Do not write outside the box

0 4 **Table 1** shows data of speed v and kinetic energy E_k for electrons from a modern version of the Bertozzi experiment.

Table 1

v / 10^8 m s^{-1}	E_k / MeV	
2.60	0.5	13.52
2.73	0.7	10.64
2.88	1.3	6.38
2.96	2.6	3.37
2.99	5.8	1.54

0 4 . 1 Classical mechanics predicts that $E_k \propto v^2$.

Deduce whether the data in **Table 1** are consistent with this prediction.

[2 marks]

18 time

$$\frac{E_k}{v^2} = k$$

clearly not

As the amount of Ek provided incerases we can see that the v is reaching a peark value approaching C

Increases in Ek are providing smaller increases in v than predicted

THis is because the mass of the electrons are increasing as their velocity increases

As we get closer to C then the mass begins to increases very rapidly, (tending to infinite) meaning very large/infinite amounts of energy are required to make any increase in v

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0 4 . 2 Discuss how Einstein's theory of special relativity explains the data in **Table 1**.

[4 marks]

see above

0 4 . 3 Calculate, in J, the kinetic energy of one electron travelling at a speed of $0.95c$.

[3 marks]

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \quad \text{or} \quad E = \frac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

$\boxed{\text{total}}$

$$E = \frac{9.11\times10^{-31}\times(3\times10^{8})^2}{\sqrt{1-(0.95)^2}} = \frac{8.2\times10^{-14}}{0.312} = 2.63\times10^{-13}\ \text{J}$$

total

$$E_m + E_k = \text{total}$$

$$8.2\times10^{-14} + E_k = 2.63\times10^{-13}$$

kinetic energy = 1.8×10^{-13} J

END OF QUESTIONS

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0 4 . 1 A muon travels at a speed of $0.95c$ relative to an observer.

The muon travels a distance of 2.5×10^3 m between two points in the frame of reference of the observer.

Calculate the distance between these two points in the frame of reference of the muon.

[2 marks]

$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$

Proper length, L_0, is measured by an observer who is stationary cf the reference frame that things are occuring in - muon movement in this case. This means that L_0 is 2500m

$L = 2500 \sqrt{1 - (0.95)^2}$

$L = 780$ m.

distance = ______________________ m

0 4 . 2 Measurements of muons created by cosmic rays can be used to demonstrate relativistic time dilation.

State the measurements made and the observation that provides evidence for relativistic time dilation.

[2 marks]

we know the half life of muons. We measure how many muons arrive at the stationary observer on earth cf on top of a mountain at known height cf first observer.
we know muons speed
We find more muons arrive as time has slowed down in the frame of the muon.

CLock is running slower in muon's time frame

Do not write outside the box

0 4 . 3 As the muons travel through the atmosphere, their speeds are reduced by interaction with the particles in the air.

Discuss, with reference to relativity, the effect that this reduction of speed has on the rate of detection of the muons on the surface of the Earth.

[3 marks]

reduction of speed is in both frames of reference
reudces the lorentz factor
time slows down less for the muon than previously
this means more will decay
reducing the number detected on the earth cf the mountain

say that in our fame the muon is going at v=100

the muon will only expereince say 50 units of time passing

Now if v is reduced by collisions the muon will expericen less of a drop in time - so say 70 unitls of time pass meaning more decays meaning lower number of particles

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END OF QUESTIONS

0 4 . 1 State what is meant by an inertial frame of reference.

[1 mark]

a frame with no acceleration therefore moving at a constant velocity

0 4 . 2 A pair of detectors is set up to measure the intensity of a parallel beam of unstable particles.
In the reference frame of the laboratory, the detectors are separated by a distance of 45 m. The speed of the particles in the beam is $0.97c$.

The intensity of the beam at the second detector is 12.5% of the intensity at the first detector.

Calculate the half-life of the particles in the reference frame in which they are at rest.

[4 marks]

$$L = L_0\sqrt{1-\frac{v^2}{c^2}}$$

L_0 is the distance measured by the stationary observer - so it is 45m

Find l, which is the distance the particle 'thinks' it is travelling.

$$L = 45\sqrt{1-(0.97)^2} = 10.93\ \text{m}$$

$v = d/t$

t is $\frac{10.93c}{0.97} = 3.75\times10^{-8}\ \text{s} = 3\,t_{1/2} = 1.25\times10^{-8}$

half-life = 1.25×10^{-8} s

0 4 . 3 In calculations involving time dilation, it is important to identify proper time.

Identify the proper time in the calculation in Question **04.2**.

[1 mark]

Time 'at rest' from the particle's perspective - ie 3.75×10^{-8} sec

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END OF QUESTIONS