



KINGSWAY CHRISITAN COLLEGE

12 ATAR Physics 2016
End of Unit Test

The Standard Model

Name: _____

NOTE: Formula and constants sheet may be used.
All answers are to be accurate to three significant figures.
Marks will be given to correct working and diagram despite an incorrect final answer.
Conversely, working is required to demonstrate how a correct final answer was arrived at.

SECTION A	60	
SECTION B	20	
TOTAL	80	

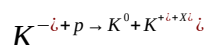
PART A – Short answer questions

Question 1 (8 marks)

The table below shows the 6 types of sub-nuclear particles known as quarks and lists their properties.

NAME	SYMBOL	Charge (Q)	Baryon Number (B)	Strangeness (S)	Charm (c)	Bottomness (b)	Topness (t)
<i>Up</i>	u	$\frac{+2}{3} e$	$\frac{1}{3}$	0	0	0	0
<i>Down</i>	d	$\frac{-1}{3} e$	$\frac{1}{3}$	0	0	0	0
<i>Strange</i>	s	$\frac{-1}{3} e$	$\frac{1}{3}$	-1	0	0	0
<i>Charmed</i>	c	$\frac{+2}{3} e$	$\frac{1}{3}$	0	+1	0	0
<i>Bottom</i>	b	$\frac{-1}{3} e$	$\frac{1}{3}$	0	0	-1	0
<i>Top</i>	t	$\frac{+2}{3} e$	$\frac{1}{3}$	0	0	0	+1

When a K^- meson collides with a proton, the following reaction can take place.



X is a particle whose quark structure is to be determined.

The quark structure of the mesons in the reaction is given below.

particle	quark structure
K^-	$\bar{u}s$
K^+	$u\bar{s}$
K^0	$d\bar{s}$

(a) Is the original K^- particle a hadron, a lepton or an exchange particle? Explain.

- (b) A proton has a charge of +1 and its s, c, b and t values are all zero. State the quark structure of a proton. (2 marks)

(1 mark)

- (c) State and explain whether X is a charged particle.

(2 marks)

- (d) Given that X has a baryon number of 1, deduce the quark structure of X. Show your reasoning.

(3 marks)

Question 2 (6 marks)

- (a) For the particles listed below, circle those that are composed of quarks.

Proton Electron Neutrino Neutron Photon Positron

(1 mark)

- (b) The existence of the neutrino was theorised by Pauli in 1930, but it was not until 1956 that they were detected. Explain, referring to two properties of the neutrino, why they were (and still are) so difficult to detect.

(2 marks)

- (c) Can electrons and neutrinos be subject to the strong force? Explain.

(2 marks)

- (d) If neutrinos are involved in a collision reaction, why is it unlikely that this was governed by the electromagnetic force?

(1 mark)

Question 3 (6 marks)

A positron-electron pair can be formed from a high energy gamma ray.

- (a) Use Einstein's energy-mass equivalence to calculate the minimum energy, in **electron-volts**, of a gamma ray that could result in the production of such a pair.

(3 marks)

- (b) If an electron collided with a positron, explain what would happen.

(3 marks)

Question 4 (2 marks)

State two general properties of leptons that distinguish them from the hadrons.

(2 marks)

Question 5 (4 marks)

Give the quark composition of the following hadrons:

(a) the sigma plus baryon (Σ^+), with $Q = +1$, $B = +1$, and $S = -1$ and $c = b = t = 0$

(b) the charmed Xi baryon (Ξ_c^0), with $Q = 0$, $B = +1$, $S = -1$, $c = +1$ and $b = t = 0$

(c) the D^+ meson, with $Q = +1$, $B = 0$, $c = +1$ and $S = b = t = 0$

(d) the strange B meson (B_s^0), with $Q = 0$, $B = 0$, $S = -1$, $b = +1$ and $c = t = 0$

Question 6 (4 marks)

Fill in the following table.

<i>Hadron</i>	<i>Charge (e)</i>	<i>Quark combination</i>
<i>A positively charged baryon</i>	<i>+2</i>	
<i>A neutral baryon</i>	<i>0</i>	
<i>A negatively charged meson</i>	<i>-1</i>	
<i>A positively charged meson</i>	<i>+1</i>	

Question 7 (4 marks)

Galaxy NGC 3351 is in the constellation of Leo. It is a distance of 11.7 megaparsecs from Earth. One parsec equals 3.26 light-years. A light-year is the distance travelled by light in one year. Calculate the distance to NGC 3351 in kilometres.

Question 8 (4 marks)

Electrons are fundamental particles that cannot be split. When high energy electrons are fired at individual protons or neutrons (nucleons), the electrons penetrate the nucleons in an inelastic collision, resulting in the electrons being scattered through a range of angles. This is evidence that a nucleon contains small dense regions of charge.

(a) Explain what is responsible for these regions of charge.

(1 mark)

- (b) State how many charge regions you would expect in a proton or a neutron.

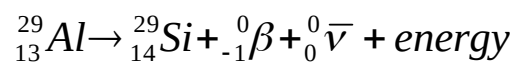
(1 mark)

- (c) Explain how a neutron can have separate regions of charge when the charge of a neutron is zero.

(2 marks)

Question 9 (5 marks)

Aluminium-29 decays to Silicon-29 by beta emission as described in the nuclear equation:



- (a) Identify the particle with the symbol ${}_0^0\bar{\nu}$

(1 mark)

- (b) Which force is involved in this decay reaction

(1 mark)

- (c) The beta particle is an electron that has come from the nucleus. Explain how the beta particle and the ${}^0_0\bar{\nu}$ particle appeared.

(3 marks)

Question 10 (3 marks)

The resolving power of any telescope defines whether an observer can clearly see two distant stars as two separate images. An angle of 10^{-5} radians between two clear images is considered to be the minimum acceptable. This angle is denoted by Φ in the equation

$$\Phi = \frac{\lambda}{D}$$

where λ is the wavelength of the radiation received and
 D is the diameter of the receiving dish or antenna

An optical telescope with a 10 m diameter dish can collect useful information in the optical range of wavelengths. The proposed Square Kilometre Array radio wave telescope, intended to detect electromagnetic radiation at a wavelength of 21 cm, needs to cover an area of hundreds of square kilometres. Explain this difference.

Question 11 (10 marks)

Determine which of the following reactions can occur. For those that cannot occur, determine the conservation law (or laws) violated and show evidence for your conclusion.

(a) $p \rightarrow \pi^0$

(b) $p + p \rightarrow p + p + \pi^0$

(c) $p + p \rightarrow p$

(d)

(e) $n + p \rightarrow e + \bar{\nu}_e$

(f) $\pi^0 \rightarrow n$

Question 12 (4 marks)

The Steady State Theory (also called The Infinite Universe Theory) was a model developed by the respected astronomer Fred Hoyle and others in 1948. It proposed that the universe had no beginning or end over infinite time. Fred Hoyle is reported to have used the phrase 'Big Bang' as a derogatory term when referring to an alternative theory that is nowadays the most widely accepted.

Describe two piece of observational evidence that support the Big Bang Theory.

(i)

(ii)

PART B – Comprehension

Question 13 Hubble's Law (20 marks)

When a source of waves is moving, a stationary observer notices a change in frequency of the waves. This effect is observed for both longitudinal and transverse waves. For example, if an ambulance moves towards you the sound frequency you hear is higher than the frequency its siren is emitting. This is known as the Doppler Effect.

If a source of electromagnetic waves, such as a star, is travelling away from an observer then the wavelengths of the lines in its electromagnetic spectrum are shifted to higher values. This is called red shift. An equation for the relationship is as follows:

$$z = \frac{\Delta\lambda}{\lambda}$$

It can also be shown that:

$$z = \frac{v}{c_0}$$

z = red shift
 $\Delta\lambda$ = change in wavelength (moving source) (nm)
 λ = wavelength of stationary source (nm)
 v = recessional speed of galaxy (m s^{-1})
 c_0 = speed of light in a vacuum (m s^{-1})

Edwin Hubble analysed the red shifts of various galaxies in 1920 and deduced that most galaxies are moving away from the Earth, this suggests that the Universe is expanding. Hubble also discovered that the further away a galaxy is, the bigger its red shift and the faster it is moving away. This relationship is known as Hubble's Law and can be stated algebraically as follows:

$$v_{\text{galaxy}} = H_0 \cdot d$$

v_{galaxy} = recessional speed of galaxy (km s^{-1})
 d = distance to galaxy (Mpc)
 H_0 = Hubble's constant ($\text{km s}^{-1} \text{Mpc}^{-1}$)

The distances to galaxies can be estimated by observing Cepheid Variables within a galaxy. A Cepheid Variable is a class of star that pulsates. The relationship between the period of pulsation and the size of the star is very precise. An understanding of how brightness diminishes with distance allows astronomers to estimate distances to galaxies with a high degree of confidence.

The following data was recorded by the Hubble Space Telescope for five galaxies.

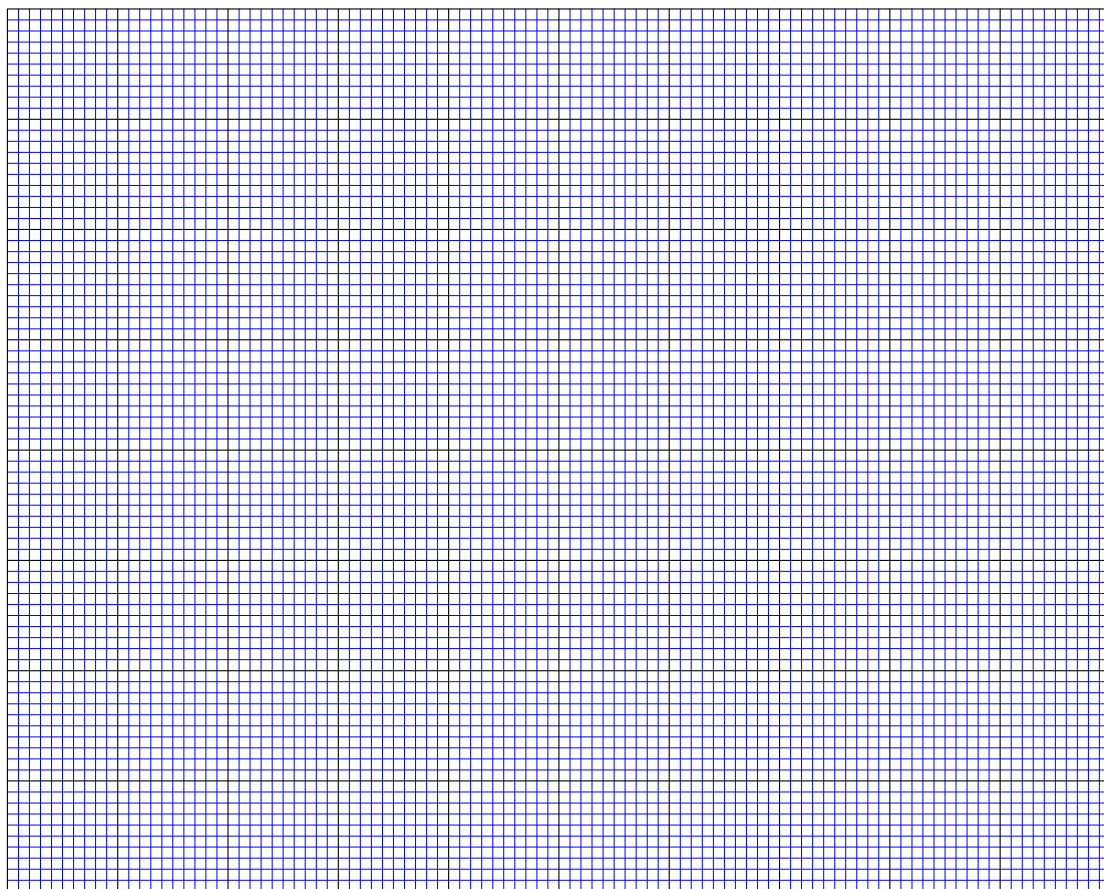
Distance (Mpc)	Red shift - z	Recessional speed of galaxy v_{galaxy} (km s^{-1})
3.1	0.00095	285
8.6	0.00212	
12.2	0.00273	
16.1	0.00402	
19.4	0.00473	

- (a) Calculate the appropriate values in the final column of the table (the first value has been done for you).

(2 marks)

- (b) Plot a correctly labelled graph of **recessional speed** versus **distance to galaxy** on the graph paper and draw a line of best fit.

(4 marks)



- (c) Calculate a value for Hubble's constant, in the correct units, showing how you obtained this value from your graph.

(3 marks)

- (d) State two reasons why you think that measurements of Hubble's constant have varied widely since Hubble's first determination in 1920.

(2 marks)

- (e) Why does the value of red shift z , have no units?

(1 mark)

- (f) A line in the spectrum of ionised calcium has a wavelength of 393.3 nm when measured in the laboratory. When similar light from the galaxy NGC 3350 is measured, its wavelength is 394.64 nm. Use the red shift formulae to determine the recessional speed of this galaxy.

(2 marks)

- (g) For the recessional speed you calculated (in part f), use your graph and the line of best fit to determine the distance to this galaxy in Mpc.

(1 mark)

- (h) Determine how many years it takes for light from galaxy NGC 3350 to reach Earth.
(1 parsec = 3.26 ly)

(2 marks)

- (i) Using your value for Hubble's constant (from part c), calculate the age of the universe (in years)

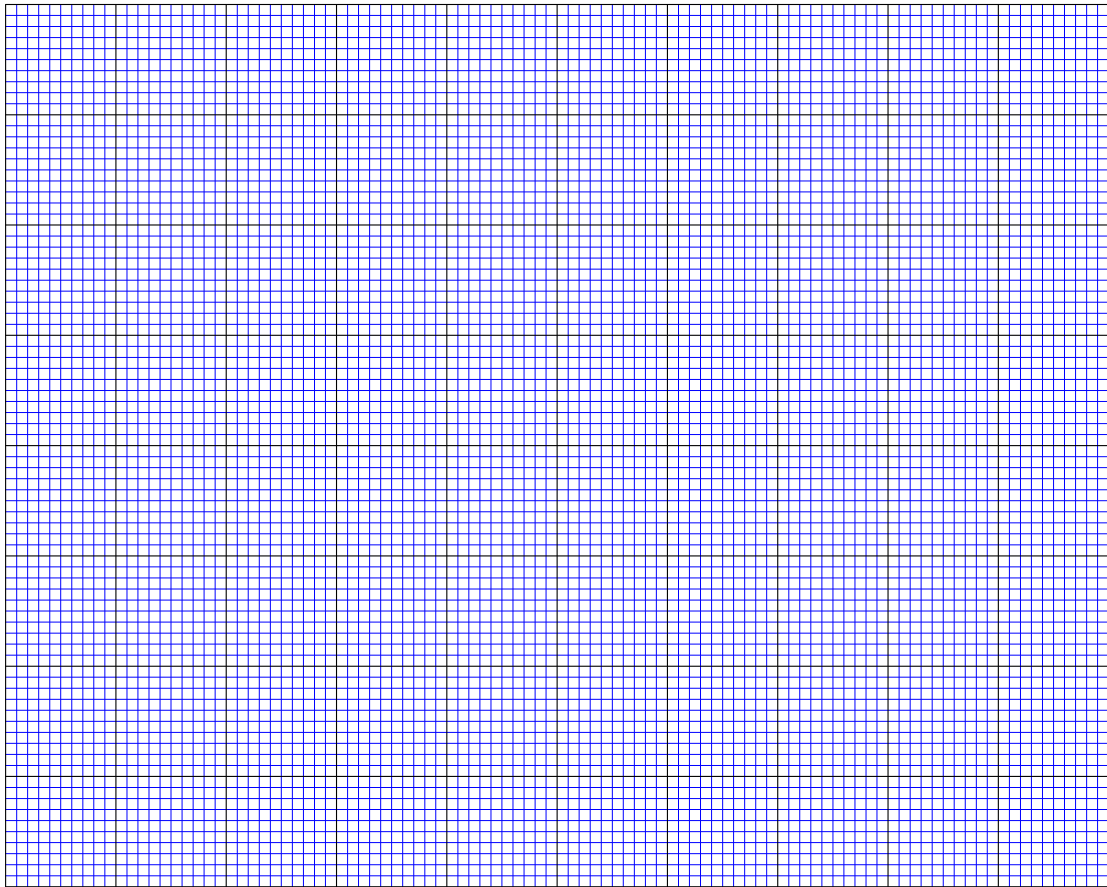
(3 marks)

End of Test

The LAST test!



Additional working space and spare graph paper



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Spare page (to continue calculation answers if required)