Name: ____________________________ (   )   CT Group: 24S0 _______

RAFFLES INSTITUTION

2023 YEAR 5 PROMOTIONAL EXAMINATION

2 October 2023

H2 PHYSICS

Section C

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section C in the spaces provided on the question paper.

You are advised to write all your workings and answers clearly. Marks may be deducted for unclear workings.

For Examiner's Use		
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This document consists of **8** printed pages.

Section C (30 marks)

6 A body of mass 2.6 kg is oscillating in simple harmonic motion between points P and Q. The variation with displacement *x* from point P of the kinetic energy of the body is shown in Fig. 6.1.

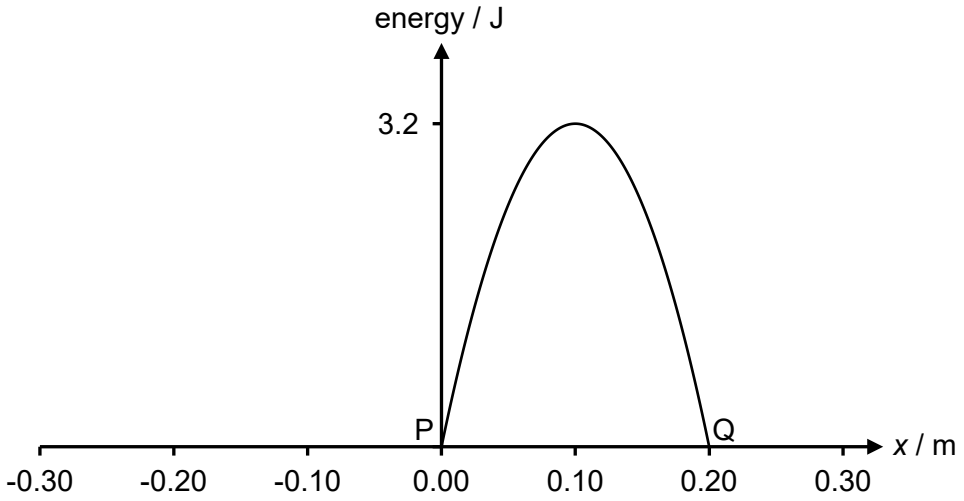

Fig. 6.1

(a) State the displacement *x* of the equilibrium position of the body.

..... [1]

(b) Calculate the maximum speed of the body.

maximum speed = ... m s^{-1} [2]

(c) Calculate the maximum acceleration of the body.

maximum acceleration = ... m s^{-2} [2]

(d) Calculate the period of the motion.

period = ... s [2]

(e) On Fig. 6.1, sketch the variation with x of the potential energy of the body.

[1]

(f) The body is at point P at time $t = 0$ s.

On Fig. 6.2, sketch the variation with t of the potential energy of the body from $t = 0$ s to $t = 0.80$ s.

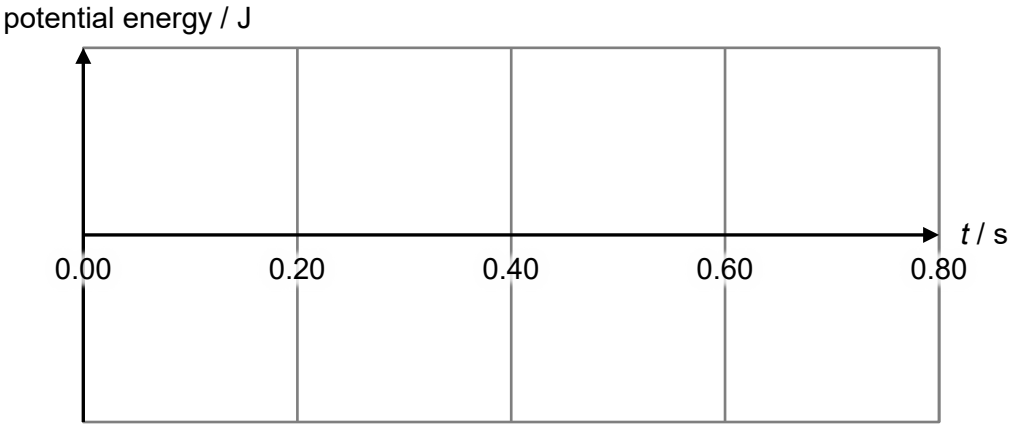

Fig. 6.2

[2]

(g) On Fig. 6.3, sketch the variation with x of the velocity v of the body.

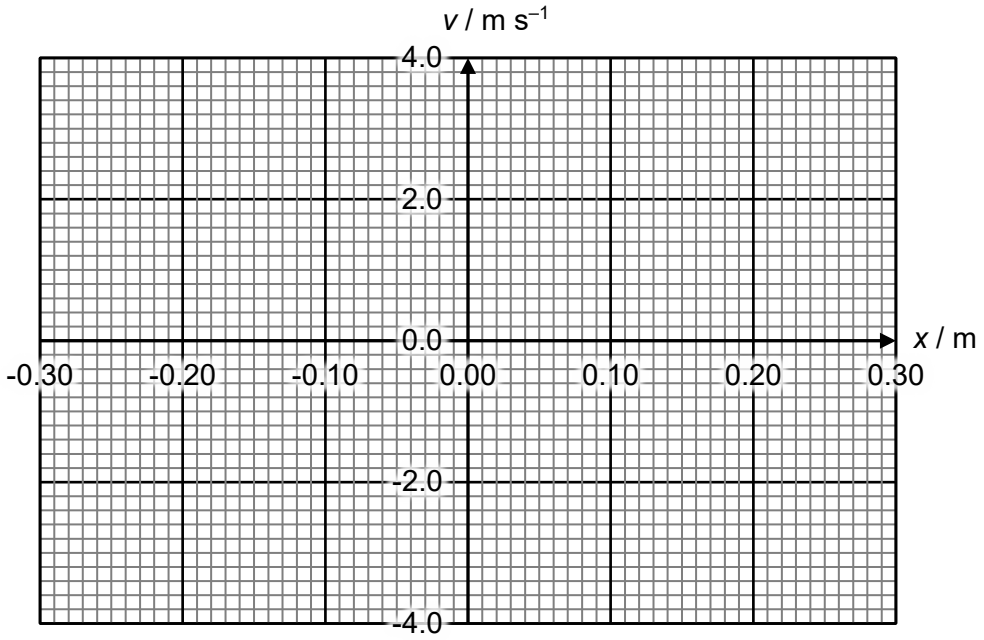

Fig. 6.3

[2]

(h) The body is now immersed in a beaker of water. The body is then released from point P and it undergoes oscillation.

(i) On Fig. 6.3, sketch the variation with x of v of the body for 2 cycles.

[1]

(ii) State and explain whether the body will attain maximum speed before it reaches the equilibrium position, at the equilibrium position or after it passes the equilibrium position from the time it is released.

.....

.....

.....

.....

.....

..... [2]

7 Read the passage below and answer the questions that follow.

Humans have ventured into space since the launch of Sputnik, the first artificial satellite to orbit the Earth. Space exploration has gone a long way since then, with milestone events like the first human to be in space, the first spacewalk and landing astronauts on the Moon. All these were possible by the advances made in rocket-propulsion design.

SpaceX, a privately-owned spaceflight company, specialises in rocket technology and design. The company is currently developing the Starship system, a fully reusable transportation system designed to carry both crew and cargo to low Earth orbit, the Moon, Mars and beyond.

The Starship system uses a two-stage rocket which burns liquid oxygen and methane that it carries on board as fuel. As the rocket operates, it continuously ejects burned fuel gases to create thrust. The gases are ejected in a direction opposite to the direction of travel of the rocket. The first stage of the rocket system, Super Heavy, is powered by 33 Raptor engines. The second stage of the system, Starship, is designed for long-duration space flight. Fig. 7.1 is a schematic sketch of the Starship system.

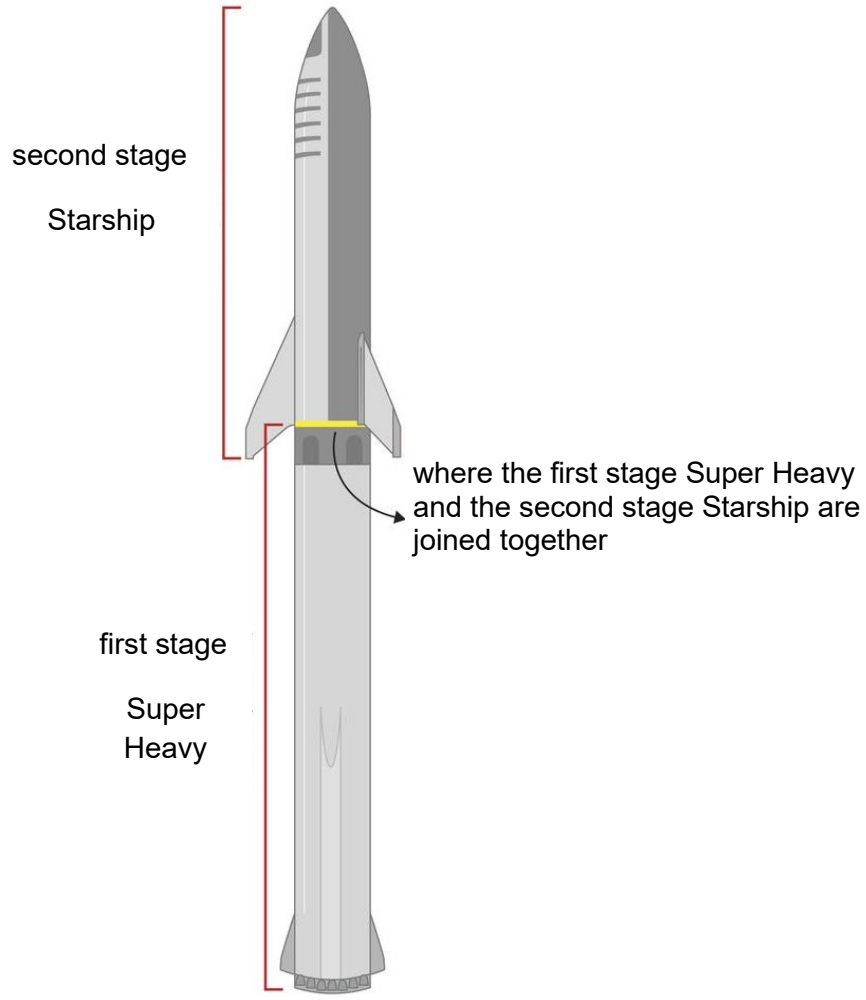

Fig. 7.1 (the Starship system)

During the first stage of the launch from Earth, the Raptor engines are powered for 162 s before the Super Heavy separates from the Starship and returns to Earth. The Raptor engines are then used for a controlled landing on land or water so that the Super Heavy can be reused for future missions.

The specific impulse I_s is a measure of how efficiently a rocket engine creates thrust. It can be calculated by the equation

$$I_s = \frac{F}{m_f}$$

where F is the thrust produced and m_f is the mass of the ejected gases flowing through the engine per second.

Data for specific impulse I_s measured at sea level and in vacuum for a single Raptor engine are shown in Table 7.1. The mass of the ejected gases per second m_f is also given.

Table 7.1

for a single Raptor engine	at sea level	in vacuum
I_s / m s^{-1}	3250	3560
m_f / kg s^{-1}	620	

(a) Using Newton's laws, explain how the rocket creates thrust.

.....

.....

.....

.....

.....

..... [2]

(b) Determine the thrust produced by a single Raptor engine just after take-off.

thrust = ... N [2]

(c) Use Table 7.1 to determine if the Raptor engine works more efficiently at sea level or in vacuum. Explain your reasoning.

.....

.....

..... [2]

(d) The Super Heavy rocket still has some fuel remaining when it separates from the Starship. Suggest why it does not burn all its fuel before separating and returning to Earth.

.....

..... [1]

(e) The Starship system has a total mass of 5.0×10^6 kg just after a vertical take-off.

2.0 minutes after take-off, the Starship system is still travelling vertically and the thrust is provided by all 33 Raptor engines working at the same time. It reaches an altitude of 30 km. The atmospheric pressure at this altitude is so low that the Starship system is effectively travelling in vacuum.

(i) Calculate the total thrust produced by the 33 Raptor engines.

thrust = ... N [1]

(ii) Determine the total mass of fuel consumed in 2.0 minutes.

Assume the rate of fuel consumption to be the same as the rate the gases are ejected from the 33 Raptor engines.

mass = ... kg [1]

(iii) Determine the acceleration of the Starship system 2.0 minutes after take-off.

Assume that the variation in the magnitude of the gravitational field strength can be neglected.

acceleration = ... $m\ s^{-2}$ [2]

(iv) Explain why the variation in the magnitude of the gravitational field strength can be neglected in **(e)(iii)**.

.....

.....

..... [1]

(f) A test flight of the Starship system was conducted in April 2023. The second stage Starship exploded after the Super Heavy rocket separated from it. It was found that the Starship, initially travelling upwards at $300\ m\ s^{-1}$, separated into three identical fragments immediately after the explosion. One fragment continued moving upwards at $360\ m\ s^{-1}$ while a second fragment moved to the right at $240\ m\ s^{-1}$.

By considering the conservation of momentum in the horizontal and vertical directions, determine the speed of the third fragment immediately after the explosion.

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

END OF SECTION C