CORPUS CHRISTI COLLEGE
SEQUERE DOMINUM

12 ATAR Physics

Modern Physics Test 2017 (5%)

Student name: _____

1. A spacecraft moving at 95% of the speed of light passes the Earth on a journey to the star Lalande-21185 a distance of 8.29 light years.

In the frame of reference of the spacecraft (experienced by the crew) what time and spatial measurements of the journey are different compared to those measured by an Earth based observer? Which statements is correct? **[1 marks]**

a) Length contraction states, '*the path length through space is longer than 8.29 light years*'.
✓ b) Length contraction states, '*the path length through space is shorter than 8.29 light years*'.
c) Time dilation states, '*the clock on earth is moving slower*'.
d) Time dilation states, '*the clock on the spacecraft is moving slower*'.

(1)

In the frame of reference of the Earth what time and spatial measurements of the journey are different compared to those measured by an observer on the spacecraft? Which **TWO** statements are correct? **[2 marks]**

a) Length contraction states, '*the path length through space is shorter than 8.29 light years*'.
✓ b) Length contraction states, '*the path length through space will be 8.29 light years*'.
c) Time dilation states, '*the clock on earth is moving slower*'.
✓ d) Time dilation states, '*the clock on the spacecraft is moving slower*'.

(2)

2. Explain what is meant by the term, '*inertial reference frame*'. **[1 mark]**

STUDENTS STATE :

- IT IS NOT ACCELERATING (OK)
- NEWTON'S LAWS ARE OBEYED. ✓

(1)

(4)

3. Explain what is meant by the term, '*luminiferous aether*' and what experiment lead to its demise? **[2 marks]**

STUDENTS STATE:

(1) THE PREVIOUSLY (CLASSICALLY) ACCEPTED MEDIUM FOR EM RADIATION. ✓

(2) PROVEN NOT TO EXIST BY THE M & M EXPERIMENT. ✓

2

4. State the two postulates of Special Relativity that Einstein used to reject the necessity for the luminiferous aether. **[2 marks]**

(1) NO LAW OF PHYSICS CAN IDENTIFY A STATE IN ABSOLUTE REST. ✓

(2) THE SPEED OF LIGHT WILL ALWAYS BE THE SAME NO MATTER HOW THE LIGHT SOURCE OR OBSERVERS ARE MOVING. ✓

2

5. A student is on a spaceship traveling at 0.5c away from a star, at what speed would the starlight pass the student? Explain your answer. **[3 marks]**

STUDENTS STATE:

(1) WILL ALWAYS PASS AT $3 \times 10^8 ms^{-1}$ (c) ✓

(2) SPEED OF LIGHT IS CONST IN ANY REF FRAME. ✓

(3) ACCORDING TO THE 2nd POSTULATE OF SPECIAL RELATIVITY. ✓

3

7

6. The proposed new Sydney to Perth bullet train that travels at a speed of 0.482**c**. A passenger on the bullet train drops a shiny stainless-steel ball bearing from a height of 1.36m.

a) What would be the time measured by the passenger for the ball bearing to fall to the floor? **[2 marks]**

$$s = ut + \tfrac{1}{2}gt^2 \quad (u=0)$$

$$\therefore\ t^2 = \frac{2s}{g} = \frac{2(1.36)}{9.8} = 0.28$$ ✓

$$\therefore\ t = 0.53 \text{ secs}$$ ✓

2

b) As the train passes through a level crossing, a stationary observer notices the ball bearing fall to the floor of the train. What would be the time measured by the stationary observer for the ball bearing to fall to the floor? **[5 marks]**

$$0.482c = (0.482)(3\times10^8)$$ ✓
$$= 1.446\times10^8 \text{ ms}^{-1}$$

$$\gamma = \frac{1}{\sqrt{1-v^2/c^2}} = \frac{1}{\sqrt{1-\frac{(1.446\times10^8)^2}{(3\times10^8)^2}}}$$ ✓

$$\therefore\ \gamma = 1.14$$ ✓

$$\therefore\ t = (0.53)(1.14) = 0.60 \text{ secs}$$ ✓ ✓

5

7

7. One of the biggest accelerators in the world is at CERN in Geneva, the site of the Large Electron-Positron (LEP) collider. It is 27 km long and accelerates the electrons (and positrons) to enormous energies in the 50 GeV in energy range.

a) Calculate the '*rest-mass*' energy of a positron. Give your answer in MeV. **[2 marks]**

$E = mc^2 = (9.11 \times 10^{-31})(3 \times 10^8)^2$

$= 8.199 \times 10^{-14}$ J. ✓

$= \underline{0.512 \text{ MeV}}$. ✓

(2)

b) Calculate the relativistic mass of an electron traveling along the particle accelerator with a speed of 0.99**c** **[4 marks]**

$0.99c = (0.99)(3 \times 10^8) = 2.97 \times 10^8 \text{ ms}^{-1}$ ✓

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - \frac{(2.79 \times 10^8)^2}{(3 \times 10^8)^2}}}$$ ✓

(4)

$\therefore \gamma = 7.09$

SINCE $m = \gamma m'$ $= (7.09)(9.11 \times 10^{-31})$ ✓

$= \underline{6.46 \times 10^{-30} \text{ Kg}}$ ✓

(6)

c) What is the relativistic energy of an electron traveling along the particle accelerator with a speed of 0.99**c**? **[4 marks]**

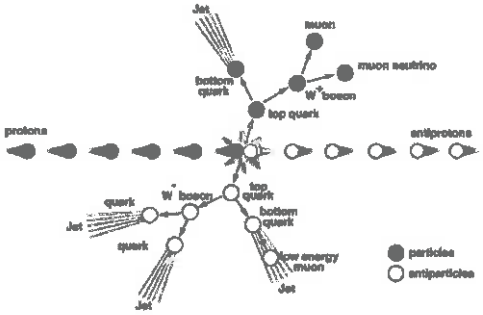
$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}} = \frac{(9.11 \times 10^{-31})(3 \times 10^8)^2}{\sqrt{1 - \frac{(2.79 \times 10^8)^2}{(3 \times 10^8)^2}}}$$

$$= \frac{8.199 \times 10^{-14}}{0.8649}$$

$$\therefore E = 9.48 \times 10^{-14} \text{ J}$$

(4)

8. A stationary observer, monitoring the LHC elementary particle beams from the side, noticed that the protons move with velocity of 0.8**c**, while the antiprotons move with a velocity of 0.60**c** in the opposite direction. What is the velocity of the particles, relative to each other? **[4 marks]**



$$u' = \frac{V - u}{1 - \frac{Vu}{c^2}} \qquad V = 0.8c \qquad u = -0.6c$$

(4)

$$\therefore u' = \frac{(0.8c) - (-0.6c)}{1 - \frac{(0.8c) - (0.6c)}{c^2}} = \frac{(0.8c) + (0.6c)}{1 + 0.48}$$

$$\therefore u' = \frac{1.4c}{1.48} = 0.95c$$

(8)

9. The Hubble space telescope (HST), was the first space based telescope used for serious scientific research. The HST can collect data using both the IR and microwave regions of the EM spectrum. Explain why it is necessary to place such a telescope into space. **[5 marks]**

STUDENTS STATE:

- THE CO_2 IN THE ATMOSPHERE ABSORBS IR THROUGH RESONANCE. ✓
- THE H_2O IN THE ATMOSPHERE ABSORBS MICROWAVES THROUGH RESONANCE. ✓
- VERY LITTLE IR OR MICROWAVE EM WOULD REACH THE SURFACE. ✓

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10. One of the most intense sources known to radio astronomers is the Galaxy NGC5128. Long exposure photographs show it to be a giant elliptical galaxy crossed by a band of dark. It lies about 1.50×10^7 lightyears away from earth. Using a value of the Hubble constant of 73 $kms^{-1}Mpc^{-1}$, calculate the recessional velocity of NGC5128. (*Note: 1lyr = 3.26pc*) **[4 marks]**

$V = H_o d$ ✓

$V = (73)\left(\frac{1.5 \times 10^7}{3.26 \times 10^6}\right)$ ✓

$= 336$ ✓ kms^{-1} ✓

4

9

11. The K-line of light from singly ionised calcium has a wavelength of 393.3nm when measured in a laboratory. The same line in the spectrum of galaxy NGC 4889 has a wavelength of 401.8nm. Calculate the recessional velocity of NGC4889. **[4 marks]**

$z = \frac{\Delta\lambda}{\lambda}$ It can also be shown that: $z = \frac{v}{c_0}$

(4)

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

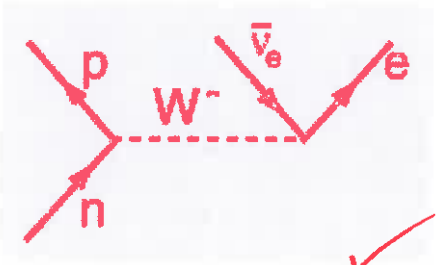
$$\therefore \quad v = \frac{\Delta\lambda}{\lambda} c = \frac{(401.8 - 393.3)}{393.3} \times (3 \times 10^8).$$

$$= 6483600 \text{ ms}^{-1}$$

$$\therefore \quad \underline{v = 6,484 \text{ Kms}^{-1}}$$

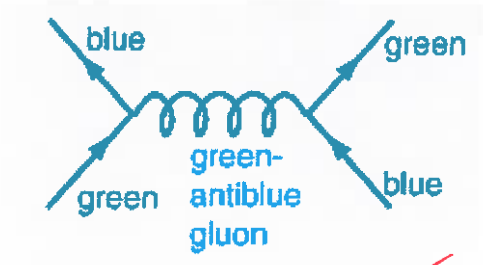
12. Consider the Feynman diagrams shown below. Identify the fundamental force begin described in each diagram. Write your answer in the space provided below the diagram. **[4 marks]**

a) ELECTROMAGNETIC

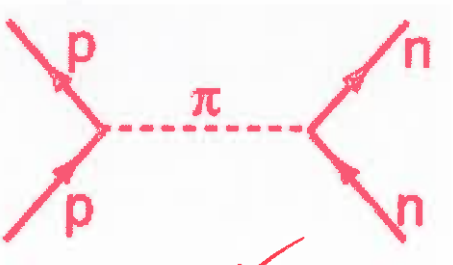


b) WEAK FORCE

(4)



c) STRONG FORCE



d) STRONG FORCE

(8)

13. Determine which of the following reactions are forbidden. Explain your answer.

a) $p^+ + p^- \rightarrow \mu^+ + e^-$ **[2 marks]**

Charge:	(1) +(-1) → (1) + (-1)
Baryon number:	(-1) +(1) → (0) + (0)
Lepton number:	(0) +(0) → (-1) + (1)

Not forbidden since all conserved

b) $p^+ + p^+ \rightarrow p^+ + \pi^+$ **[2 marks]**

Charge:	(1) +(1) → (1) + (1)
Baryon number:	(1) +(1) → (1) + (0)
Lepton number:	(0) +(0) → (0) + (0)

Forbidden since baryon number is **not** conserved

c) $\pi^- + p^+ \rightarrow p^+ + \pi^+$ **[2 marks]**

Charge:	(-1) +(1) → (1) + (1)
Baryon number:	(0) +(1) → (1) + (0)
Lepton number:	(-1) +(0) → (0) + (1)

Forbidden since charge and lepton number is **not** conserved

End of questions