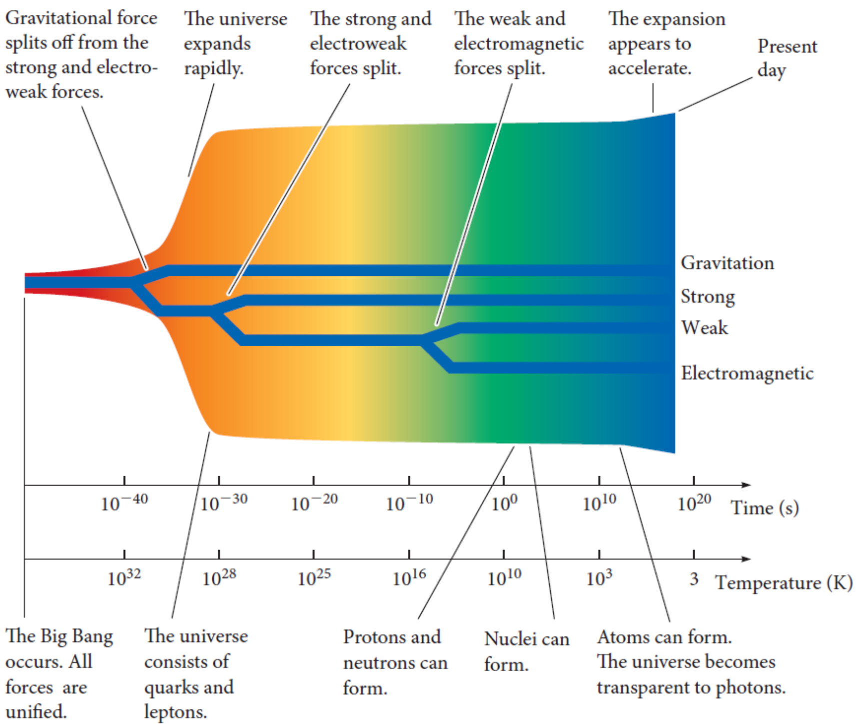
Year 12 ATAR Physics
Standard Model Topic Test
September 2016

Time allowed: 50 minutes
Total marks available: 50
Use appropriate significant figures for accuracy

Student Name: Solutions

1. The diagram refers to the Big Bang Theory.



a. Name the 3 main sources of evidence that support the Big Bang Theory. (3)

1. Cosmic Background Radiation
2. Red shift of light from distant galaxies
3. Abundance of light elements in the universe

b. Explain what is meant by the term “evolution of forces” with respect to the Big Bang Theory? (2)

At start of Big Bang only one force existed ✓ (unified force) as time progressed the other forces became separated in a sequence (gravity then strong then weak and EM) ✓ or similar

c. List the first two types of elementary particles to exist in the universe after the Big Bang event occurred? (1)

1. Quarks
2. Leptons

2. What is Cosmic Background Radiation in the context of the Standard Model?

(2)

Cosmic Background Radiation is a type of black body spectrum that was emitted in all directions (by scattering) from matter in the early universe. (until age approx. 380,000 yrs).
This can be viewed from all directions as em radiation corresponding to a black body emission of approx. 2.7 K.
Residual radiation from the Big Bang. Any 2 valid points.

3. A rubber balloon can be charged by rubbing it on your hair. It is then possible to stick the balloon to a wall. Name the Standard Model fundamental force responsible for this attraction and the gauge boson involved.

(2)

Electromagnetic force
Photon

4. Particle accelerators are used to investigate the Standard Model. For example, an electron and a positron can be collided together to make a W^+ and a W^-. Why is it necessary to have these charged leptons travelling at near light speeds in order to make the boson particles?

(2)

Bosons formed are more massive than the leptons. ✓

Energy is required to be converted to mass, this comes from the Kinetic energy of the leptons ($E = mc^2$) ✓
Note – electrostatic repulsion not relevant as these leptons have opposite charge. SNF, strong force does not act between leptons

5. The mass of the Delta-zero baryon is given in table 9.1. Convert this mass into kilograms.

(3)

mass = 1232 MeV/c^2 ✓ from data sheet

Mass (kg) = $\frac{1232 \times 10^{6} \times 1.60 \times 10^{-19}}{(3 \times 10^{8})^2}$ ✓ $= 2.19 \times 10^{-27}\ kg$ ✓

6. NGC 5127 is a galaxy group that can be observed from the Hubble Space telescope. A line absorption spectrum of light passing through calcium in this galaxy shows one line with a wavelength of 573.2 nm. The same line in the spectrum measured on Earth is 568.4 nm.

a) Is the galaxy NGC 5127 moving towards or away from the Earth? (1)

Away

b) Briefly explain your answer to a) (1)

Wavelength has increased due to redshift

c) Calculate the velocity of NGC 5127 relative to the Earth using the relationship: (3)

$$\frac{\Delta\lambda}{\lambda_{rest}} = \frac{v}{c_0}$$ where $\Delta\lambda = \lambda_{shifted} - \lambda_{rest}$ and v = recessional velocity (m s^{-1})

$$\frac{\Delta\lambda}{\lambda_{rest}} = \frac{v}{c_0}$$

$$\frac{573.2 - 568.4 \checkmark}{568.4 \checkmark} = \frac{v}{3 \times 10^8}$$

$$v = 2533427.164 = 2.53 \times 10^6\ m\ s^{-1} \checkmark$$

d) Calculate the distance in Mpc to galaxy NGC 5127 using the velocity you calculated in part c). (if you could not solve part (c) use a value 2.53×10^6 m s^{-1})

Hubble's law states that: $v = H_0 d$

v = recessional velocity (km s^{-1})
d = distance Mpc
$H_0 = 74.0$ km s^{-1} Mpc^{-1}

(2)

$$v = 2533427.164 = 2.53 \times 10^3\ km\ s^{-1}$$

$$v = H_0 d$$

$$2.53 \times 10^3 = 74 \times d \checkmark$$

$$d = 34.2355\ MPc \checkmark$$

e) How many years will it take light from this galaxy to reach Earth? (1 parsec = 3.26 ly) (1)

$$d = 34.2355\ MPc = 34.2355 \times 10^6 \times 3.26 = 1.12 \times 10^8\ ly$$

$$light\ takes\ 1.12 \times 10^8\ years\ (112\ million\ years)$$

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7. Are the following quark combinations possible or not? If so, classify this combination as a meson, baryon or anti-baryon. If the combination is not possible explain why.

(2)

Quark Combination	Possible Yes/No	Classify or Explain why not possible
tc	No	2 quark hadrons are meson which must have 1 quark and 1 antiquark
$\bar{d}\,\bar{s}\,\bar{b}$	Yes	Antibaryon

Each row must be fully correct for 1 mark

8. Refer to table 10.3. Name the baryon that has the quark combination dds and verify its charge.

(2)

Name: Sigma-minus (Σ^-)

Charge = -1/3e + -1/3e + -1/3e, = -1 e (do not accept -1 with no qualification)

9. Explain why a meson always has a baryon number of zero. You must refer to quarks in your response.

(2)

A meson is always composed of a quark and an anti-quark, quarks have baryon number = +1/3, antiquarks have baryon number = -1/3 ✓ so the sum is always zero ✓

10. Are the following equations allowed by the conservation of all lepton numbers? You must justify your response to gain any marks.

An appraisal of all lepton numbers is required in each part of the question, any errors -1

a) A Tau-minus decays to an electron an electron anti-neutrino and a Tau-neutrino.

(2)

$$\tau^- \rightarrow e^- + \bar{\nu}_e + \nu_\tau$$

L_e before = 0 after = +1 + -1 = 0 so OK

L_μ before = 0 after = 0 so OK

L_τ before = +1 after = +1 so OK Therefore allowed

b) An Eta-prime decays to a muon-positive an electron-neutrino and a muon-neutrino.

(2)

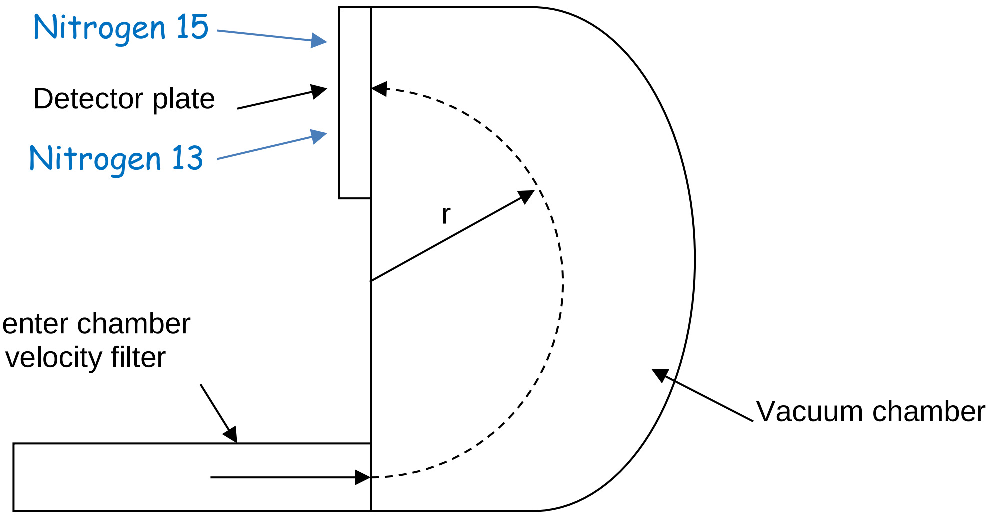
$$\eta' \rightarrow \mu^+ + \nu_e + \nu_\mu$$

L_e before = 0 after = +1 = 0 so not OK

L_μ before = 0 after = -1 + 1 = 0 so OK

L_τ before = 0 after = 0 so OK Therefore not allowed

11. Ionised nitrogen atoms (N^{3-}) are fed into a uniform magnetic field in a vacuum chamber. They follow the path shown in the diagram. The ions enter with a speed of 2.84×10^5 m s^{-1} into a magnetic field with a flux density of 65.7 mT. The entry path of the nitrogen ions and the magnetic field lines are at right angles to each other.



a) Indicate on the diagram the direction of the magnetic field in the vacuum chamber required to produce the semi-circular path shown.

(1)

Out of the pages - dots

b) The path shown is for a Nitrogen-14 ion, show clearly on the diagram where isotopes of Nitrogen-13 and Nitrogen-15 are likely to strike the detector plate. Label them with an arrow.

(2)

As above

c) Explain why the Nitrogen ions undertake a circular path once they enter the magnetic field.

(2)

The magnetic force (qvB) applies a force perpendicular to the motion which initiates a curved path for the particle. ✓ As particle turns the Force is still perpendicular. This is equates to a centripetal force. ✓ **Two good points**

d) Calculate the magnitude of the force acting on the Nitrogen ions once they enter the magnetic field.

(2)

The magnetic force F = qvB.

$F = 3 \times 1.60 \times 10^{-19} \times 2.84 \times 10^5 \times 65.7 \times 10^{-3}$ ✓

$F = 8.96 \times 10^{-15}$ N ✓

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e) A Nitrogen-14 ion follows a semi-circular path of diameter 42.0 cm, calculate the mass of the Nitrogen-14 ion.

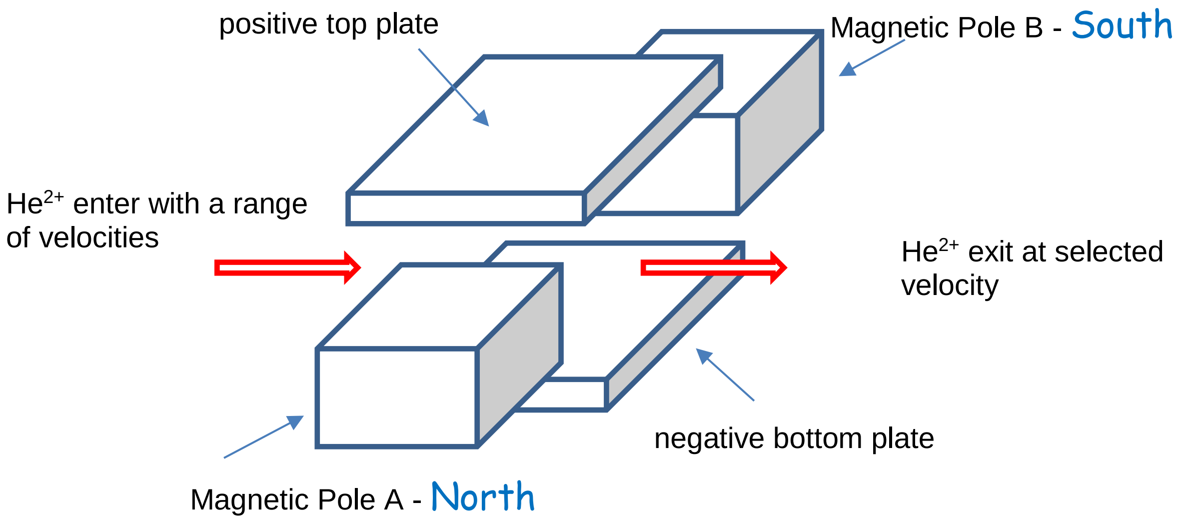
(3)

$$m = \frac{rqB}{v}$$

$$m = \frac{0.21 \times 3 \times 1.60 \times 10^{-19} \times 0.0657 \checkmark}{2.84 \times 10^{5} \checkmark}$$

$$m = 2.33 \times 10^{-26}\ kg \checkmark$$

12. Alpha particles (He^{2+}) of mass 6.64 x 10^{-27} kg accelerated by a Linac enter a velocity selector with a range of velocities up to 4.00 x 10^{6} m s^{-1}. A simple diagram of the velocity selector is shown below. The region that the particles pass through consists of a magnetic field and an electric field at right angles to each other.



a) The relative charge of the top and bottom plate is shown in the diagram. Indicate on the diagram the polarity of Magnetic Poles A and B. You should state north or south poles in each case.

(1)

As above – N or S not accepted

b) Derive the expression: $v = \frac{E}{B}$, for the speed of alpha particles that will pass through the velocity selector in a straight line. Your derivation must consider the relationship between the magnetic and electric fields with word explanations and algebraic steps that start with equations on your data sheet.

(2)

From data sheet equations required: $E = F/q$ and $F_{mag} = qvB$

$F(magnetic) = F(electric)$ – Word statement that these forces must be equal magnitude, opposite direction. ✓

$$qvB = E.q$$

$vB = E$ $\quad v = \frac{E}{B}$ ✓ (correctly stepped)

c) The filter is required to select alpha particles with a velocity of $4.07 \times 10^5\ m\ s^{-1}$. If the magnetic flux density within the velocity selector is set to 8.23×10^{-2} T calculate the required electric field strength between the two charged plates.

(2)

$$v = \frac{E}{B}$$

$$E = vB$$

$$E = 4.07 \times 10^5 \times 8.23 \times 10^{-2}$$ ✓

$E = 33500 = 3.35 \times 10^4\ N\ m^{-1}$ ✓

d) Will Chlorine ions (Cl^-) with a single negative charge and mass 5.89×10^{-26} kg entering at the same speed also be selected at a velocity of 4.07×10^5 m s^{-1}? Explain briefly with reference to mass and charge.

(2)

$$v = \frac{E}{B}$$

Consider the equation, neither charge nor mass of the particle are factors✓, so yes will select at same speed. ✓

End of test