Name of the Student:_____
Max. Marks : 24 Marks **Time : 24 Minutes**

Q1.

(a) The theory of special relativity is based on two postulates. One of these postulates is that the speed of light in free space is invariant.
State the other postulate.

_____

_____

(1)

(b) An electron in the Stanford linear accelerator is accelerated to an energy of 24.0 GeV.

(i) An electron travelling with this energy has a velocity v.

Show that the value of $\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}$ is about 2.1×10^{-5}.

(3)

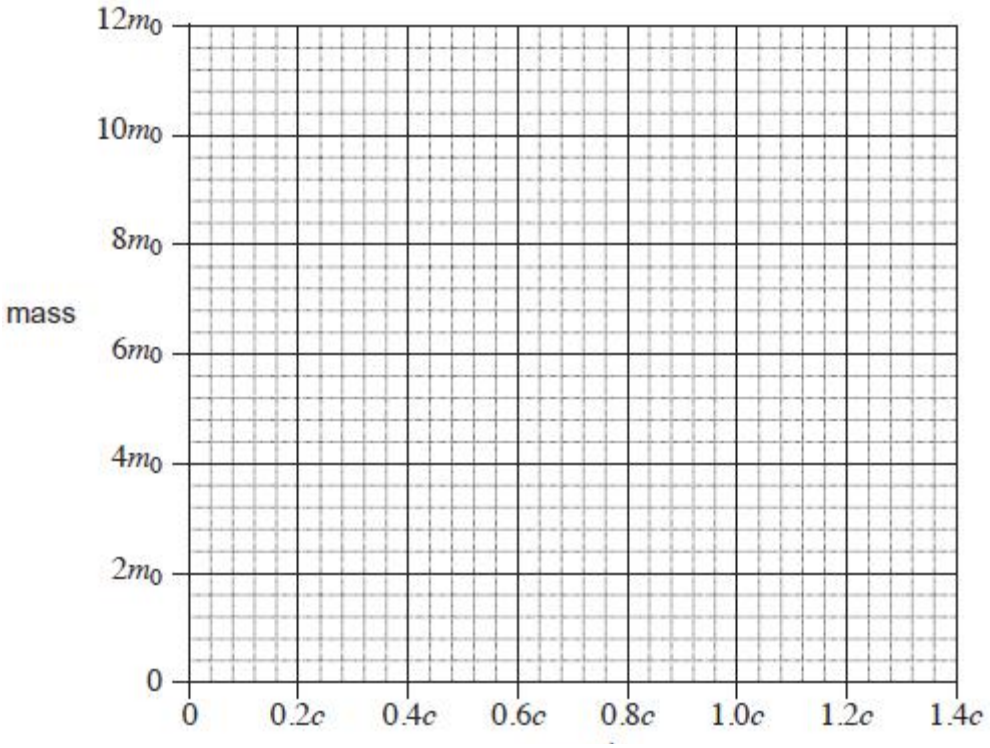
(ii) The Stanford linear accelerator has a length of 3.0 km. Assume that the electron travels for the full length of the accelerator with an energy of 24 GeV.
Calculate the length, in m, of the accelerator in the reference frame of the electron.

length of accelerator = _____ m

(1)

(c) Draw a graph to show how the relativistic mass of an electron varies with speed as it is accelerated from rest.

Rest mass of an electron = m_0



(2)

(Total 7 marks)

Q2.

(a) Maxwell predicted the existence of electromagnetic waves that travelled in free space.

Identify the **two** quantities that vary in an electromagnetic wave and state the phase relationship between them.

Quantity 1 _____

Quantity 2 _____

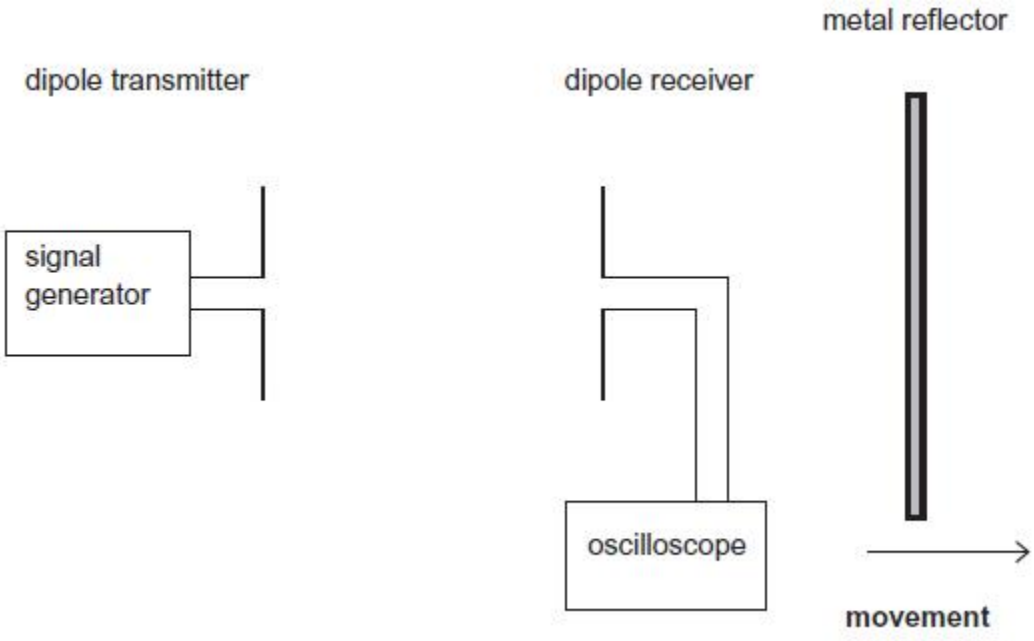
_____

Phase relationship _____

_____

(2)

(b) Hertz determined the speed of electromagnetic waves and found that they travelled at 3.0×10^8 m s^{-1}. The diagram shows an arrangement using radio waves that is similar to that used by Hertz in his determination.



The dipole transmitter radiates an electromagnetic wave of frequency 2.2 GHz.
A signal is detected by the dipole receiver.
When the metal reflector is moved in the direction shown in the diagram, the detected signal strength alternates between maximum and minimum intensities.

(i) Explain why the detected signal strength changes from a maximum to a minimum as the metal reflector is moved.

_____

_____

_____

_____

_____

_____

(3)

(ii) Determine the least distance the reflector has to move for the detected signal strength to change from a maximum to a minimum to confirm Hertz's value for the speed of electromagnetic radiation.

least distance = _____ m

(2)

(iii) Which **one** of the following observations originally led to the conclusion that light is an electromagnetic wave?

Place a tick (✔) in the right-hand column to show the correct answer.

	✔ if correct
Light is diffracted when it falls on a narrow slit.	
Light travels at 3×10^8 m s^{-1} in free space.	
Light changes speed when it enters a medium of different optical density.	
Light can be polarised when it passes through Polaroid.	

(1)

(Total 8 marks)

Q3.

(a) J J Thomson devised the first experiments to determine the specific charge for cathode rays produced in discharge tubes. He found that the value did not depend on the gas in the tube. He also discovered that particles emitted by a heated filament and particles emitted in the photoelectric effect had the same specific charge.

State **two** conclusions that were drawn from Thomson's experiments.

1. _____

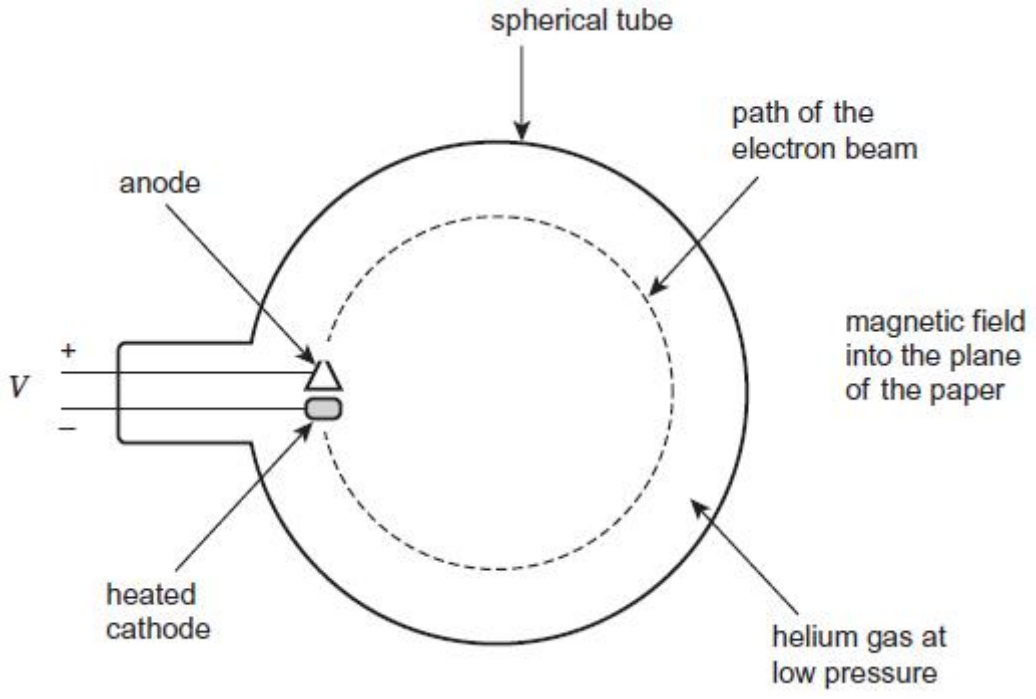
_____

2. _____

_____

(2)

(b) The diagram shows a spherical tube, filled with low-pressure helium gas, that is used in an experiment to determine the specific charge of an electron.



Electrons are accelerated by a potential difference (pd) V applied between the cathode and anode. A magnetic field of known flux density B, directed into the plane of the diagram, causes the electrons to move in a circular path.

(i) Explain the process that causes the low-pressure helium gas to emit light so that the path of the electron beam can be seen.

_____

_____

_____

_____

_____

_____

(3)

(ii) In one experiment using the apparatus in the diagram, the accelerating pd is 1.6 kV and the flux density of the magnetic field is 2.2 mT. The path of the electron beam has a radius of 0.059 m.

Determine a value for the specific charge of an electron using these data. State an appropriate unit for your answer.

specific charge = _____ unit = _____

(4)

(Total 9 marks)