# Standard Model Test 2017

Wednesday, 13 September 2017 9:42 AM

Standard Model Test 2017

ALL SAINTS' COLLEGE

Year 12 ATAR Physics
Standard Model Topic Test
September 2017

Student Name: ________________

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

1. Can radio waves be red-shifted? Explain what this means when applied to radio waves. (2)

Red Shift when there is recession between a source of radio wave ✓ and a receiver, the wavelength will be longer (Compared to source and receiver at rest) ✓

2. Explain why Cepheid variable stars are useful when considering the Standard Model. (2)

They are a standard measure of brightness (standard candle) ✓ the relative brightness (relative magnitude) can be used to calculate distance to the Cepheid. ✓
(pulse frequency related to absolute magnitude at brightest)

3. The Big Bang Theory is supported by 3 main pieces of evidence. The expansion of the universe, Cosmic Microwave Background radiation and a third. Describe the third piece of evidence and explain how it supports the Big Bang Theory. (3)

Abundance of light elements. ✓
The high ratio of hydrogen, helium and lithium existing in the universe is predicted by mathematical ✓ models of the big bang.
These ratios are confirmed by measurement. ✓

4. Explain the origin of Cosmic Microwave Background radiation and why no electromagnetic radiation is visible from the first few thousand years after the Big Bang event. (3)

The first transmission of emr from the hot dense matter that formed the early universe. ✓ The first scattering of emr after the universe stopped being opaque ✓

In the early universe all emr as absorbed by matter in hot, dense, plasma state. ✓

5. If the Earth still exists in several thousand years and humans are still studying Physics the frequency of the Cosmic Microwave Background radiation will appear: (circle a response) (1)

The same as present

[✓ Shifted towards radio waves] ✓

Shifted towards Infra-Red

No longer be visible

6. Consider beta negative decay.

a) Name the gauge boson involved in beta negative decay (1)

W-negative ✓

b) The gauge boson is only short lived. Explain how its mass and energy is conserved after it ceases to exist. (2)

It decays to form a beta-negative particle ✓ (an electron) and an anti-neutrino ✓

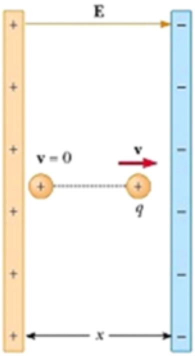
7. The mass of the Omega baryon is shown on the table 9.1. Convert this mass into kilograms. (3)

$\Omega^-$ mass = 1672 MeV/$c^2$ ✓

$$\text{mass (kg)} = \frac{1672\times10^{6}\times1.60\times10^{-19}}{(3\times10^{8})^{2}}$$ ✓

mass (kg) = $2.97\times10^{-27}$ kg ✓

8. A positron is accelerated in the Stanford Linear Accelerator by a potential difference of 330 kV. Calculate the relativistic speed that the positron reaches.



Hint: You will need the equation

$$\frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}} = KE + m_0c^2$$

$W_d = \Delta KE = qV$

$$\frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}} = qV + m_0c^2$$ ✓ Concept

insertion of data matches placeholders ✓ (4)

$$m_0c^2 = (qV + m_0c^2) \times \sqrt{1-\frac{v^2}{c^2}}$$

$$\frac{m_0c^2}{(qV+m_0c^2)} = \sqrt{1-\frac{v^2}{c^2}} = \frac{9.11\times10^{-31}\times(3\times10^8)^2}{(1.60\times10^{-19}\times330{,}000\times9.11\times10^{-31}\times(3\times10^8)^2}$$

algebra steps

$$\sqrt{1-\frac{v^2}{c^2}} = 0.608279$$ ✓

$$1-\frac{v^2}{c^2} = 0.370004006$$

$$\frac{v^2}{c^2} = 0.62999$$

$$v^2 = 0.62999\,c^2$$

$$v = 0.794\,c \quad (2.38\times10^8\,\text{m/s})$$ ✓

9. The mass of an up quark is approximately 2.4 MeV/c². The mass of a down quark is approximately 4.8 MeV/c².

Stay in MeV/c²

a) Compare the total mass of the individual quarks that make up a proton with the mass of a proton itself. Calculate the difference in mass (MeV/c²) (3)

Total mass of individual quarks in a proton: u + u + d $2.4 + 2.4 + 4.8 = 9.6\ \frac{\text{MeV}}{c^2}$ (show working) ✓

Mass of a proton: 938.3 MeV/c² ✓

Mass difference between component quarks and proton: 928.7 MeV/c² ✓

b) Suggest why there is such a big difference in mass-energy between the component quarks and the proton. (2)

gluons that exchange between quarks ✓ within proton account for remainder of mass/energy ✓ content. (gluons mediate the strong force)

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10. Consider the following proposed reaction in a particle accelerator.

The collision of a proton with a neutron to form an antiproton, a muon-plus and a muon-minus

$$p + n \rightarrow \bar{p} + \mu^+ + \mu^-$$

Is this allowed according to the conservation of Baryon number? Explain briefly. (2)

$B \quad 1 + 1 \mid -1 \quad 0 \quad 0$ ✓

$2 \neq -1$ ✓

∴ not possiple

11. Consider the following proposed decay.

A Tau particle decays to an electron, an electron anti-neutrino and a Tau neutrino

$$\tau^- \rightarrow e^- + \overline{\nu}_e + \upsilon_\tau$$

Is this allowed according to the conservation of Lepton numbers? Explain briefly. (2)

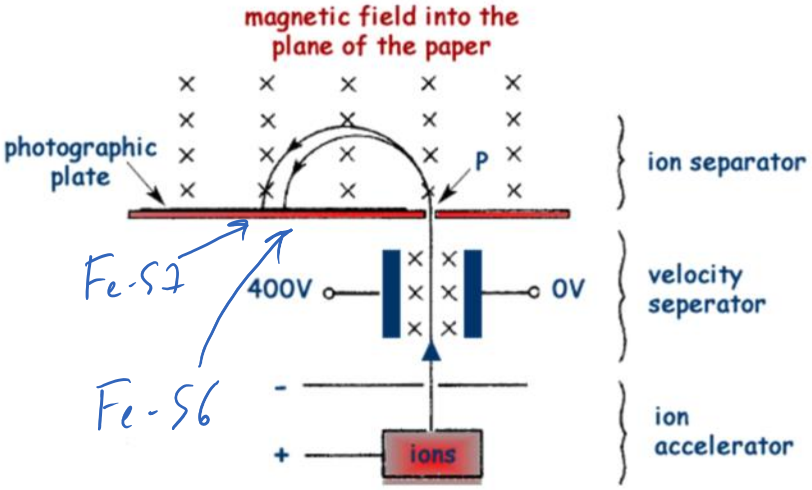
$L_e \quad 0 \rightarrow 1 + -1 + 0 \quad (0 = 0$ ✓ ok)

$L_\tau \quad 1 \rightarrow 0 + 0 + 1 \quad (1 = 1$ ✓ ok) ✓

∴ reaction is allowed. ✓

N.B $L_\mu$ not applicaple here.

12. The diagram shows a mass spectrometer used for separating isotopes of ionised atoms of iron (Fe-56 and Fe-57). The iron is ionised to the $Fe^{3+}$ form, the ions enter the separator at a speed of $1.79 \times 10^5$ m s$^{-1}$ and the magnetic field has a flux density of 204 mT



a) Indicate on the diagram where each isotope will strike the photographic plate with the labels Fe-56 and Fe-57.

(1)

✓

b) Derive the expression $r = \frac{mv}{Bq}$ from other equations on the data sheet.

(1)

$$F_{mag} = F_{cent}$$

$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{qB}$$ ✓

c) Explain the operating principles of the mass spectrometer and why the mass spectrometer can separate the 2 isotopes of iron.

(3)

magnetic force puts ions into circular motion ✓ where radius is given by

$$r = \frac{mv}{qB}$$ ✓

If v, q, B constant then $r \propto m_{ion}$ ✓

d) The diameter of one of the ion paths is measured to be 34.0 cm. Calculate the mass of this isotope.

(3)

derives $m = \frac{r.q.B}{v}$ $r = 0.17\,m$ ✓

$$m = \frac{0.17 \times 3 \times 1.60 \times 10^{-19} \times 0.204}{1.79 \times 10^{5}}$$ ✓

$$m = 9.30 \times 10^{-26}\ kg$$ ✓

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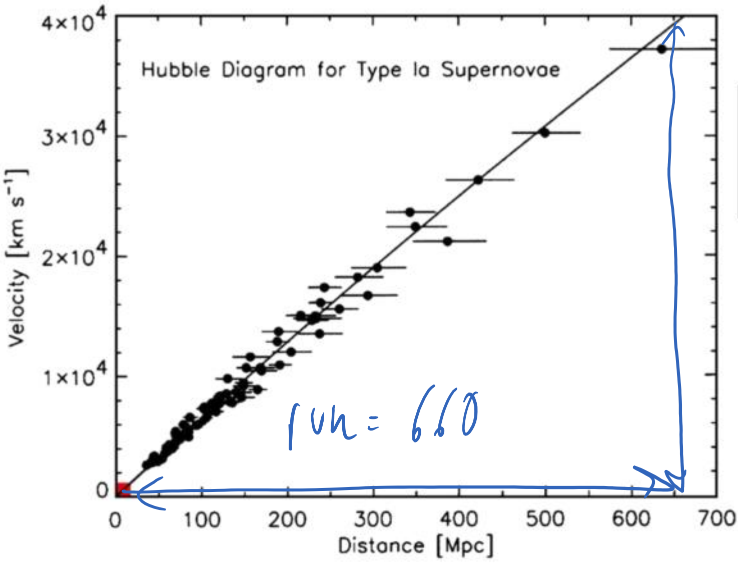
13. The graph shows data collected from Type 1A Supernovae stars in 1976.



Hubble's Law:

$$v = H_0 d$$

rise = $4 \times 10^4$

a) Calculate the value of Hubble's constant according to this graphical data. You must clearly show how you obtained information from the graph.

(3)

Shows rise/run on graph ✓

$$H_0 = \frac{\text{rise}}{\text{run}} = \frac{4 \times 10^4}{660} = 60.6 \text{ kms}^{-1} \text{Mpc}^{-1}$$

✓ ✓

b) The value of the Hubble constant was approximately 61.0 km s⁻¹ Mpc⁻¹ in 1976. Calculate the age of the universe based on this value. Note that one Parsec = 3.26 Light Years. Give your answer in billions of years.

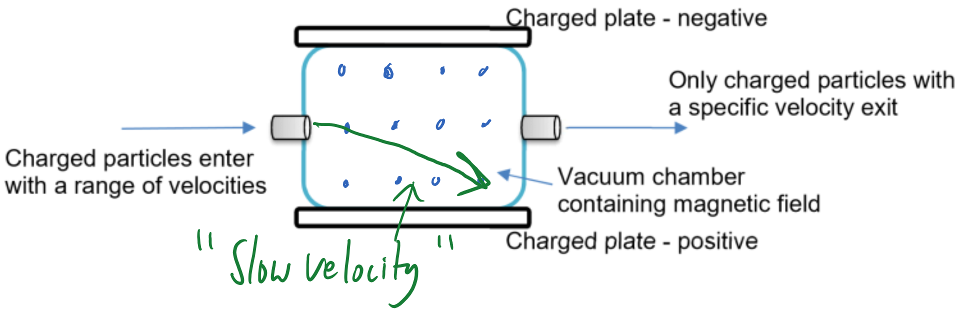
(3)

$$\text{Age} = \frac{1}{H_0}$$

$$\text{Age} = \left| \frac{61 \times 1000}{10^6 \times 3.26 \times 3 \times 10^8 \times 365 \times 24 \times 60 \times 60} \right|^{-1} \text{seconds}$$ ✓

$$\text{Age (Years)} = \left( \frac{10^6 \times 3.26 \times 3 \times 10^8}{61 \times 1000} \right) = 16.0 \text{ billion years } (\times 10^9)$$ ✓ ✓

14. The diagram shows a side view of a velocity filter (aka velocity selector).



a) What is the direction of magnetic field required to filter charged particles at a specific velocity. You should sketch the magnetic field direction onto the diagram. (1)

Out of page ✓

b) With reference to the forces acting on the charged particles, explain how the velocity filter can allow only particles travelling at a specific velocity to continue in a straight-line path. Refer to negatively charged particles in your explanation. (3)

$F_{mag} = q.v.B$ acts to curve negative particles upward ✓

$F_{electric} = q.E$ acts to curve negative particles downward ✓

If $F_{electric} = F_{mag}$, $qvB = qE$ particles follow straight line path, v can be set by $v = \frac{E}{B}$ ✓

c) Negatively charged particles that are travelling slower than the filter velocity will not exit the velocity filter. Explain why they will not be filtered along a straight-line path and generally which direction they will travel. (2)

In this case $F_{mag} = q.vB < F_{electric}$. particles will curve down under greater influence of $F_{electric}$ ✓. sketch ✓

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