Year 12 Physics – Stage 3
PWQ – SAPs, Relativity, Astrophysics
August 2013

Time allowed: 50 minutes
Total marks available: 50
Use appropriate significant figures for accuracy

Student Name: Solutions

1. Give two examples of names of subatomic particles for each of the following types of particles (do NOT state Baryon, Meson or Quark as part of your response).

(2)

Lepton:

Boson:

Hadron:

2. What is the difference between a Baryon and a Meson?

(1)

3. There are six flavours of quark (normal matter versions). These are detailed in the table.

Quark	Charge
Up (u)	$+\frac{2}{3}e$
Down (d)	$-\frac{1}{3}e$
Charmed (c)	$+\frac{2}{3}e$
Strange (s)	$-\frac{1}{3}e$
Top (t)	$+\frac{2}{3}e$
Bottom (b)	$-\frac{1}{3}e$

a. Determine the charge of the following particles that are made from quarks:

Lambda-Plus (udc)

B-minus (bū)

(2)

b. Explain briefly why quarks of like charge are not repelled from each other in a Hadron.

(1)

4. Quarks exchange gluons via Colour Charge in the model of quantum chromo dynamics. This leads to the residual strong nuclear force between nucleons. If a meson has one quark with a colour charge of ‘Blue’ then explain the other colour charge/s within that meson.

(2)

5. Strontium-90 undergoes **beta negative decay**.

a. Write a balanced nuclear equation to show this. You must identify the type of leptons formed as part of this decay.

(2)

b. Explain, with reference to Protons and Neutrons within the nucleus, how a beta particle is formed and emitted from the nucleus in this decay process. You must refer to the quarks that make up the hadrons involved.

(2)

c. Explain why a neutrino is difficult to detect.

6. An initial estimate for the rest mass of a Higgs Boson (H^0) is 125.3 GeV/c^2

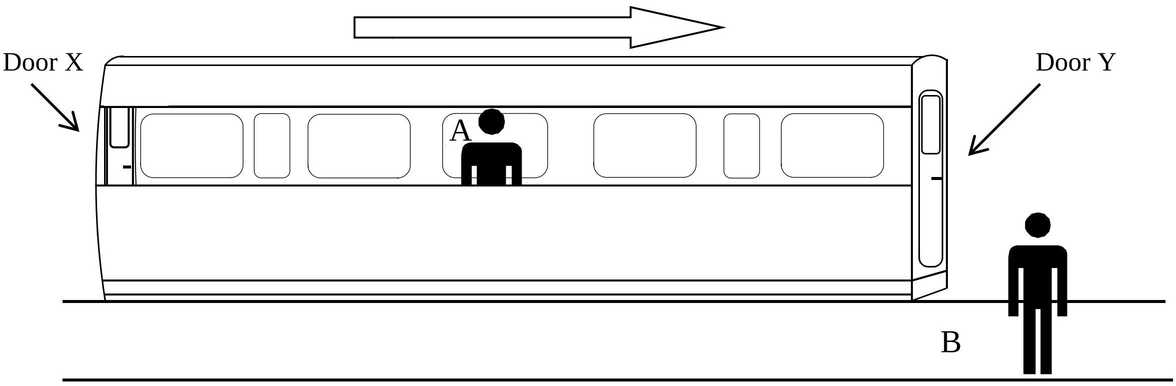
a) Calculate the mass of the Higgs Boson (H^0) in kg.

(2)

b) If the mass of the Higgs Boson (H^0) is converted to energy, calculate the energy in joules. (If you could not solve part a) use a mass of 2.23×10^{-25} kg)

(2)

Train moving at very high velocity



7. An observer at position A at the midpoint of a train carriage presses once on an infrared remote control that sends a signal to both the front and back of the carriage to open doors at each end. Another observer at position B stands on the platform and watches the train move past him at high velocity.

a) Does observer A see the doors in the carriage open simultaneously, or at different times?

(1)

b) Does observer B see the doors in the carriage open simultaneously or at different times?

(1)

c) If the observations are different, whose observation is correct? Explain your reasoning from the frame of reference of both A and B.

(2)

8. A spaceship is racing back towards a space station at a speed of 1.00×10^8 m s^{-1}. The space station sends out a laser light signal directly at the spaceship. What is the speed of the laser beam in the frame of reference of the spaceship? Explain

(2)

9. Science fiction writers often imagine space travellers being able to reach distant galaxies by travelling at speeds greater than the speed of light. Explain why this is impossible based on evidence that is currently available to mankind.

(2)

10. Two identical atomic clocks of extreme accuracy are synchronized on Earth. One of the clocks is put onto a spacecraft that moves at a constant speed of 0.85c relative to Earth. The spacecraft makes a journey to Barnard's Star a distance of 5.96 light years from Earth.

(a) Explain how time appears to be progressing on Earth from the frame of reference of the spacecraft.

(1)

(b) Explain the 'paradox' in this situation.

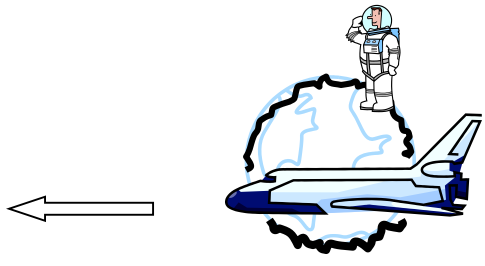
(1)

(c) At this speed what spatial dimension is contracting in the frame of reference of the spacecraft?

(1)

(d) As the spacecraft passes a stationery asteroid, a miner on the asteroid remarks that the spacecraft looks 'smaller' than when he saw it docked at the space station. Explain how accurate or not this statement is – assume that he was able to photograph the spacecraft. (Diagram not to scale – you should refer to the diagram in your answer)

(2)

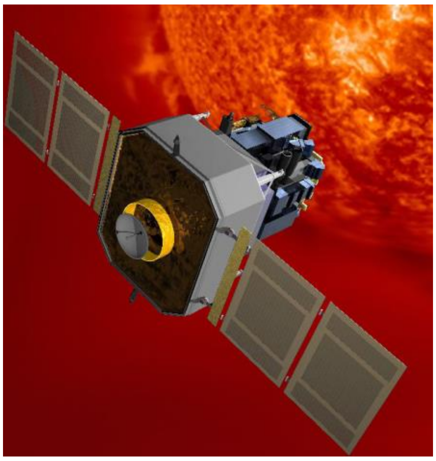


11. The large hadron collider can accelerate lead (Pb) nuclei to speeds approaching the speed of light in a circular path by using electromagnets. Explain with reference to Special Relativity why a constant force produced by the magnets is NOT able to provide a constant acceleration to the lead nuclei.

(2)

12. The EIT telescope is an instrument on the SOHO spacecraft used to obtain high-resolution images of the solar corona. The EIT is sensitive to light of four different wavelengths: 17.1, 19.5, 28.4, and 30.4 nm, corresponding to light produced by highly ionized iron and helium.

Which part of the electromagnetic spectrum is the telescope observing? Refer to data sheet electromagnetic spectrum.



(2)

13. Muons are subatomic particles (leptons) created 60 km above sea level when cosmic rays collide with molecules in the upper atmosphere. Their half-life is approximately 2 μs but as they travel at approximately the speed of light we observe that it takes them 200 μs to travel to ground. After 100 half-lives there should be practically none left. But 1 in 8 survives.

(a) In the reference frame of the muon, how is this possible?

(1)

(b) In the reference frame of an Earth based observer, how is this possible?

(1)

14. In 1927 Georges Lemaître proposed a theory of the Universe that was to become known later as the ‘Big Bang’. Lemaître’s theory is now widely accepted as correct.

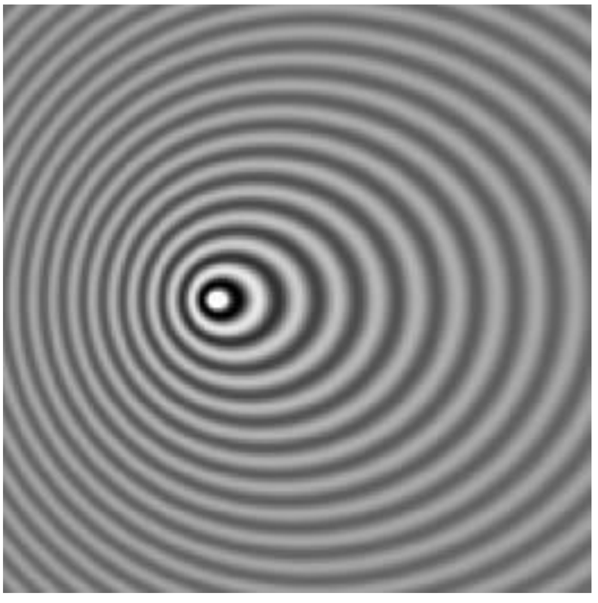
a) Describe two pieces of evidence that support this theory?

(2)

b) Explain what is meant by the phrases ‘open universe’ and ‘closed universe’ in the context of the ‘Big Bang theory’

(2)

15. The following photograph represents a moving galaxy as a source of e.m. waves.



a) Show a location on the edge of the diagram that receives ‘blue shifted’ waves

(1)

b) How does the wave speed differ here, compared to a location receiving ‘red shifted’ waves?

(1)

16. NGC 2987 is a galaxy group that can be observed from the Hubble Space telescope. The line absorption spectrum of light passing through iron in this galaxy shows one line with a wavelength of 439.5 nm. The same line in the iron spectrum measured on Earth is 438.2 nm.

(a) Is the spiral galaxy NGC 2987 moving towards or away from the Earth? (1)

(b) Briefly explain your answer to (a) (1)

(c) Calculate the recessional velocity of NGC 2987 using the relationship: (3)

$$\frac{\Delta\lambda}{\lambda_{rest}} = \frac{v}{c_0}$$ where $\Delta\lambda = \lambda_{shifted} - \lambda_{rest}$ and v = recessional velocity (m s^{-1})

(d) Using Hubble's law, calculate the distance in Mpc to galaxy NGC 2987 using the velocity you calculated in part (c).

(if you could not solve part (c) then use a value of 8.90×10^5 m s^{-1})

Hubble's law states that: $v = H_0 d$

v = recessional velocity (km s^{-1})
d = distance Mpc
H_0 = 74.0 km s^{-1} Mpc^{-1}

(2)

(e) How many years will it take light from this galaxy take to reach Earth? (1 parsec = 3.26 ly)

(1)