**TASK 7 SM, BB and SR Test Marking key**

**TOTAL 51 marks**

**Section 1**

**Question 1**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| Recognise anti particles are opposite charge | **1** |
| +⅔+ -⅔+ -⅓+ -⅔  -1e | **1** |

**Question 2**

A proton of mass 1.67 x 10-27 kg is accelerated in the Large Hadron Collider until it reaches 0.95*c*   
(*c* = speed of light).

1. Estimate the new mass of the proton from the graph. (2 marks)

*From graph mass increases roughly by 3X*

*(1 mark)*

*1.67 x 10-27 x 3 = 5.01 x 10-27 kg (1 mark)*

1. What is the reason for this apparent increase in mass? (1 mark)

*Some of energy being put into proton to accelerate causes a mass increase E = mc2.*

*(1 mark)*

Einstein derived the mathematical equation showing how mass changes with speed.



where m0 is the rest mass and mv is the mass when moving (in kg).

1. Using the equation above, calculate the mass of the proton when it is moving at 0.99*c*. (2 marks)

 *(1 mark)*

= 1.67 x 10-27

0.141

= 1.18 x 10-26 kg or about a 7X increase. (1 mark)

**Question 3**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| s= vt = 3x108 x 2.2x10-6 | **1** |
| 660m | **1** |

b)

|  |  |
| --- | --- |
| **Description** | **Mark** |
| As the speed increased the time dilation increases (may discuss either muon or Earth frame of reference) | **1** |
| The muons last longer as they travel so fast | **1** |

**Question 4**

1. The vertical axis is labelled ‘redshift’ with units for velocity (km s-1). Explain briefly the

relationship between redshift and the speed of the object. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** |  | **Marks** |
| How much the lines are shifted is related to the star’s velocity |  | 1 |
| States or explains that redshift increases with velocity. |  | 1 |
|  | **Total** | **2** |

1. Use the gradient of the graph to extrapolate a value for the maximum distance, in Mpc, for a galaxy to be observed from in the Earth. Show **all** workings. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** |  | **Marks** |
| Maximum speed c=3×108 m s-1 or 3×105 km s-1 |  | 1 |
| Determines gradient 31 000/500= 62 km s-1/Mpc. Allow range 60-65 km s-1/Mpc. |  | 1 |
| Maximum distance of the Universe => 3×105/(62 km s-1/Mpc) =  4800 Mpc  Allow 4600-5000 Mpc |  | 1 |
|  | **Total** | **3** |

**Question 5**

1. A photon must have a minimum energy in order to create an electron and a positron.

Calculate the minimum energy of the photon in joules. Give your answer to an appropriate number of significant figures.

[3]

energy = 2×rest mass energy) 🗸

energy = 2 × 0.510999 = 1.021998 (MeV) 🗸

energy = 1.021998 × 1.60 × 10-13 = 1.64 × 10-13 J 🗸

1. A photon of slightly higher energy than that calculated in part (b) is converted into an electron and a positron.

State what happens to the excess energy.

[1]

kinetic energy (of electron and positron) 🗸

1. Describe what is likely to happen to the positron shortly after its creation.

[2]

(meet an electron and) annihilate 🗸

(converting into two or more) photons OR gamma rays 🗸

**Section 2**

**Question 6 (12 marks)**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| 1 s | **1** |

**b)**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| t = | **1** |
| 1.90 s | **1** |

**c)**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| The observer in the spacecraft is not moving relative to the clock so is measuring a proper time | **1** |
| There is a relative motion between the observer on Earth and the spacecraft | **1** |
| To maintain the ratio of distance to time to keep the speed of light constant, there must be a dilation in time for the observer in the Earth’s reference frame | **1** |

**d)**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| l = 119 x | **1** |
| 62.7 m | **1** |

**e)**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| No change | **1** |
| Length contraction only occurs in the direction of motion | **1** |

**f)**

|  |  |
| --- | --- |
| **Description** | **Mark** |
|  | **1** |
| 2.84x108 m s-1 | **1** |

**Question 7**

**a**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| Spin 1 ½ | **1** |
| Charge +1e | **1** |
| Baryon number +1 | **1** |

**b**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| 1. BN for n = +1 BN for p = +1 (same both sides) | **1** |
| 1. LN for e- is +1 but is 0 on the left so not conserved | **1** |
| 1. Electron antineutrino | **1** |

**c**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| Identifies and describes one type of gauge boson | **1 – 2** |
| Examples   * Gluon: provides strong force between quarks * Photon: provides electrostatic force between protons * Higgs boson: provides mass to particles * W,Z boson: provides weak force (beta decay) |  |

**Section 3**

**Question 8**

**a**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| Moving away | **1** |

**b**

|  |  |
| --- | --- |
| **Description** | **Mark** |
| The wavelength of the calcium line in the spectrum from NGC 1357 has increased | 1 |
| This is a characteristic of a source moving away from an observer  (Earth 396.85 nm, NGC 1357 399.72 nm) | 1 |
| Diagram to show changes in wavelengths towards and away from observer. | 1 - 2 |

**c**

|  |  |
| --- | --- |
| **Description** | **Mark** |
|  | 1 |
| v = 2.17 x 106 m s-1 | 1 |

**d**

|  |  |
| --- | --- |
| **Description** | **Mark** |
|  | 1 |
| 7.791 x 10-11 m = 0.0791 nm | 1 |