Applecross Senior High School
Year 12 Physics
Modern Physics Problem Sets Validation Test

/25

Name: ______________________

Useful Data : Kiloparsec, 1 kpc = 3262 light-years = 3.086 x 10^{16} km

$v_{galaxy} = H_0 d$ and $v_{galaxy} = \frac{\Delta\lambda}{\lambda}$

Hubble Constant = 70 km s^{-1} Mpc^{-1}

1. Alpha Centauri is a star 4.367 light years from Earth. A time traveller taking this journey at near light speed in a starship was confused by the fact that the journey took less than four years on the starship clock. How would you explain this to the traveller? How would this be viewed by an observer on Earth? (2 marks)

+ To the traveller, the distance has dilated and appears less than 4.367 ly. ✓

+ To an observer on Earth, the traveler's clock is running slow, so he's not surprised the traveler measures the trip as shorter. ✓

2. You are the pilot on a spaceship looking for a safe runway on which to land. You see one on a planet you are passing at a speed of 0.75c and measure it to be 1.90 km long and 700 m wide. What are the actual dimensions of this landing strip as measured from the ground? (2 marks)

$$\gamma = \frac{1}{\sqrt{1-\frac{0.75^2 \cancel{c^2}}{\cancel{c^2}}}} = 1.5119$$

$$L = \frac{L_0}{\gamma} \Rightarrow L_0 = \gamma L = 1.5119 \times 1.9$$

✓ $= 2.87$ km long) $\frac{1}{2}$

(& 700 m wide) $\frac{1}{2}$

3. Two spacecraft leave Earth travelling in opposite directions, one travelling at 0.85c and the other at 0.90c. Calculate the relative velocity of the slower craft as seen by the faster one. (2 marks)

$u = 0.85\,c$ $\quad$ $v = -0.9\,c$

$$u' = \frac{u-v}{1-\frac{vu}{c^2}} = \frac{0.85c-(-0.9c)}{1-\frac{0.85\cancel{c}\cdot -0.9\cancel{c}}{\cancel{c^2}}} = \frac{1.75}{1.765}$$

$$= 0.992\,c$$

4. Fill in the missing baryons or leptons in each of the following equations. Assume that charge, baryon number and lepton number are all conserved, and that the mass of the reactants cannot be less than the mass of the products. (4 marks)

a) $n \rightarrow p + e^- + \underline{\bar{\nu}_e}$

b) $\underline{\nu_e} + n \rightarrow \underline{p} + e^-$

c) $\pi^+ \rightarrow \mu^+ + \underline{\bar{\nu}_\mu}$

d) $p \rightarrow n + \nu_e + \underline{e^+}$

5. For each of these quark combinations, give the resulting particle's charge, strangeness and baryon number and all possible spins. (4 marks)

	Q	S	B	Spin
a) $\overline{dds}$	+1e	+1	−1	
b) bbt	0	0	1	
c) uus	+1e	−1	1	
d) $\overline{uus}$	−1e	1	−1	

✓ ✓ ✓ ✓

6. An atomic nucleus decays emitting an alpha particle with a kinetic energy of 4.7 MeV. What is the mass equivalent of this energy? (2 marks)

$E = mc^2 = 4.7 \times 1.6 \times 10^{-13}$ J

$\Rightarrow m = \dfrac{4.7 \times 1.6 \times 10^{-13}}{9 \times 10^{16}}$ ✓

$= 8.36 \times 10^{-30}$ kg ✓

7. A proton in the LHC, circumference of 27 km was accelerated to 0.999997c.
   a) Calculate its apparent mass at this speed. (2 marks)

$$m = \gamma m_0 = \frac{1}{\sqrt{1 - \frac{0.999997^2 c^2}{c^2}}} \times 1.67\times10^{-27}$$ ✓

$$= 6.82\times10^{-25}\ \text{kg}$$

   b) How long would the path in the LHC appear to the particle? (1 marks)

$$L = \frac{L_0}{\gamma} = \frac{27}{408.249} = 0.0661\ \text{km}$$

8. The 'Coma Cluster' of galaxies is about 90 Mpc from the Earth. At what speed are they receding from us? Is this a significant fraction of the speed of light? ($c = 3 \times 10^8\ ms^{-1}$) (2 marks)

$$v = Hd = 70\ \frac{\text{km s}^{-1}}{\cancel{\text{Mpc}}} \times 90\ \cancel{\text{Mpc}}$$

$$= 6300\ \text{km s}^{-1}$$ ✓

$$= 2.10\%\ c\ (0.021c)$$ So yes, significant ✓

9. Why do astronomers look at very distant objects in the Universe? Are the distant objects different from those closer to us? (2 marks)

Distant objects offer insight into the early universe (½) because their light has taken so long to reach us (½)

Yes, they are different. Galaxies look different & quasars exist in the early universe ✓

10. Hubble's original value for the constant in his law was 500 km s^{-1} Mpc^{-1}. What would this have suggested about the age of the Universe? Do you see a problem with this age? (2 marks)

Since $t = \frac{1}{H}$, this suggested a very young universe (specifically $t = 500\ \frac{\cancel{\text{km}}\ s^{-1}}{\cancel{\text{Mpc}}} \times \frac{1}{3.086\times10^{19}}\ \cancel{\text{Mpc/km}}$

$$= 1.620\times10^{-17}\ s^{-1}$$

So $\frac{1}{H} = 6.172\times10^{16}\ s = 1.96\times10^{9}$ years. PROBLEM: THIS is younger