This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls
Loueizeh - Baabda

Stage Exam 03

10FEB2026

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

Subject :	A Level : Physics P2RB	
Class :	12A	
Teacher :	Dr. Ruth Brett	
Duration :	1 hour	
Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

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- 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.

Questions

Q1. Which of the following is a fundamental particle?

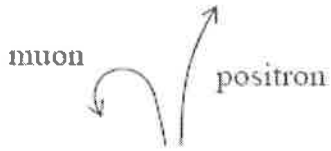
- ☐ **A** pion
- ☐ **B** proton
- ☐ **C** neutrino
- ☐ **D** neutron

(Total for question = 1 mark)

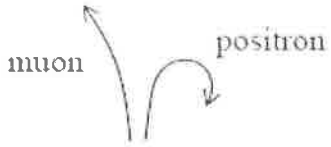
Q2. A positron and a muon travel at the same speed through a magnetic field.
The magnetic field is directed into the page.

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

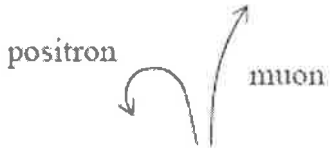
☐ **A**



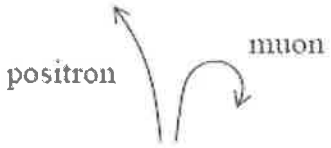
☐ **B**



☐ **C**



☐ **D**



(Total for question = 1 mark)

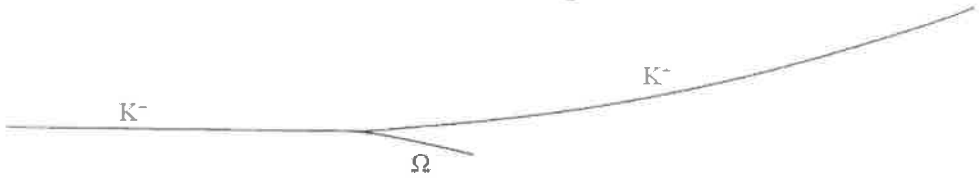
Q3. Muons can travel at speeds close to the speed of light. At these speeds the lifetime and mass of a muon are different from those of a stationary muon.

Which row of the table describes the lifetime and the mass of a high-speed muon compared to a stationary muon?

		Lifetime	Mass
☐	**A**	shorter	smaller
☐	**B**	shorter	larger
☐	**C**	longer	smaller
☐	**D**	longer	larger

(Total for question = 1 mark)

Q4. The diagram shows particle tracks in a detector. A negative K meson collided with a stationary proton. An omega baryon and a positive K meson were produced after the impact.



(a) (i) Describe the structure of a baryon and a meson.

(2)

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(ii) A magnetic field acts in the detector.
State the direction of the magnetic field that resulted in the tracks being in the directions shown.

(1)

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(iii) Deduce the charge and baryon number for the omega particle produced by this collision.

(3)

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(b) The rest mass of the omega baryon is significantly larger than the rest mass of the proton.

Discuss how energy is conserved during this collision.

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(Total for question = 12 marks)

Q5. Experiments with muons are taking place at Fermilab in the USA to improve our understanding of the standard model.

(a) The muon belongs to the same family of particles as the electron.

State how the muon is classified in the standard model.

(2)

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(b) A muon (μ) can be produced by the decay shown in this nuclear equation.

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

State the names of the two other particles involved.

(2)

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(c) A website states: "The rest mass of a muon is 106 MeV / c^2, which is a little over 200 times that of an electron."

Deduce whether this statement is correct.

(3)

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(d) Muons are stored in a 'storage ring' at Fermilab. The website describes the ring as having a circumference of 44.7 m and using a magnetic field of flux density 1.45 T.

The website claims that this enables the storage ring to confine muons with a momentum of 3.10 GeV / c.

(i) Deduce whether the website's claim of the momentum of the muons being 3.10 GeV/c is correct.

muon charge = -1.6×10^{-19} C

3.10 GeV/c = 1.65×10^{-18} N s

(3)

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(ii) Stationary muons are unstable and have a mean lifetime of a few microseconds.

Explain why muons in the ring are observed to have a much greater mean lifetime.

(2)

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(Total for question = 12 marks)

Q6. A stationary anti-neutron decays by emitting a positron.

(a) Explain how energy is conserved in this decay.

(2)

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(b) The equation shows the decay of an anti-neutron.

$$ {}^{1}_{0}\bar{n} \rightarrow {}^{1}_{-1}\bar{p} + {}^{0}_{1}\bar{e} + \nu_e $$

Explain how this equation shows that the decay obeys three conservation laws.

(6)

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(Total for question = 8 marks)

Q7. In 1977 a fifth quark, named the bottom quark, was discovered by particle physicists.

The table shows the particles in the standard model known at that time.

Quarks		Leptons	
up	down	electron	electron neutrino
strange	charm	muon	muon neutrino
bottom		tau	

(a) A short time after formation, most quarks combine to make particles known as hadrons. There are two categories of hadron.

Name the two categories of hadron.

(1)

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(b) In 1995 the sixth quark, known as the top quark, was discovered using the Tevatron collider at Fermilab. A collision of a proton with an anti-proton produced a top quark and a top anti-quark.

Particle experiments may direct beams of particles at stationary targets or collide beams of particles travelling in opposite directions.

(i) Explain the advantage of colliding beams of particles.

(4)

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(ii) In the collider experiment, the protons and anti-protons had a total energy of 900 GeV. Calculate the maximum kinetic energy, in joules, of a top quark produced in this experiment.
rest energy of top quark = 173 GeV

(3)

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Maximum kinetic energy = ... J

(iii) Deduce whether a top quark with kinetic energy 1.2×10^{-7} J is travelling at a relativistic speed.
rest mass of top quark = 173 GeV/c^2

(3)

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(Total for question = 11 marks)

Q8. A particle with charge Q and momentum p follows a circular path of radius r. The path is at right angles to a magnetic field of magnetic flux density B.

(a) Derive the equation linking the radius of the orbit and the momentum:

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

(2)

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(b) By finding the momentum of an alpha particle of energy 5.4 MeV, calculate B.

mass of alpha particle = 6.64×10^{-27} kg
$r = 0.096$ m

(4)

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$B =$ .....

(Total for question = 6 marks)

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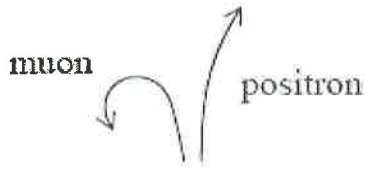
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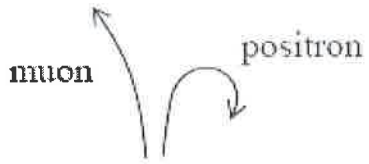
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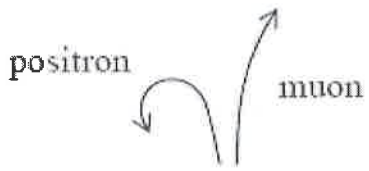
- ☐ **A**



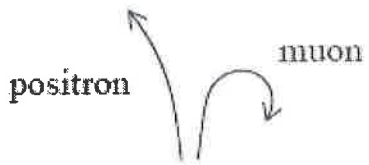
- ☐ **B**



- ☒ **C**



- ☐ **D**



(Total for question = 1 mark)

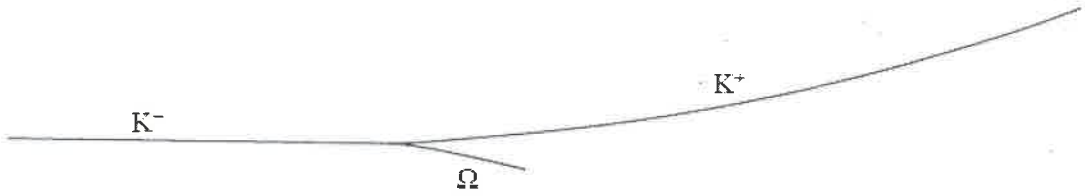
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☒	D	longer	larger

(Total for question = 1 mark)

Q4. The diagram shows particle tracks in a detector. A negative K meson collided with a stationary proton. An omega baryon and a positive K meson were produced after the impact.



(a) (i) Describe the structure of a baryon and a meson.

(2)

A baryon has 3 quarks (1)

A meson has a quark and an antiquark (1)

(ii) A magnetic field acts in the detector.
State the direction of the magnetic field that resulted in the tracks being in the directions shown.

(1)

Into the page (1)

(iii) Deduce the charge and baryon number for the omega particle produced by this collision.

(3)

Conservation of charge $+1 - 1 \rightarrow +1 + q$ (1)

$p^+ + K^- \rightarrow K^+ + \Omega$

Ω must have charge of -1 (1)

$p^+ + K^- \rightarrow K^+ + \Omega$

Baryon number $1 + 0 \rightarrow 0 + 1$

Ω must have baryon number of 1 (1)

(b) The rest mass of the omega baryon is significantly larger than the rest mass of the proton.

Discuss how energy is conserved during this collision.

(4)

Total mass-energy is conserved :-

mass-energy of proton + mass-energy of K^- + E_k of K^-

= mass-energy of Λ + mass-energy of K^+ + E_k of Λ + E_k of K^+ (1)

K^- had high kinetic energy (1) which is converted to

the mass of the Λ particle (1) using $\Delta E = \Delta m c^2$ (1)

(Total for question = ~~12~~ 10 marks)

Q5. Experiments with muons are taking place at Fermilab in the USA to improve our understanding of the standard model.

(a) The muon belongs to the same family of particles as the electron.

State how the muon is classified in the standard model.

(2)

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

(b) A muon (μ) can be produced by the decay shown in this nuclear equation.

$$\pi^- \longrightarrow \mu^- + \bar{\nu}_\mu$$

State the names of the two other particles involved.

(2)

negative pion (1)

muon antineutrino (1)

(c) A website states: "The rest mass of a muon is 106 MeV / c^2, which is a little over 200 times that of an electron."

Deduce whether this statement is correct.

(3)

$106\,MeV/c^2 \rightarrow kg$ $\quad \frac{106 \times 10^6 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2} = 1.884 \times 10^{-28}\,kg$ (1)

$\frac{1.884 \times 10^{-28}}{9.11 \times 10^{-31}} = 207$ times heavier than an electron (1)

so the statement is correct.

(d) Muons are stored in a 'storage ring' at Fermilab. The website describes the ring as having a circumference of 44.7 m and using a magnetic field of flux density 1.45 T.

The website claims that this enables the storage ring to confine muons with a momentum of 3.10 GeV / c.

(i) Deduce whether the website's claim of the momentum of the muons being 3.10 GeV/c is correct.

muon charge = -1.6×10^{-19} C

3.10 GeV/c = 1.65×10^{-18} N s

(3)

Circumference = $44.7\text{m} = 2\pi r$ (1) $\quad r = \frac{44.7}{2\pi} = 7.11\text{m}$

$r = \frac{mv}{BQ} = \frac{p}{BQ} \Rightarrow r = \frac{1.65 \times 10^{-18}}{1.45 \times 1.6 \times 10^{-19}}$ (1) $= 7.11\text{m}$

So the momentum of 3.10 GeV/c is correct (1)

(ii) Stationary muons are unstable and have a mean lifetime of a few microseconds.

Explain why muons in the ring are observed to have a much greater mean lifetime.

(2)

Muons travel close to the speed of light (1) so relativistic effects increase the particle lifetime. (1)

(Total for question = 12 marks)

Q6. A stationary anti-neutron decays by emitting a positron.

(a) Explain how energy is conserved in this decay.

(2)

Mass of the products is less than the mass of the antineutron (1). The difference in mass is related to kinetic energy by $\Delta E = \Delta m c^2$ (1)

(b) The equation shows the decay of an anti-neutron.

$$^{1}_{0}\bar{n} \rightarrow {}^{1}_{-1}\bar{p} + {}^{0}_{1}\bar{e} + \nu_e$$

Explain how this equation shows that the decay obeys three conservation laws.

(6)

Conservation of charge (1) $0 \longrightarrow -1 + 1 + 0$

LHS = 0 RHS $-1+1+0=0$ (1)

Conservation of baryon number (1) $-1 \rightarrow -1 + 0 + 0$

LHS = -1 RHS = -1 (1)

Conservation of lepton number (1) $0 \rightarrow 0 + -1 + 1$

LHS = 0 RHS = $0-1+1=0$ (1)

(Total for question = 8 marks)

Q7. In 1977 a fifth quark, named the bottom quark, was discovered by particle physicists.

The table shows the particles in the standard model known at that time.

Quarks		Leptons	
up	down	electron	electron neutrino
strange	charm	muon	muon neutrino
bottom		tau	

(a) A short time after formation, most quarks combine to make particles known as hadrons. There are two categories of hadron.

Name the two categories of hadron.

(1)

mesons and baryons (1)

(b) In 1995 the sixth quark, known as the top quark, was discovered using the Tevatron collider at Fermilab. A collision of a proton with an anti-proton produced a top quark and a top anti-quark.

Particle experiments may direct beams of particles at stationary targets or collide beams of particles travelling in opposite directions.

(i) Explain the advantage of colliding beams of particles.

(4)

If beams collide, the total initial momentum is zero so the products may have no/low momentum. (1)
This means the kinetic energy of the products is zero or very low. (1)
Therefore almost all the kinetic energy of the colliding particles can be transfered to the mass of the products, (1)
so the products will have more mass. (1)

(ii) In the collider experiment, the protons and anti-protons had a total energy of 900 GeV. Calculate the maximum kinetic energy, in joules, of a top quark produced in this experiment.
rest energy of top quark = 173 GeV

(3)

$E_K = 900\,GeV - 173\,GeV = 727\,GeV$ (1)

In joules $727\,GeV = 727 \times 10^9 \times 1.6 \times 10^{-19}$ (1)

$= 1.163 \times 10^{-7}\,J$

Maximum kinetic energy = 1.16×10^{-7} (1) J

(iii) Deduce whether a top quark with kinetic energy 1.2×10^{-7} J is travelling at a relativistic speed.
rest mass of top quark = 173 GeV/c^2

(3)

mass in kg $= \dfrac{173 \times 10^9 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2} = 3.075\bar{5} \times 10^{-25}\,kg$ (1)

$E_K = \frac{1}{2} mv^2$ $\quad v = \sqrt{\dfrac{2E_K}{m}} = \sqrt{\dfrac{2 \times 1.2 \times 10^{-7}}{3.075\bar{5}}}$ (1)

$v = \sqrt{7.8 \times 10^{17}}$

$v = 8.83 \times 10^6\,ms^{-1}$

$8.83 \times 10^6\,ms^{-1} > 3 \times 10^8\,ms^{-1}$ so it is travelling at a relativistic speed (1)

(Total for question = 11 marks)

Q8. A particle with charge Q and momentum p follows a circular path of radius r. The path is at right angles to a magnetic field of magnetic flux density B.

(a) Derive the equation linking the radius of the orbit and the momentum:

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

(2)

$F = \frac{mv^2}{r} = BQv$ (1)

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

$p = mv$ so $r = \frac{p}{BQ}$ (1)

(b) By finding the momentum of an alpha particle of energy 5.4 MeV, calculate B.

mass of alpha particle = 6.64×10^{-27} kg
$r = 0.096$ m

(4)

$E_k = \frac{p^2}{2m}$ $E_k = 5.4 \times 10^6 \times 1.6 \times 10^{-19} = 8.64 \times 10^{-13}$ J (1)

$p = \sqrt{2mE_k} = \sqrt{2 \times 6.64 \times 10^{-27} \times 8.64 \times 10^{-13}}$ (1)

$p = \sqrt{1.147 \times 10^{-38}}$

$p = 1.071 \times 10^{-19}$ kg m s^{-1} (1)

$B = \frac{p}{rQ} = \frac{1.071 \times 10^{-19}}{0.096 \times 1.6 \times 10^{-19} \times 2} = 3.49$ T

↑ α has charge of +2

$B = 3.5$ T (1)

(Total for question = 6 marks)