IB PHYSICS

Name: ______________________________

Period: ________ Date: ________________

\# Marks: **94** Raw Score: ____ IB Curve: ____

DEVIL PHYSICS

BADDEST CLASS ON CAMPUS

CHAPTER 7 TEST REVIEW

1. An alpha particle is accelerated through a potential difference of 10 kV. Its gain in kinetic energy is

A. 10 eV.

B. 20 eV.

C. 10 keV.

D. 20 keV.

(Total 1 mark)

2. The rest mass of a proton is 938 MeV c^{-2}. The energy of a proton at rest is

A. 9.38 J

B. 9.38 × 108 × (3 × 108)2 J

C. 9.38 × 108 eV.

D. 9.38 × 108 × (3 × 108)2 eV

(Total 1 mark)

3. Different nuclides spontaneously undergo radioactive decay, emitting either α, β or γ radiation. Which of the following correctly identifies all the emissions that **do not** have discrete energies?

A. α

B. β

C. γ

D. α and γ

(Total 1 mark)

4. The half-life of a radioactive isotope is 10 days. What is the percentage of the sample remaining after 25 days?

A. 0 %

B. 18 %

C. 25 %

D. 40 %

(Total 1 mark)

5. Two samples of radioactive substances X and Y have the same initial activity. The half-life of X is T and the half-life of Y is $3T$. After a time of $3T$ the ratio

$$\frac{\text{activity of substance X}}{\text{activity of substance Y}} \text{ is}$$

A. 8.

B. 4.

C. $\frac{1}{4}$.

D. $\frac{1}{8}$.

(Total 1 mark)

6. Which of the following correctly identifies the three particles emitted in the decay of the nucleus $^{45}_{20}Ca$ into a nucleus of $^{45}_{21}Sc$?

A. α, β^-, γ

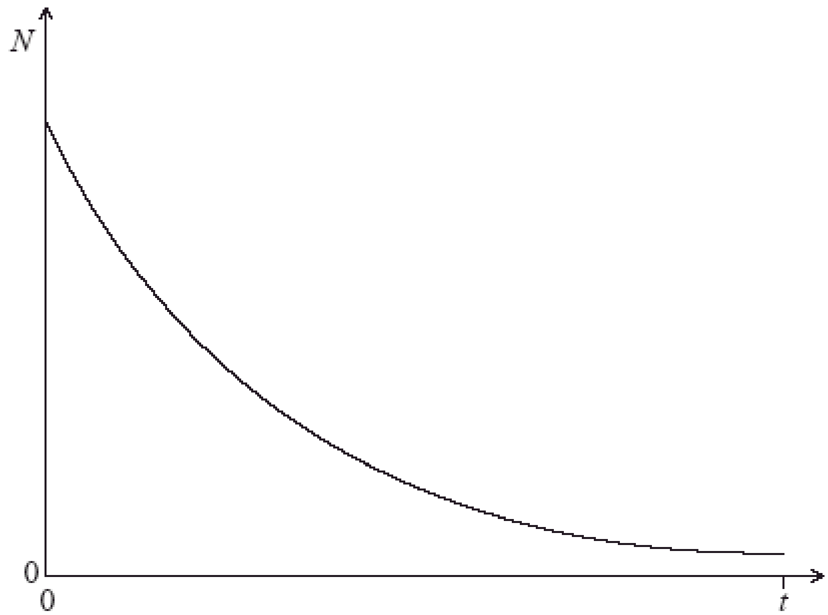
B. β^-, γ, $\bar{\nu}$

C. α, γ, $\bar{\nu}$

D. α, β^-, $\bar{\nu}$

(Total 1 mark)

7. The graph below shows the number of nuclei *N* of a radioactive isotope as a function of time *t*.



The slope of the curve at any given time is

A. independent of the decay constant.

B. proportional to the half-life of the isotope.

C. proportional to the number of radioactive nuclei remaining at that time.

D. proportional to the number of radioactive nuclei decayed.

(Total 1 mark)

8. Which of the following is true about beta minus (β^-) decay?

A. An antineutrino is absorbed.

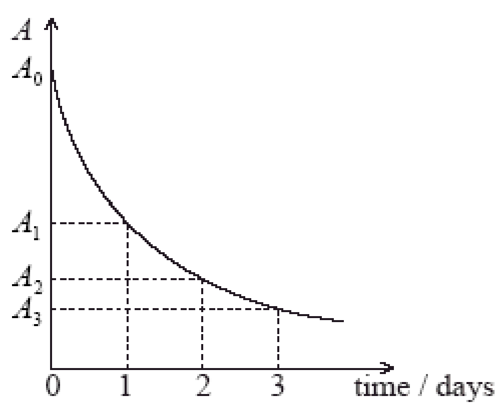
B. The charge of the daughter nuclide is less than that of the parent nuclide.

C. An antineutrino is emitted.

D. The mass number of the daughter nuclide is less than that of the parent nuclide.

(Total 1 mark)

9. A radioactive isotope has an initial activity A_0 and a half-life of 1 day. The graph shows how the activity *A* varies with time.



The ratio $\frac{A_0}{A_2}$ is equal to which of the following?

A. $\frac{A_1}{A_3}$

B. $\frac{A_0}{A_3}$

C. $\frac{A_0}{2}$

D. $\frac{A_3}{3}$

(Total 1 mark)

10. Which of the following causes the greatest number of ionizations as it passes through 1 cm of air? (The total energy of the ionizing radiation is the same.)

A. An alpha particle

B. A beta particle

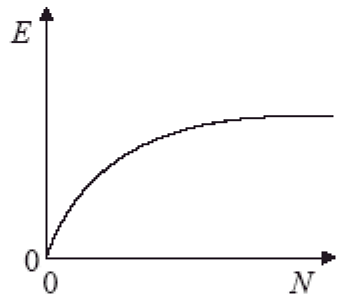
C. A gamma-ray

D. An X-ray

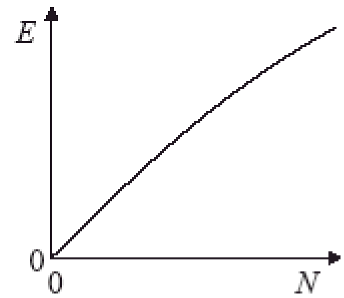
(Total 1 mark)

11. Which of the following graphs best shows the variation with nucleon number *N* of the binding energy per nucleon *E*?

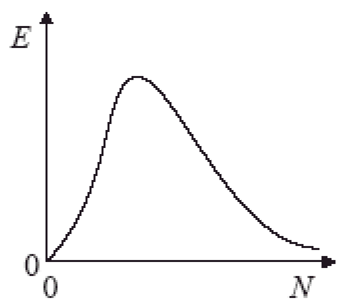
A.



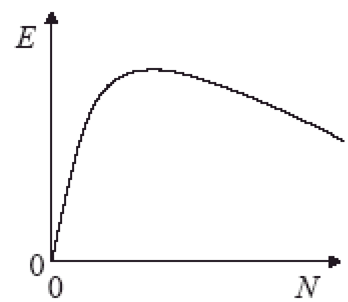
B.



C.



D.



(Total 1 mark)

12. A radioactive source emits alpha particles that then travel through air. With reference to the range of the alpha particles consider the following three quantities.

I. The charge of the alpha particle

II. The kinetic energy of the alpha particle

III. The density of the air

Which of the above determines the range of the alpha particles?

A. I only

B. II only

C. I and II only

D. I, II and III

(Total 1 mark)

13. The rest mass of a proton is 938 MeV c^{-2}. The energy of a proton at rest is

A. 9.38 J.

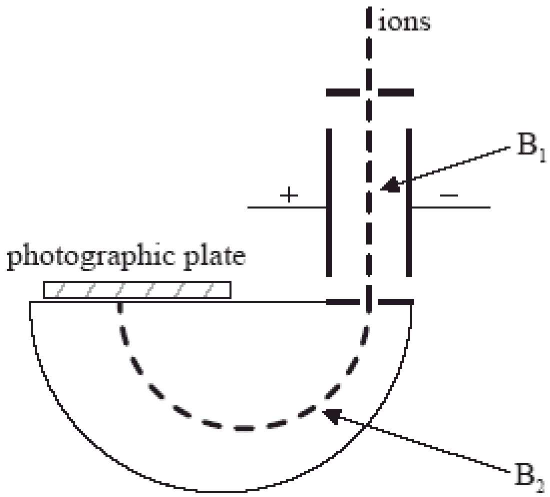
B. $9.38 \times 10^8 \times (3 \times 10^8)^2$ J.

C. 9.38×10^8 eV.

D. $9.38 \times 10^8 \times (3 \times 10^8)^2$ eV.

(Total 1 mark)

14. The diagram is a schematic representation of the Bainbridge mass spectrometer. Positive ions are injected between the plates of the speed selector.



Which of the following correctly shows the direction of the magnetic fields B_1 and B_2?

	B_1	B_2
A.	out of the page	out of the page
B.	into the page	into the page
C.	out of the page	into the page
D.	into the page	out of the page

(Total 1 mark)

15. This question is about the decay of radium-226.

(a) The nuclear reaction equation for the decay of radium-226 (Ra) may be written as

$$^{226}_{88}\text{Ra} = \text{Rn} + \alpha$$

(i) State the value of the proton number and neutron number of the isotope of radon (Rn).

Proton number: ....

Neutron number: ....

(1)

(ii) Compare, with reference to the nuclear reaction in (a), the binding energy of Ra with that of Rn.

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(2)

(b) The following data are available.

mass of Ra	= 226.0254 u
mass of Rn	= 222.0175 u
mass of α	= 4.0026 u

Show that the energy released in the decay of a Ra nucleus is 4.94 MeV.

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(2)

(c) An α-particle of energy 4.94 MeV emitted in the decay of a Ra nucleus, travels a distance *d* in air before coming to rest.

(i) Show that the initial speed of the α-particle is 1.54×10^{7} m s^{-1}.

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(3)

(ii) State the relationship between the magnitude of the average force F acting on the α-particle, the change in kinetic energy ΔE_K and the distance d.

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(1)

(iii) Use your answer to (c)(ii) to calculate F given that $d = 4.20 \times 10^{-2}$ m.

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(2)

(iv) Estimate the time that it takes the α-particle to come to rest.

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(4)

16. This question is about α-particle scattering and nuclear processes.

α-particle scattering

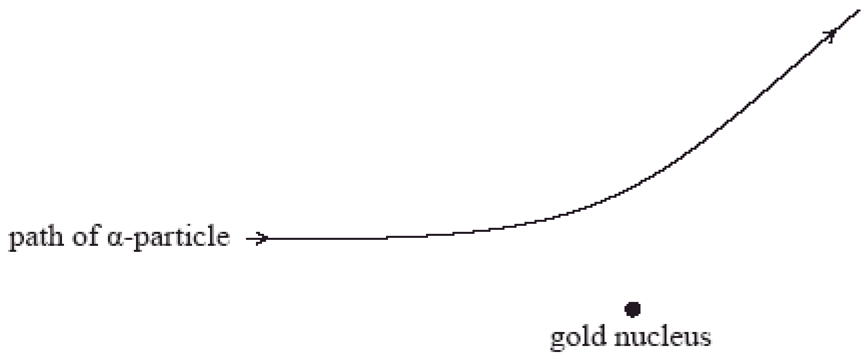
Radium-226 decays with the emission of α-particles to radon (Rn).

(a) Complete the nuclear reaction equation.

$$^{226}_{88}\text{Ra} \rightarrow \qquad \text{Rn} \quad +$$

(2)

(b) Experimental evidence that supports a nuclear model of the atom was provided by α-particle scattering. The diagram represents the path of an α-particle as it approaches and then recedes from a stationary gold nucleus.



(i) On the diagram, draw lines to show the angle of deviation of the α-particle. Label this angle *D*.

(1)

(ii) The gold nucleus is replaced by another gold nucleus that has a larger nucleon number. Suggest and explain the change, if any, in the angle *D* of an α-particle with the same energy and following the same initial path as in (b)(i).

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(2)

(c) The diagram shows the initial path of an α-particle that approaches the gold nucleus along a line joining their centres. On the diagram draw the subsequent path of the α-particle.

(1)

Nuclear processes

(d) The main nuclear process that gives rise to energy emission from the Sun may be simplified to

$$4\text{H} \rightarrow \text{He} + \text{energy.}$$

(i) State the name of this nuclear process.

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(1)

(ii) The total mass of four hydrogen (H) nuclei is 6.693×10^{-27} kg and the mass of a helium (He) nucleus is 6.645×10^{-27} kg. Show that the energy released in this reaction is 4.3×10^{-12} J.

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(2)

(iii) The Sun has a radius R of 7.0×10^{8} m and emits energy at a rate of 3.9×10^{26} W. The nuclear reactions take place in the spherical core of the Sun of radius $0.25R$. Use these data and the answer in (d)(ii) to determine the number of nuclear reactions occurring per cubic metre per second in the core of the Sun.

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(3)

17. This question is about radioactive decay.

Nitrogen-13 ($^{13}_{7}\text{N}$) is an isotope that is used in medical diagnosis. The decay constant of nitrogen-13 is 1.2×10^{-3} s^{-1}.

(a) (i) Define *decay constant*.

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(1)

(ii) A sample of nitrogen-13 has an initial activity of 800 Bq. The sample cannot be used for diagnostic purposes if its activity becomes less than 150 Bq. Determine the time it takes for the activity of the sample to fall to 150 Bq.

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(2)

(b) (i) Calculate the half-life of nitrogen-13

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(1)

(ii) Outline how the half-life of a sample of nitrogen-13 can be measured in a laboratory.

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(3)

(c) Nitrogen-13 undergoes β^+ decay. Outline the experimental evidence that suggests another particle, the neutrino, is also emitted in the decay.

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(2)

18. This question is about β^+ (positron) decay.

(a) In a β^+ decay, a positron is emitted along with a neutrino, and a γ-ray photon. Although the energy spectrum for γ-rays involved is discrete, the energy spectrum for the positrons is continuous.

(i) State the difference between a discrete energy spectrum and a continuous energy spectrum.

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(1)

(ii) Explain how the existence of the neutrino accounts for the continuous nature of the positron energy spectrum.

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(2)

(b) Sodium-22 is a radioisotope used in nuclear medicine that undergoes β^+ decay.
The half-life of sodium-22 is 2.6 years.
A sample of sodium-22 has an initial activity of 6.2×10^9 Bq.

(i) Define *decay constant.*

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(1)

(ii) Calculate the decay constant of sodium-22.

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(1)

(iii) Calculate the activity of the sample of sodium-22 after 8.0 years.

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(3)

19. This question is about unified atomic mass unit and a nuclear reaction.

(a) Define the term *unified atomic mass unit*.

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(1)

(b) The mass of a nucleus of rutherfordium-254 is 254.1001 u. Calculate the mass in GeV c^{-2}.

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(1)

(c) In 1919, Rutherford produced the first artificial nuclear transmutation by bombarding nitrogen with α-particles. The reaction is represented by the following equation.

$$\alpha + {}^{14}_{7}\text{N} \rightarrow {}^{17}_{8}\text{O} + \mathbf{X}$$

(i) Identify **X**.

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(1)

(ii) The following data are available for the reaction.

Rest mass of α = 3.7428 GeV c^{-2}
Rest mass of $^{14}_{7}N$ = 13.0942 GeV c^{-2}
Rest mass of $^{17}_{8}O$ + **X** = 16.8383 GeV c^{-2}

The initial kinetic energy of the α-particle is 7.68 MeV. Determine the sum of the kinetic energies of the oxygen nucleus and **X**. (Assume that the nitrogen nucleus is stationary.)

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(3)

(d) The reaction in (c) produces oxygen (O-17). Other isotopes of oxygen include O-19 which is radioactive with a half-life of 30 s.

(i) State what is meant by the term isotopes.

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(1)

(ii) Define the term *radioactive half-life*.

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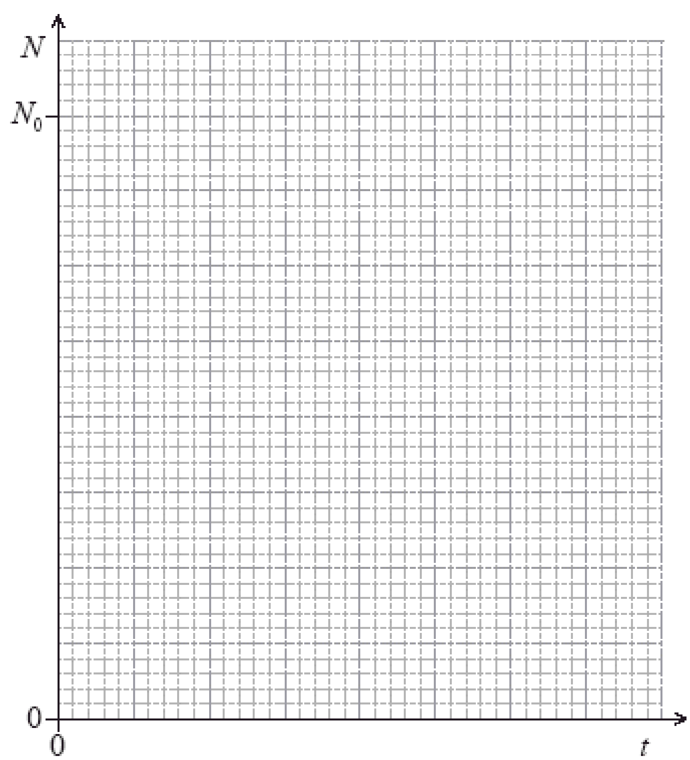
(1)

(e) A nucleus of the isotope O-19 decays to a stable nucleus of fluorine. The half-life of O-19 is 30 s. At time $t = 0$, a sample of O-19 contains a large number N_0 nuclei of O-19.

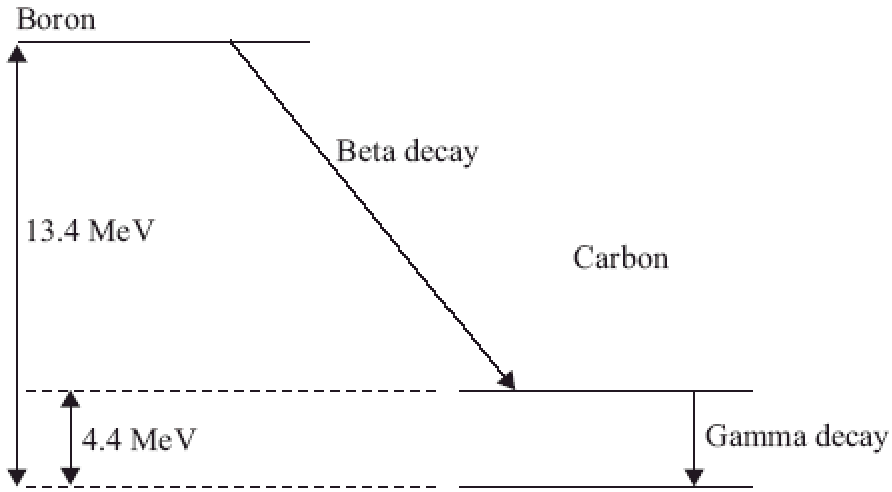
On the grid below, draw a graph to show the variation with time t of the number N of O-19 nuclei remaining in the sample. You should consider a time of $t = 0$ to $t = 120$ s.



(2)

20. This question is about nuclear energy levels and radioactive decay.

The diagram shows some of the nuclear energy levels of the boron isotope $^{12}_{5}B$ and the carbon isotope $^{12}_{6}C$. Differences in energy between the levels are indicated on the diagram. A particular beta decay of boron and a gamma decay of carbon are marked on the diagram.



(a) Calculate the wavelength of the photon emitted in the gamma decay.

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(2)

(b) Calculate the maximum kinetic energy of the electron emitted in the beta decay indicated.

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(1)

(c) Explain why the electrons emitted in the indicated beta decay of boron do not always have the kinetic energy calculated in (b).

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(2)

21. This question is about quarks.

The table below gives the electric charge of the three lightest quarks in terms of *e*, the charge of the proton.

Quark flavour	up u	down d	strange s
Electric charge / *e*	$\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$

(a) Using the data in the table, determine the

(i) quark content of a meson with charge +1 and strangeness 0 and that of a baryon with charge –1 and strangeness –3.

Meson: ....

Baryon: ....

(2)

(ii) possible spin values of the meson in (a)(i).

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(1)

(b) State the Pauli exclusion principle.

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(1)

(c) Explain how the baryon with quark content uuu and spin $\frac{3}{2}$ does not violate the Pauli exclusion principle.

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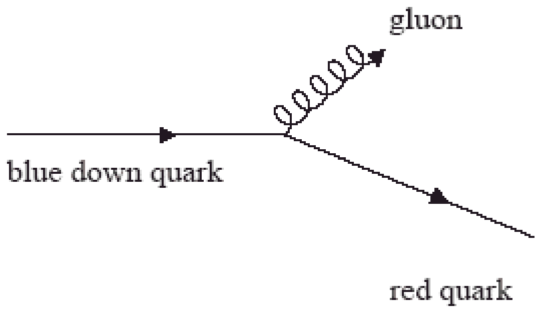
(1)

(d) In the Feynman diagram shown a blue down quark emits a gluon and produces a red quark.



Deduce the

(i) quark flavour (type) of the produced quark.

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(1)

(ii) colour quantum numbers of the emitted gluon.

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(1)

(e) The positive kaon K^+ (quark content $u\bar{s}$) decays into an anti-muon and a neutrino according to the reaction below.

$$K^+ \rightarrow \mu^+ + \nu$$

Explain how it may be deduced that this decay is a weak interaction process.

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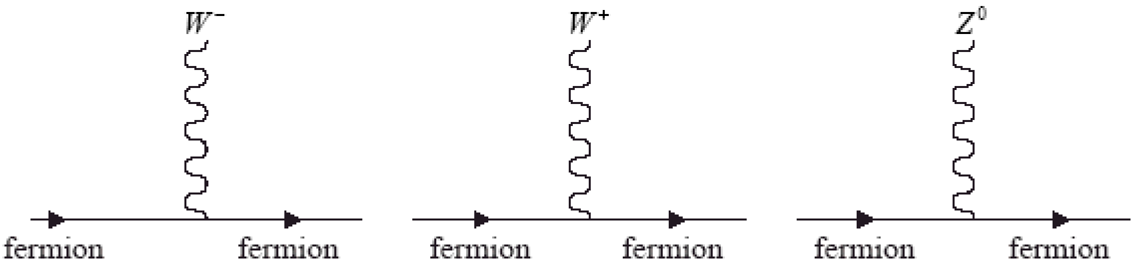
(1)

(f) The diagram shows three of the interaction vertices for the weak interaction.



Using the appropriate vertex, draw a Feynman diagram for the decay $K^+ \rightarrow \mu^+ + \nu$ labelling all particles involved.

(3)

22. This question is about energy and conservation laws.

Two protons moving at the same speed in opposite directions, collide with each other producing three protons and an anti-proton, as shown below.

$$\text{p} + \text{p} \rightarrow \text{p} + \text{p} + \bar{\text{p}} + \text{p}$$

(a) Calculate the minimum possible kinetic energy of **one** of the colliding protons.

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(2)

(b) Explain why the following reaction is not possible, even if the colliding particles have enough energy.

$$\text{p} + \text{n} \rightarrow \text{p} + \text{p} + \bar{\text{p}}$$

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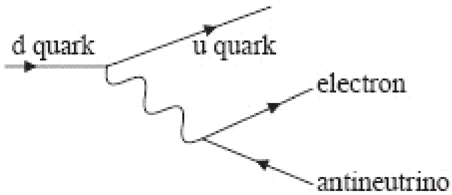
(2)

23. This question is about fundamental interactions.

(a) The Feynman diagram below represents a β^- decay via the weak interaction process.



The exchange particle in this weak interaction is a virtual particle.

(i) State what is meant by a virtual particle.

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(1)

(ii) Detemine whether the virtual particle in the process represented by the Feynman diagram is a W^+, a W^- **or** a Z^0 boson.

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(2)

(b) The order of magnitude of the mass of the $W^{\pm}$ and Z^0 bosons is 100 GeV c^{-2}. Estimate the range of the weak interaction.

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(3)