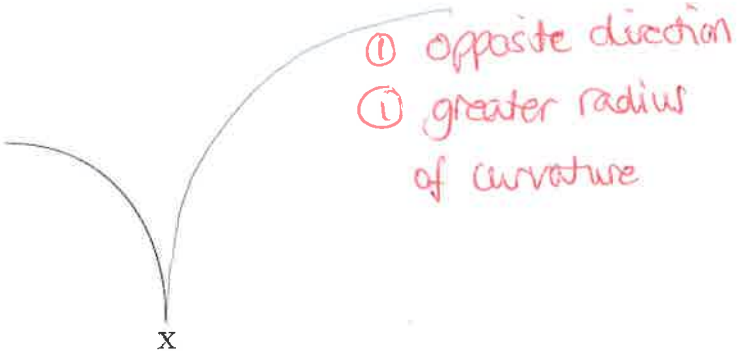
A pion is a meson (1) which consists of a quark and an antiquark (1)

A ~~lepton~~ muon is a lepton (1) which is a fundamental particle. (1)

(Total for question = 4 marks)

Q8. Scientists studying anti-matter recently observed the creation of a nucleus of anti-helium 4, which consists of two anti-protons and two anti-neutrons.

The diagram represents the path of a proton through a magnetic field starting at point X.



① opposite direction
① greater radius of curvature

Add to the diagram the path of an anti-helium 4 nucleus also starting at point X and initially travelling at the same velocity as the proton.

Explain any differences between the paths.

(5)

The paths curve in opposite directions because a proton is positive and antihelium is negative ①, so they have opposite charges.

$r = \frac{p}{BQ}$ ①

antihelium mass $= 4m_p$

$v = v_p$

$Q = 2Q_p$

so $\frac{p}{BQ}$ doubles for antihelium

∴ r is double. ①

(Total for Question = 5 marks)

Q9. Hadrons are a group of particles. Hadrons can be either baryons or mesons.

(a) (i) State the quark structure of a baryon.

(1)

3 quarks (1)

(ii) State the quark structure of a meson.

(1)

A quark and an antiquark (1)

(b) State **one** similarity and **one** difference between a particle and its antiparticle.

(2)

Similarity

Same mass (1)

Difference

Opposite charge (1)

(c) (i) The table gives some of the properties of up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	−1/3	0
s	−1/3	−1

One or more of these quarks combine to form a K^+, a meson with a strangeness of +1.

Write down the quark combination of the K^+.

(1)

$u\bar{s}$ (1)

(Total for Question = 5 marks)

Q10. The table gives some of the properties of the up, down and strange quarks.

Type of quark	Charge/*e*	Strangeness
u	+2/3	0
d	−1/3	0
s	−1/3	−1

There are nine possible ways of combining u, d and s quarks and their antiquarks to make nine different mesons. These are listed below

$u\bar{u}$ $u\bar{d}$ $u\bar{s}$ $d\bar{d}$ $d\bar{u}$ $d\bar{s}$ $s\bar{s}$ $s\bar{u}$ $s\bar{d}$

(a) From the list select the four strange mesons and state the charge and strangeness of each of them.

(4)

Meson	Charge/*e*	Strangeness	
$u\bar{s}$	+1	+1	(1)
$d\bar{s}$	0	+1	(1)
$s\bar{u}$	−1	−1	(1)
$s\bar{d}$	0	−1	(1)

(b) Some of the mesons in the list have zero charge and zero strangeness.

Suggest what might distinguish these mesons from each other.

(1)

Some might be more stable than others (1)

OR The masses might be different [(1) Alternative mark]

(Total for Question = 5 marks)