66.

CORPUS CHRISTI COLLEGE
SEQUERE DOMINUM

12 ATAR Physics

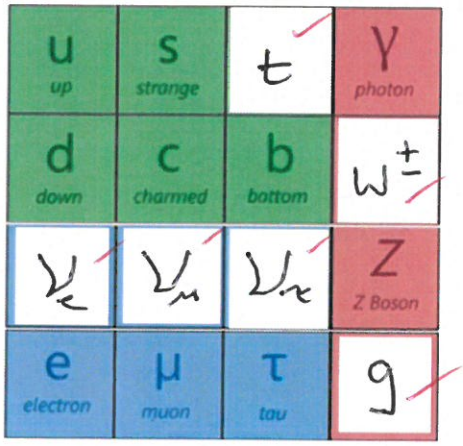
Particle Physics & Cosmology Test 2016 (5%)

Student name: Soln.

1. What name is given to the modern quantum mechanical theory that describes the interaction of all matter at the fundamental level? **[1 mark]**

THE STANDARD MODEL OF PARTICLE PHYSICS. (1)

2. Complete the table shown here, identifying the particles that are missing. **[3 marks]** (½ EA)



(3)

3. By referring to your knowledge of particle physics, explain what is meant by the term **'FERMION'**. **[4 marks]**

- ELEMENTARY PARTICLE OF MATTER ✓
- ½ INTEGER SPIN. ✓
- OBEY PAULI EXCLUSION PRINCIPLE ✓
- OBEY FERM-DIRAC STATISTICS. ✓

(4)

(8)

4. Identify two fermions that are different and describe how the properties of your chosen particles differ. **[2 marks]**

- e, μ, τ, ν_e, ν_μ, ν_τ (ANY TWO, ½ EA.).
- MASS, CHARGE. (½ EA)

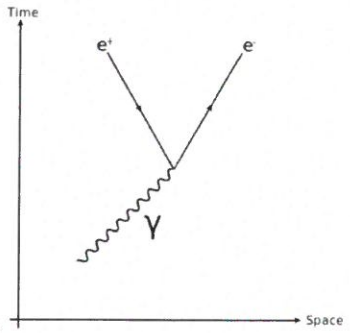
2

5. By referring to your knowledge of particle physics, explain what is meant by the term **'BOSON'**. **[4 marks]**

- ELEMENTARY FORCE CARRYING PARTICLE. ✓
- INTEGER SPIN. ✓
- DON'T OBEY PAULI EXCLUSION PRINCIPLE. ✓
- OBEY BOSE-EINSTEIN STATISTICS. ✓

4

6. Consider the Feynman diagram shown here.



a) Explain the process being described by this Feynman diagram. **[2 marks]**

A PHOTO IS DECAYING TO FORM AN ELECTRON AND POSITRON (MATTER/ANTIMATTER). ✓

2

b) If the matter/antimatter pair produced traveling with a velocity of 3.70×10^5 ms^{-1}, calculate the frequency of the original boson. **[4 marks]**

ENERGY OF ELECTRON $= \frac{1}{2}(9.11 \times 10^{-31})(3.7 \times 10^5)^2$ ✓

$= 6.24 \times 10^{-20}$ J. ✓

ENERGY OF PAIR $= (6.24 \times 10^{-20})(2)$ ✓

$= 1.25 \times 10^{-19}$ J.

4

$E = hf \therefore f = \frac{E}{h} = \frac{1.25 \times 10^{-19}}{6.63 \times 10^{-34}} = 1.88 \times 10^{14}$ Hz. ✓

12

7. Consider figure 1 and figure 2 shown below.

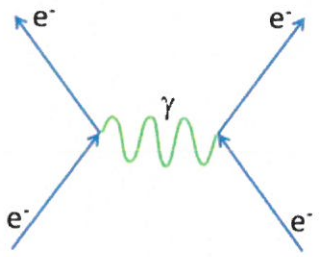


Figure 1

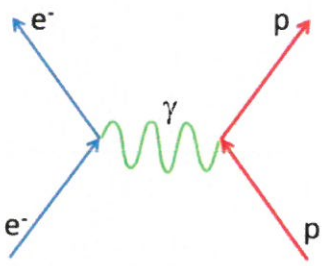


Figure 2

a) Name the fundamental force that is being represented in these diagrams. **[1 mark]**

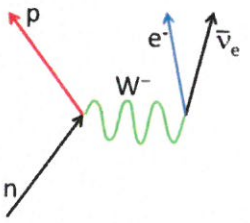
ELECTROMAGNETIC FORCE. ✓ (1)

b) Explain what process is being described by the Feynman diagrams shown as figure 1 and figure 2. **[2 marks]**

Figure 1 $(e^-)(e^-)$ REPULSION. ✓

Figure 2 $(e^-)(p^+)$ ATTRACTION. ✓ (2)

8. The Feynman diagram shown here represents a common nuclear physics process.



a) Name the process represented here. **[1 mark]**

BETA DECAY. ✓ (1)

b) Write the balanced equation to represent the process shown in the above Feynman diagram. **[2 marks]**

$n \rightarrow p^+ + e^- \bar{\nu}_e$ ✓✓ (2)

c) Name the fundamental force that is being represented in the above diagram. **[1 mark]**

WEAK FORCE ✓ (1)

(7)

9. The following table shows some of the properties of the six flavours of quarks.

Quark Flavour	Strangeness	Charm	Bottomness	Topness
Up	0	0	0	0
Down	0	0	0	0
Strange	-1	0	0	0
Charm	0	+1	0	0
Bottom	0	0	-1	0
Top	0	0	0	+1

a) Complete the table shown below for the particles given. **[4 marks]**

Particle	Constituent particles	Formula	Baryon or Meson	Charge	Baryon number
Antiproton	Anti-up, anti-up, anti-down	$\bar{u}\bar{u}\bar{d}$	B	-1	-1
Kaon-minus	Anti-up, strange	$\bar{u}s$	M	-1	0
D-plus-s	Charm, anti-strange	$c\bar{s}$	M	1	0
Upsilon	Bottom, anti-bottom	$b\bar{b}$	M	0.	0.

4

b) The four fundamental forces are:

A. Electromagnetic force
B. Weak nuclear force
C. Strong nuclear force
D. Gravitational force

i. Which of these forces mediate an interaction with the particles shown in the table of part (a)? **[1 mark]**

a. All of the forces shown
b. A, B & C only
c. B, C & D only
d. A, C & D only
e. A & C only

II ACCEPT. ✓

1

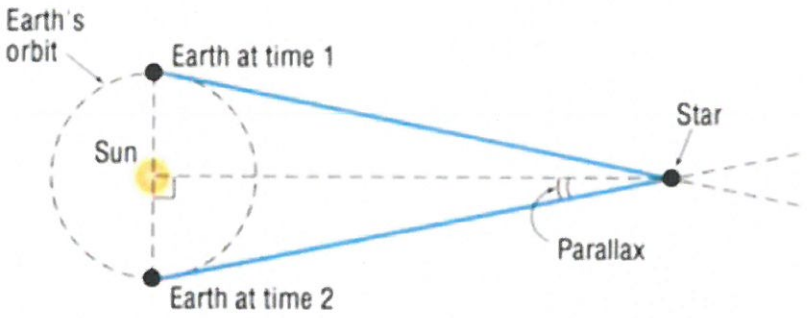
ii. Will **any** of the particles shown in the table above interact with the Higgs boson? Explain your answer. **[3 marks]**

YES. ✓ HIGGS GIVE PARTICLES MASS AND THESE PARTICLES HAVE MASS. ✓

3

8

10. The nearest star to the Sun (and thus the star with the largest parallax), is Proxima Centauri and has a parallax of 0.7687 arcsec.



Calculate the distance to Proxima Centauri:

c) In parsecs. **[2 marks]**

$$d(pc) = \frac{1}{ARCSEC} = \frac{1}{0.7687} = \underline{\underline{1.30\ pc.}}$$ (2)

d) In light years. **[2 marks]**

$$(1.30)(3.26) = \underline{\underline{4.24\ ly.}}$$ (2)

e) In meters. **[2 marks]**

$$(4.24)(9.47\times10^{15}) = \underline{\underline{4.01\times10^{-16}\ m.}}$$ (2)

11. State **two** pieces of evidence that support the Big Bang Theory and the expansion of the Universe. **[2 marks]**

- REDSHIFT.
- CMB.

(2)

(8)

12. Explain what is meant by the term, '*redshift*'. **[3 marks]**

DISPLACEMENT OF SPECTRAL LINES ✓
TOWARDS THE RED END OF THE EM ✓
SPECTRUM, DUE TO THE MOTION ✓
OF THE STELLAR OBJECT AWAY
FROM THE OBSERVER.

3

13. The spectral analysis given below shows the observed absorption spectra of hydrogen for the following cases: (i) not moving, (ii) moving away from you at 3,000 kms^{-1} and iii) moving away from you at 30,000 kms^{-1}.

i)

ii)

iii)

a) **Estimate** the redshift of object (ii) with respect to the stationary observer (i). Show **ALL** working. **[4 marks]**

EST (i) 650-660nm ✓
EST (ii) 660-670nm ✓

$z = \frac{\Delta\lambda}{\lambda} = \frac{664-656}{664}$ ✓

$\therefore z = 0.012$ ✓ NO UNITS.

4

b) Show that the recessional speed of object (ii) is around 3000 ms^{-1} with respect to observer (i). Show **ALL** working. **[3 marks]**

SHOULD BE kms^{-1}

$z = \frac{v}{c}$ $\therefore v = zc$ ✓

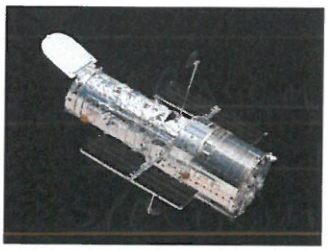
$= (0.012)(3 \times 10^8)$ ✓

$= 3600000$ ✓

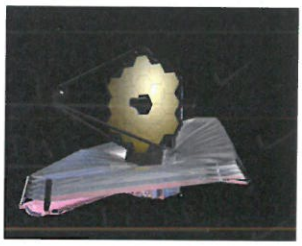
$= 3600\ kms^{-1}$.

3

10



14. The James Webb Space Telescope will replace the Hubble Space Telescope towards the end of this decade. It is due to be launched in 2018.



a) Explain why it is a big advantage to place modern telescopes into space. **[4marks]**

- WHEN DOING IR WORK: IR WOULD BE ABSORBED BY CO_2 IN THE ATMOSPHERE.

(OR)

- WHEN DOING MICROWAVE WORK: MICROWAVES WOULD BE ABSORBED BY H_2O IN THE ATMOSPHERE.

(OR)

- WHEN DOING UV WORK: UV RADIATION WOULD BE ABSORBED BY OZONE IN THE UPPER ATMOSPHERE

4

b) The Kilometre Square Array (KSA) will be one of the most advanced radio telescopes available to astrophysics and cosmology, when it comes on line in the next few years. Explain two advantages of using a radio telescope over other types of telescopes. **[2 marks]**

EITHER.

- RADIO TELESCOPES CAN BE USED DURING DAYLIGHT HOURS
- RADIO TELESCOPES ARE NOT AFFECTED BY WEATHER.
- RADIOWAVES ARE LESS AFFECTED BY GALACTIC DUST.

2

6

15. Hubble's law demonstrates the direct linear relationship between distance to inter-stellar objects and their recessional velocities.

a) Show, by algebraic manipulation, that Hubble's law can be used to determine the age of the Universe. **[3 marks]**

$V = H_0 d$ & $V = \frac{d}{t}$. ✓

So $H_0 d = \frac{d}{t}$ (d cancels). ✓

(3)

$\therefore \frac{1}{t} = H_0$.

or $t = \frac{1}{H_0}$. ✓

b) The most up-to-date and current best direct measurement of the Hubble constant is 73.8 km/sec/Mpc. Use this to calculate the age of the Universe in years. **[4 marks]**

$t = \frac{1}{H_0} = \frac{1}{\frac{73.8\ kms^{-1}}{Mpc}}$ ✓

(4)

$= \frac{1}{\frac{73800\ ms^{-1}}{(1\times10^6)(3.26)(60\times60\times24\times365.25)(3\times10^8)}}$ ✓

$= \frac{1}{\frac{73800\ ms^{-1}}{3.07\times10^{22}\ m}}$ $= \frac{1}{(2.39\times10^{-18}}\ s^{-1}$ ✓

$= 4.18\times10^{17}\ s$ ✓

$= \underline{13.3 \text{ billion yrs}}$. (7)