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

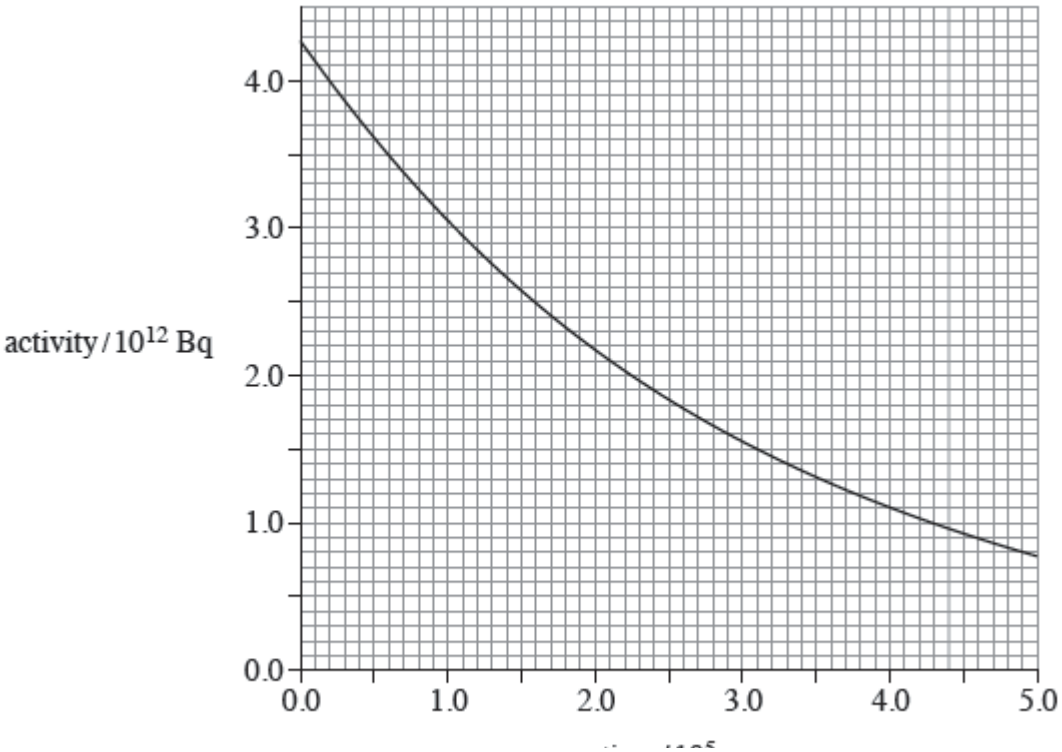
Q1.

A rod made from uranium−238 ($^{238}_{92}\mathrm{U}$) is placed in the core of a nuclear reactor where it absorbs free neutrons.
When a nucleus of uranium−238 absorbs a neutron it becomes unstable and decays to neptunium−239 ($^{239}_{93}\mathrm{Np}$), which in turn decays to plutonium−239 ($^{293}_{94}\mathrm{Pu}$).

(a) Write down the nuclear equation that represents the decay of neptunium−239 into plutonium−239.

(2)

(b) A sample of the rod is removed from the core and its radiation is monitored from time t = 0 s. The variation of the activity with time is shown in the graph.



(i) Show that the decay constant of the sample is about 3.4×10^{-6} s^{-1}.

(2)

(ii) Assume that the activity shown in the graph comes only from the decay of neptunium.

Estimate the number of neptunium nuclei present in the sample at time $t = 5.0 \times 10^5$ s.

number of nuclei _____

(1)

(c) (i) A chain reaction is maintained in the core of a thermal nuclear reactor that is operating

normally.

Explain what is meant by a chain reaction, naming the materials and particles involved.

_____

_____

_____

_____

(2)

(ii) Explain the purpose of a moderator in a thermal nuclear reactor.

_____

_____

_____

_____

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_____

(2)

(iii) Substantial shielding around the core protects nearby workers from the most hazardous radiations. Radiation from the core includes α and β particles, γ rays, X−rays, neutrons and neutrinos.

Explain why the shielding becomes radioactive.

_____

_____

_____

_____

(2)

(Total 11 marks)

Q2.

(a) Explain what is meant by a **thermal** neutron.

_____

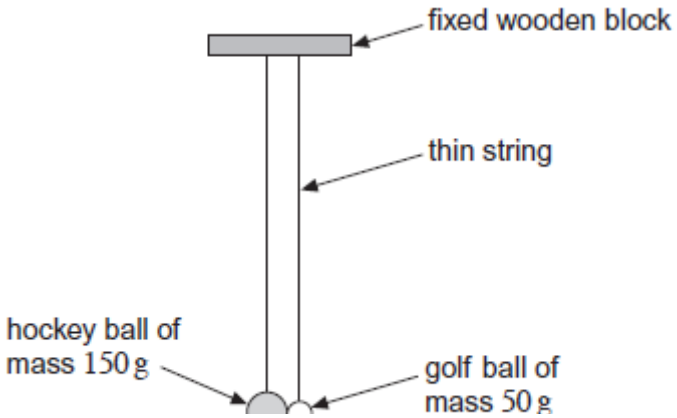
_____

_____

_____

(2)

(b) A student sets up the arrangement, shown in the diagram below, to demonstrate the principle of moderation in a nuclear reactor.



A golf ball of mass 50 g is initially hanging vertically and just touching a hockey ball of mass 150 g. The golf ball is pulled up to the side and released. It has a speed of 1.3 m s^{-1} when it collides head-on with the hockey ball. After the collision the balls move in opposite directions with equal speeds of 0.65 m s^{-1}.

(i) Calculate the height above its initial position from which the golf ball is released. Assume that there is no air resistance.

height _____ m

(2)

(ii) Show that momentum is conserved in the collision and that the collision is perfectly elastic.

(4)

(iii) Calculate the percentage of the kinetic energy of the golf ball transferred to the hockey ball during the collision.

percentage transferred _____ %

(2)

(iv) Explain how this demonstration relates to the moderation process in a reactor and state **one** way in which the collisions in a reactor differ from the collision in the demonstration.

_____

_____

_____

_____

(2)

(v) Name the substance used as the moderator in a pressurised water reactor (PWR).

_____

(1)

(Total 13 marks)