**Rossmoyne Senior High School Physics Unit 3 and 4 2021**

**Period Zero Test 4: Special Relativity and the Standard Model**

**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Score: \_\_\_\_\_\_\_\_\_ /40**

**Time:** 45 min + 5 min reading

**Materials Provided:** This Question/Answer Booklet and the Formulae and Data Booklet

**Instructions:** When calculating numerical answers, show your working or reasoning clearly and include appropriate units. Give final answers to **three** significant figures or other if specified. When estimating numerical answers, give final answers to a maximum of **two** significant figures.

1. On the axes below, the length of an object as a function of velocity according to classical theory is shown. Sketch in the relativistic length as a function of velocity. [2 marks]

0 0.25 0.50 0.75 1.00 1.25 1

1. The first postulate of special relativity states that all inertial frames are equivalent.
   1. Describe the requirements for a frame to be inertial. [1 mark]

* 1. An observer on a train sees a car on the freeway. The car is observed to be at rest relative to the train. Justify whether you can confidently claim the car is an inertial frame or not. [3 marks]

1. An astronaut making her way from Mars to Pluto observes the distance between the planets to be 0.25 light years. An observer on Mars measures the astronaut's speed as 0.70c.
2. How long will the astronaut observe the journey to take in years? [2 marks]
3. Calculate the time of the journey as measured by an observer on Pluto. [2 marks]
4. A proton is confined within a synchrotron that has a 250 m radius and a 3.26 × 10-2 T field.
   1. Show that the proton has a momentum of 1.30 × 10-18 kg m s-1. [2 marks]
   2. Thus, determine the velocity of the proton. [3 marks]
5. An ion wind is receding (moving away) at 0.30c from the perspective of a spacecraft. This spacecraft had taken off from a planet to move directly away from the ion wind. The planet based observatory monitors the spacecraft moving away at 0.70c. What velocity does the planet observatory observe the ion wind to have? [5 marks]

Ion wind

Planet

Spacecraft

1. An observer at rest with a pair of parallel plates watches a ball moving at 60.0 % of the speed of light at an angle as shown in the diagram. The observer records the time it takes for the ball to move from one plate to the other as 1.45 × 10-8 s.

35.00

1. Does the observer record a proper or dilated time for the ball moving between the plates? Justify your choice. [2 marks]

1. Argue whether changing the angle shown in the diagram would have effect on the **perpendicular** distance between the plates, when observed within the ball's frame of reference. [3 marks]

1. In an atom, there is a delicate balance between the forces that hold it together and that try to blow it apart. Complete the table with the appropriate missing terms. [4 marks]

|  |  |  |
| --- | --- | --- |
| Force of | Name of force | Mediating particles |
| Attraction between electrons and the nucleus |  |  |
| Repulsion between protons |  |  |
| Attraction between protons and neutrons |  |  |
| Attraction between protons |  |  |

1. Use the table below to assist with your answers to the following questions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Quark** | **Relative Electric Charge** | **Strangeness** | **Bottomness** |
| Up | +2/3 | 0 | 0 |
| Down | -1/3 | 0 | 0 |
| Top | +2/3 | 0 | 0 |
| Bottom | -1/3 | 0 | -1 |
| Charm | +2/3 | 0 | 0 |
| Strange | -1/3 | -1 | 0 |

Note that antiquarks have equal but opposite sign for electric charge, strangeness and bottomness

1. Give the quark composition of a baryon that has a +1 electric charge, -1 strangeness and 0 bottomness. [2 mark]
2. Give the quark composition of an antibaryon that has a +1 electric charge, 0 strangeness and +2 bottomness. [2 mark]
3. Give the quark composition of electrically neutral meson that has a +1 strangeness and 0 bottomness. [2 mark]
4. In addition to the energy-mass equivalence described in special relativity, an energy-momentum equivalence was established:

This relationship is consistent with Einstein’s energy-mass relationship.

This relationship shows that even massless particles (), such as light, have an intrinsic momentum () because of their energy content (). Maybe surprisingly, the momentum of light was theorised and experimentally confirmed before Einstein's theory of special relativity and was used as the basis for de Broglie's work on the wave nature of matter.

There are also similarities between this energy-momentum equation and Pythagoras' theorem. The square of the energy content of a particle is equal to the sum of the squares of the rest energy and the value of .

1. Using the energy-momentum relationship, show that the expression for the momentum of a photon of light as a function of its frequency, , is . [2 marks]
2. Find the momentum of a 1.50 × 1015 Hz photon. [1 mark]
3. The two right angled triangles shown below represent the energy-momentum equation. Each triangle is for the same particle but at different velocities. Label the three sides of each triangle with its value (, or ). [2 marks]

Slow particle

Fast particle