Name of the Student:_____
Max. Marks : 23 Marks **Time : 23 Minutes**

Q1.

Figure 1 shows the H-shaped posts used in a game of rugby.

Figure 1

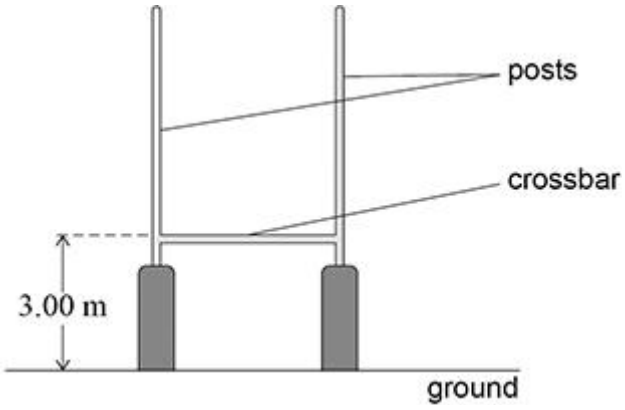
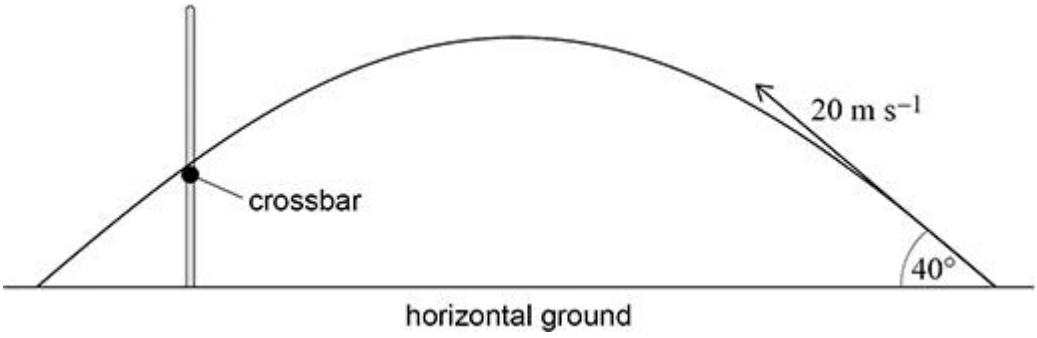


Figure 2 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is 20.0 m s^{-1} at an angle of 40.0° to the ground.

You should consider air resistance to be negligible and treat the ball as a simple projectile.

Figure 2



The top of the crossbar is 3.00 m above the horizontal ground.

(a) Show that the minimum speed of the ball in flight is about 15 m s^{-1}.

Explain your answer.

_____

_____

_____

(2)

(b) The ball just passes over the crossbar at a time t after it is kicked.

Show that t must satisfy the following equation:

$$4.91t^2 - 12.9t + 3.00 = 0$$

(2)

(c) There are two solutions to the equation

$$4.91t^2 - 12.9t + 3.00 = 0$$

Discuss which of the two solutions is the time taken for the ball to pass over the crossbar from when it is kicked.

In your answer you should

- state the value for t given by each solution
- explain the physical significance of the other solution.

solution 1 = _____ s

solution 2 = _____ s

_____

_____

_____

_____

_____

_____

(4)

(d) Another attempt is made to kick the ball over the crossbar. The initial velocity of the ball is the same as in the first attempt.

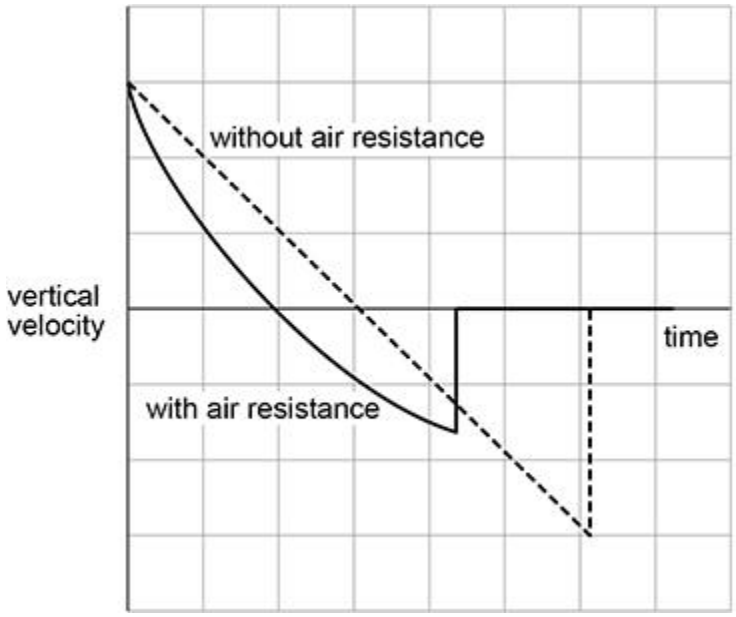
This kick is made from a horizontal distance of 38 m from the posts.

Deduce whether the ball can pass over the crossbar.

(1)

(e) **Figure 3** shows the variations with time of the vertical velocity of a ball with and without air resistance.

Figure 3



Discuss the features of the motion of the ball shown by the two graphs.

In your answer you should refer to

- the gradients of the graphs
- the area between each line and the time axis.

_____

_____

_____

_____

(5)

(Total 14 marks)

Q2.

(a) Explain, in terms of binding energy, why energy can be released when two nuclei undergo nuclear fusion.

_____

_____

_____

_____

_____

_____

(2)

(b) During the collapse of a supermassive star, helium-3 and oxygen-17 fuse to release energy. The equation for this reaction is

$$^{3}_{2}\mathrm{He} + ^{17}_{8}\mathrm{O} \rightarrow ^{20}_{10}\mathrm{Ne}$$

The table below gives data for these nuclei.

Nucleus	Mass / u
$^{3}_{2}\mathrm{He}$	3.01603
$^{17}_{8}\mathrm{O}$	16.99913
$^{20}_{10}\mathrm{Ne}$	19.99244

Calculate, in J, the energy released when this reaction occurs.

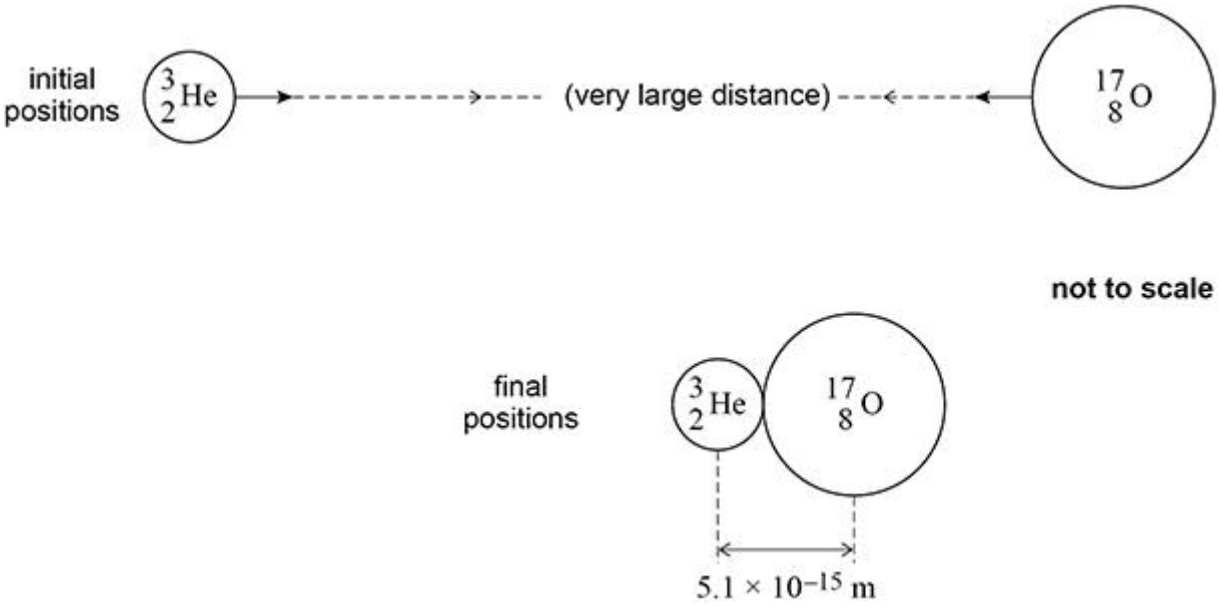
energy released = _____ J

(2)

(c) One model of nuclear fusion suggests that fusion happens when nuclei touch.

Initially the helium nucleus and oxygen nucleus are separated so that the force between them is negligible. They move towards each other until they fuse. Fusion occurs when their centres are separated by a distance of 5.1×10^{-15} m.

The figure below shows the initial positions and final positions of the nuclei.



Calculate the total change in electrostatic potential energy between the initial positions and final positions of the nuclei.

change in electrostatic potential energy = _____ J

(2)

(d) $^{3}_{2}He$ can undergo fusion reactions with either $^{34}_{16}S$ or $^{17}_{8}O$ at the same temperature in a star.

The nucleus has properties that depend on its proton number and its nucleon number. These properties affect the fusion reaction.

Discuss, for this star, how these properties affect the rate of fusion of $^{34}_{16}S$ with $^{3}_{2}He$ compared to the rate of fusion of $^{17}_{8}O$ with $^{3}_{2}He$.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)