



CORPUS CHRISTI COLLEGE
SEQUERE DOMINUM

12 ATAR Physics

Modern Physics Test 2018 (5%)

Student name: _____

Additional formulae and data

$$z = \frac{\lambda_o - \lambda_e}{\lambda_e} = \frac{v}{c}$$

Where: z is the redshift of the receding galaxy
 λ_o is the wavelength of the receding galaxy
 λ_e is the wavelength measured at rest
 v is the recessional velocity of the receding galaxy

Hubble's Law

$$v = H_0 d$$

v = recession velocity in km/sec

d = distance in Mpc

H_0 = expansion rate today (*Hubble Parameter*)

Unit	Abbreviation	Conversion
Astronomical Unit	AU	1 AU = 1.5×10^{11} m
Light Year	lyr	1 ly = 9.46×10^{15} m
Parsec	pc	1 pc = 3.08×10^{16} m
		1 pc = 3.26 ly or 1 pc = 206265 AU

1. The reaction $\mu^- \rightarrow e^- + \nu_e + \nu_\mu$ conserves [1 mark]
- a) muon lepton number but not electron lepton number.
 - b) electron lepton number but not muon lepton number.
 - c) neither muon lepton nor electron lepton number.
 - d) both muon and electron lepton numbers.
 - e) None of these is correct.
2. A conservation law that is not universal but applies only to certain kinds of interactions is conservation of [1 mark]
- a) lepton number
 - b) baryon number
 - c) spin
 - d) charge
 - e) strangeness
3. In quantum electrodynamics (QED), electromagnetic forces are mediated by [1 mark]
- a) the interaction of electrons.
 - b) hadrons.
 - c) action at a distance.
 - d) the weak nuclear interaction.
 - e) the exchange of virtual photons.
4. The cosmic microwave background radiation is [1 mark]
- a) radiation from the quasars that is redshifted.
 - b) produced from processes going on all over the present universe.
 - c) radiation from the Sun.
 - d) radiation from the Big Bang that was around when electrons and protons combined to form neutral hydrogen atoms.
 - e) radiation produced from electron-positron annihilation in the intergalactic regions.
5. The conservation law violated by the reaction $p \rightarrow \pi^0 + e^+$ is the conservation of [1 mark]
- a) charge.
 - b) energy.
 - c) linear momentum.
 - d) lepton number and baryon number.
 - e) angular momentum.

6. An emission line is seen in the spectrum of galaxy A at a wavelength of 459nm. Analysis of this emission line shows that it has a rest wavelength of 450nm.

a) Calculate the redshift of this galaxy.

[2 marks]

$$z = \frac{\lambda_o - \lambda_e}{\lambda_e} = \frac{459 - 450}{450}$$

$$\therefore \underline{z = 0.02.} \quad \text{No units.}$$

b) Calculate the recessional velocity, in kms^{-1} , of galaxy A.

[3 marks]

$$z = \frac{v}{c} \quad \therefore v = (z)(c) \\ = (0.02)(3 \times 10^8) \\ = \underline{6000 \text{ kms}^{-1}}$$

c) Given that Hubble's constant (H_0) has a value of $72 \text{ kms}^{-1} \text{ Mpc}^{-1}$, calculate the distance, in lightyears, to galaxy A.

[4 marks]

$$v = H_0 d \quad \therefore d = \frac{v}{H_0} = \frac{6000 \text{ kms}^{-1}}{72 \text{ kms}^{-1} \text{ Mpc}^{-1}}$$

$$\therefore d = 83.3 \text{ Mpc.}$$

$$\therefore d = (83.3 \times 10^6)(3.26) \\ = \underline{2.72 \times 10^8 \text{ Lyrs.}}$$

7. A spacecraft of rest mass 90.0 tonnes is moving away from the Earth at a constant speed.

- a) The crew of the spacecraft determine that it takes them 1.10 years to reach the star Alpha Centauri. Observers on Earth state that it took the spacecraft 4.50 years to complete the journey. Determine the speed of the spacecraft in the reference frame of Earth. [3 marks]

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \therefore 4.50 = \frac{1.10}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{So } \sqrt{1 - \frac{v^2}{c^2}} = \frac{1.10}{4.50}$$

$$1 - \frac{v^2}{c^2} = \frac{1.10^2}{4.50^2} \quad \therefore v^2 = 0.940 c^2 \quad \text{or } v = 2.91 \times 10^8 \text{ ms}^{-1}$$

- b) The crew of the spacecraft argue that time recorded on their clocks was correct, but they could reach Alpha Centauri in a time of 1.10 years for a different reason. How is the journey time explained in the reference frame of the spacecraft? Explain with reference to physics principles, no calculation is required. [2 marks]

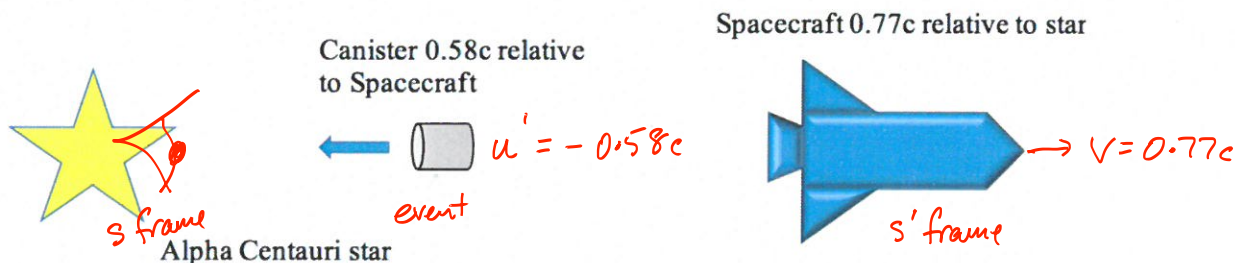
ACCORDING TO EINSTEIN'S SPECIAL THEORY OF RELATIVITY THE DISTANCE TRAVELLED WILL REDUCE DUE TO LENGTH CONTRACTION.

- c) As the spacecraft goes past Alpha Centauri it changes its speed to a new constant value of 0.77c in the reference frame of Alpha Centauri. Calculate the relativistic momentum of the spacecraft at this speed. [3 marks]

$$p_v = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{(90000)(0.77)(3 \times 10^8)}{\sqrt{1 - \frac{(0.77c)^2}{c^2}}}$$

$$\therefore p_v = 3.26 \times 10^{13} \text{ Kgms}^{-1}$$

As the spacecraft is moving away from Alpha Centauri at a speed of $0.77c$ it fires a mail canister back towards Alpha Centauri. The canister moves at a speed of $0.58c$ relative to the spacecraft.



- d) Determine the speed and direction of the canister in the frame of reference of Alpha Centauri. [3 marks]

$$u = \frac{V + u'}{1 + \frac{Vu'}{c^2}} = \frac{0.77c - 0.58c}{1 + \frac{(0.77c)(-0.58c)}{c^2}}$$

$$\therefore u = \frac{0.19c}{0.5534} = 0.343c \quad \text{AWAY FM ALPHA CENTAURI.}$$

- e) As the mail canister moves back towards Alpha Centauri it directs a laser beam towards the star. What is the speed of the laser beam in the reference frame of Alpha Centauri? Explain briefly. [2 marks]

SPEED = $3 \times 10^8 \text{ ms}^{-1}$. THE SPEED OF LIGHT IS THE SAME (c) NO MATTER THE MOTION OF THE OBSERVER.

8. An alien space ship is travelling at $0.650c$ relative to the Earth. It sends a signal to the Earth's inhabitants by flashing a light every 0.270 seconds in the ship's frame of reference. Calculate the time between each flash of light from the Earth's frame of reference. [3 marks]

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\therefore t = \frac{0.27}{\sqrt{1 - \frac{(0.65c)^2}{c^2}}}$$

$$\therefore \underline{t = 0.355 \text{ s.}}$$

9. Figure 3 below represents the decay of a particle X into a particle Y and two other particles. The quark structure of particles X and Y are shown in the diagram.

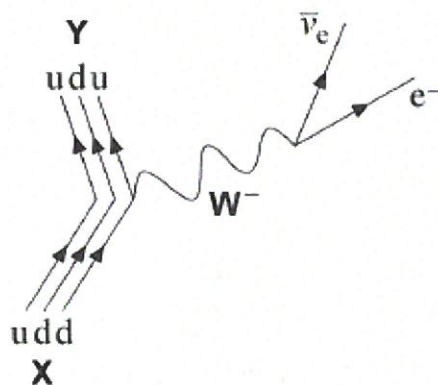


Figure 3

- a) Deduce the name of particle X.

[1 mark]

Neutron

- b) State the type of interaction that occurs in this decay. [1 mark]

Weak nuclear force (since there is a change in quark OR it involves beta decay)

- c) State the class of particles to which the W^- belongs. [1 mark]

(gauge) bosons

- d) Show clearly how charge and baryon number are conserved in this interaction. You should include reference to all the particles, including the quarks, in your answer. [2 marks]

$$\begin{array}{l}
 udd \rightarrow uud + e^- + \bar{\nu}_e \\
 Q \quad \left(+\frac{2}{3} + (-\frac{1}{3}) + (-\frac{1}{3})\right) \rightarrow \left(+\frac{2}{3} + (-\frac{1}{3}) + (+\frac{2}{3})\right) + (-1) + 0 \\
 \quad 0 \rightarrow 1e + -1e + 0 \quad \therefore 0=0 \checkmark \\
 B \quad \left(\frac{1}{3} + \frac{1}{3} + \frac{1}{3}\right) \rightarrow \left(\frac{1}{3} + \frac{1}{3} + \frac{1}{3}\right) + 0 + 0 \\
 \quad 1 \rightarrow 1 + 0 + 0 \quad \therefore 1=1 \checkmark
 \end{array}$$

- e) State the quark constituents of \bar{Y} . [1 mark]

$$\bar{Y} = (\bar{u} \bar{d} \bar{u})$$

- f) Name the only stable baryon. [1 mark]

proton

- g) A muon is an unstable particle. The incomplete decay equation is shown below.

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

- State the name of the missing particle. [1 mark]

$$\begin{array}{l}
 L_\mu \quad (+1) \rightarrow (+1) + 0 + ? \quad 1=1 \therefore \text{not } \mu. \\
 L_e \quad 0 \rightarrow 0 + (+1) + ? \\
 \therefore \text{particle must be} \\
 \quad \text{electron antineutrino}
 \end{array}$$

10. State what is meant by the term luminiferous aether and why it was important to classical physics. [2 marks]

FM PEARSON • THE AETHER WAS THOUGHT TO BE
TEXT BOOK. A MASSLESS, RIGID MEDIUM THAT
CARRIED ELECTRIC AND MAGNETIC FIELDS.
• IT WAS SUPPOSED TO BE THE MEDIUM
FOR LIGHT TO TRAVEL ON.

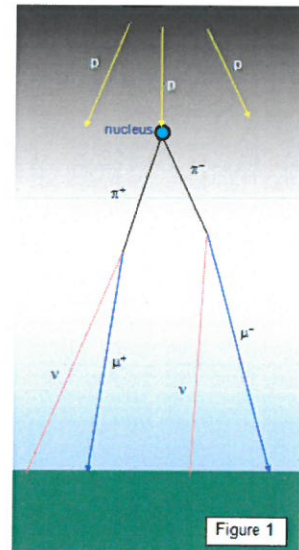
11. Explain why the concept of the aether lost favour in physics and what theory replaced it. [4 marks]

STUDENTS
MUST
MENTION.
• THE MICHELSON - MORLEY EXP. PROVED
THE AETHER DID NOT EXIST.
• EINSTEIN'S SPECIAL RELATIVITY
• EINSTEIN'S TWO POSTULATES ✓
(i) THE LAWS OF PHYSICS ARE THE SAME
IN ALL INERTIAL FRAMES OF REFERENCE.
(ii) THE SPEED OF LIGHT IS CONST FOR
AN OBSERVERS REGARDLESS OF THEIR
MOTION OR MOTION OF THE SOURCE.

12. Explain what is meant by the term, 'inertial reference frame'. [2 marks]

• A REFERENCE FRAME MOVING AT
CONST VELOCITY, NOT ACCEL.
• THE LAW OF INERTIA APPLIES
WITHIN THEM.

13. High-energy cosmic ray protons entering the upper atmosphere interact with the nuclei of oxygen and nitrogen atoms to give a group of particles known as pions. These pions then decay into muons that then move off at a speed of up to $0.994c$. These muons are formed at a height of between ten and fifteen thousand metres above the ground. Explain the significance of muons for Einstein's Special Theory of Relativity. [3 marks]



- THIS PROVED EINSTEIN'S SPECIAL THEORY OF RELATIVITY FROM THE POINT OF VIEW OF TIME DILATION.
- MUONS SEEM TO DECAY MORE SLOWLY WHEN TRAVELLING CLOSE TO THE SPEED OF LIGHT "C".

End of questions

