Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2023 Preliminary Examination

PHYSICS
Higher 2
Paper 3 Longer Structured Questions

9749/03
September 2023
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only and **circle** the question number on the cover page.

You are advised to spend one and a half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

***This booklet only contains Section B.**

For Examiner's Use		
Section B (circle question attempted)	**8**	/ 20
	9	/ 20
Deduction		

Section B

Answer **one** question from this Section in the spaces provided.

8 Fig. 8.1 shows block A of mass *m* at rest on a frictionless horizontal surface and connected to a mechanical oscillator through a horizontal light spring with spring constant *k*. The mechanical oscillator is fixed in position.

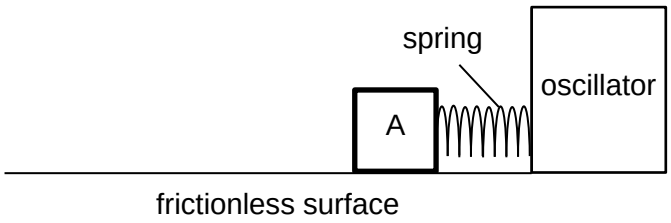

Fig. 8.1

(a) The mechanical oscillator is not switched on.
Block A is displaced from its original position along the axis of the spring and set into oscillation.

(i) For a displacement *x*, write down an expression for the force *F* exerted by the spring on block A.

.....[1]

(ii) Use Newton's second law of motion to show that block A will oscillate with simple harmonic motion. Assume that air resistance on block A is negligible.

[2]

(iii) Show that the period *T* of the oscillations of block A is given by:

$$T = 2\pi\sqrt{\frac{m}{k}}\,.$$

[2]

(b) Block A is now brought to rest at the equilibrium position. Block B of mass 18 g travels to the right with speed 5.3 m s^{-1} as shown in Fig. 8.2.

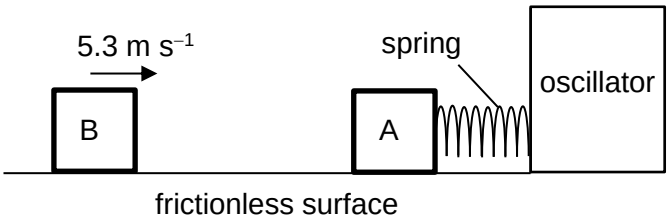

Fig. 8.2

The two blocks collide and stick together.
The mass of block A is 35 g and the force constant of the spring is 25 N m^{-1}.

(i) Determine:

1. the maximum compression of the spring

maximum compression = ... m [3]

2. the time it takes after the collision to reach this maximum compression.

time = ... s [2]

(ii) On Fig. 8.3, sketch the variation with time t of the magnitude of the acceleration a of the blocks just after they collide to the time when the spring is at its maximum compression. Label the axes with appropriate values.

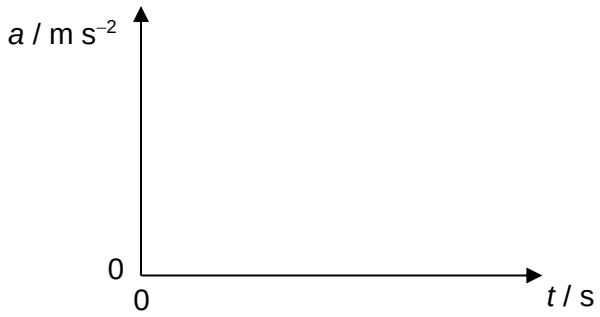

Fig. 8.3

[2]

(c) Block B is now placed on top of block A as shown in Fig. 8.4. Block A is again displaced from its original position and set into oscillation.

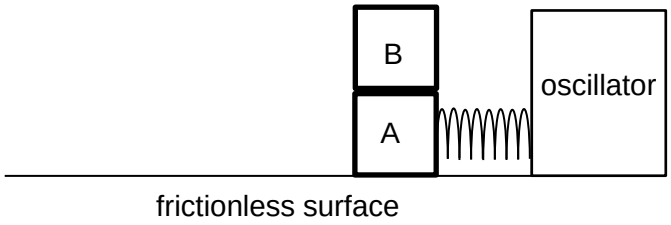

Fig. 8.4

(i) The maximum frictional force between the two blocks is 9.5×10^{-2} N.

Determine the maximum amplitude of oscillations x_0 such that block B remains stationary relative to block A.

x_0 = ... m [3]

(ii) Block B is now attached to block A. The two blocks are set into oscillation by the mechanical oscillator such that both blocks move together. As the frequency *f* of the mechanical oscillator is varied, the amplitude is recorded.

1. It is observed that the amplitude becomes very large at a particular value of *f*.

Explain this phenomenon.

.....

.....

.....

..... [2]

2. On Fig. 8.5, sketch the variation of the amplitude with *f*.

Label the frequency axis with an appropriate value and label this line P.

Fig. 8.5

[2]

3. A sheet of cardboard of negligible mass is now fixed to the blocks to cause greater damping.

On Fig. 8.5, sketch the variation of the amplitude with *f* to show the effect of this change. Label this line Q.

[1]

[Total: 20]

9 **(a)** The Rutherford alpha particle scattering experiment involved firing alpha particles at a thin gold foil. The experiment changed the existing model of the atom at that time.

State and explain the evidence from this experiment that changed the model of the atom in terms of its charge distribution and its mass distribution.

charge distribution .....

.....

.....

.....

mass distribution .....

.....

.....

..... [4]

(b) Plutonium-239 decays by α-emission spontaneously to form the isotope uranium-235. The half-life of plutonium-239 is significantly shorter than the half-life of uranium-235.

(i) Explain what is meant by *spontaneous* decay.

.....

..... [1]

(ii) Define the term *half-life*.

.....

..... [1]

(iii) The nuclear decay is given by

$$^{239}_{94}\text{Pu} \rightarrow {}^{235}_{92}\text{U} + {}^{4}_{2}\text{He}.$$

Data for the nuclei in the decay are given in Fig. 9.1.

nucleus	mass / u
plutonium $^{239}_{94}$Pu	239.052163
uranium $^{235}_{92}$U	235.043930
helium $^{4}_{2}$He	4.003860

Fig. 9.1

1. Show that the energy released in this decay is 4.08 MeV.

[2]

2. The plutonium-239 nucleus was at rest before the decay.

Calculate the speed of the uranium-235 nucleus.

speed = ... m s^{-1} [3]

(iv) Explain why an alpha radiation source poses little danger to humans unless it is ingested or inhaled.

.....

..... [1]

(c) A sample of pure plutonium-239 has N nuclei and an activity of A at time t. The variation with time t of ln A is shown in Fig. 9.2.

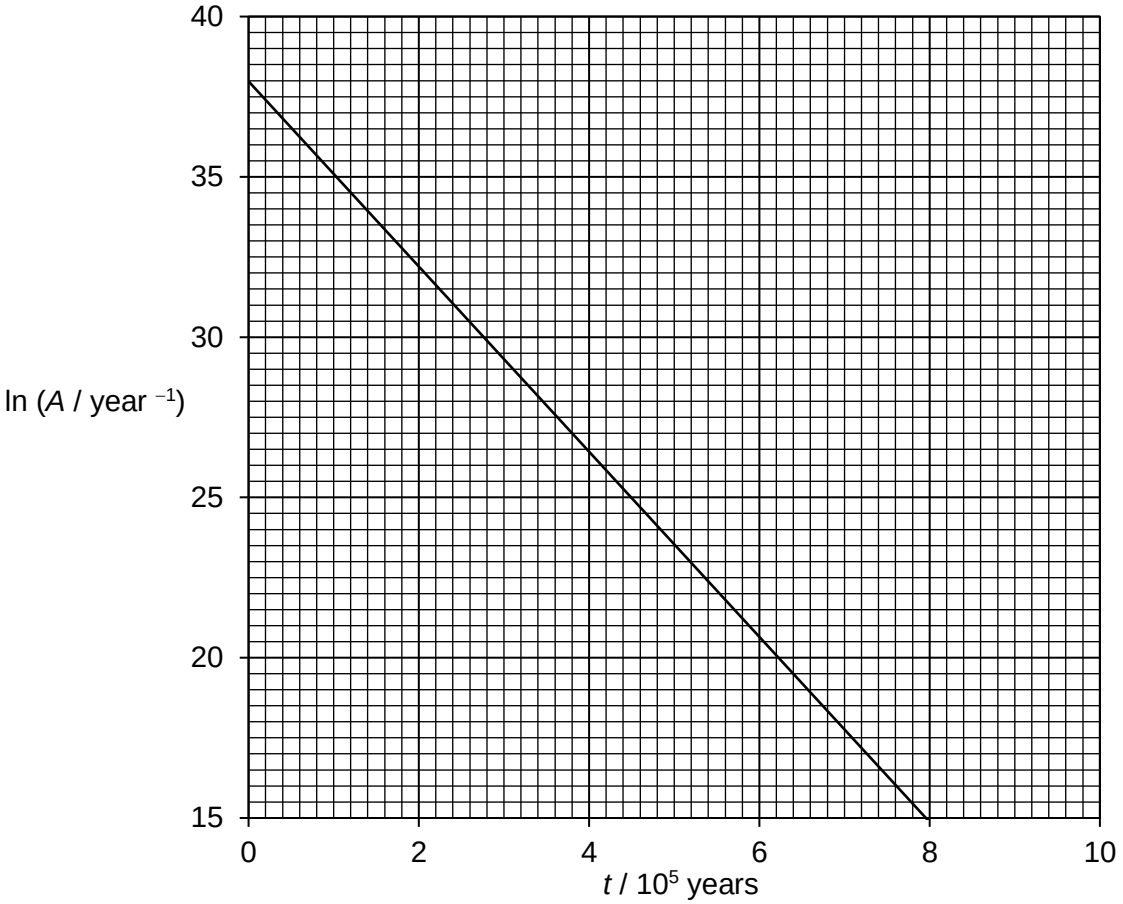

Fig. 9.2

(i) Explain why the activity decreases with time.

.....

..... [1]

(ii) Determine the half-life of plutonium-239.

half-life = ... years [3]

(iii) Determine the initial number N_0 of plutonium-239 nuclei in the sample.

N_0 = ... [2]

(d) The activity of another pure sample of radioactive nuclei X is examined. The half-life of X is 0.5 times the half-life of plutonium-239.

At t = 0, the sample of X has the same number of nuclei N_0 as the sample of plutonium-239 in **(c)**.

On Fig. 9.2, draw the graph to show the variation with time t of ln A for this sample of X. [2]

[Total: 20]