Name: ____________________________ (   )   **CT Group: 22S0** _______

RAFFLES INSTITUTION

2021 YEAR 5 PROMOTIONAL EXAMINATION

30 September 2021

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.

For Examiner's Use		
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This document consists of **10** printed pages.

Section C (30 marks)

6 **(a)** **(i)** Define *gravitational potential* at a point.

....

....

.... [1]

(ii) Explain why gravitational potential in a gravitational field is negative.

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.... [2]

(b) The variation with distance r of the gravitational potential ϕ from the centre of a planet is shown in Fig. 6.1.

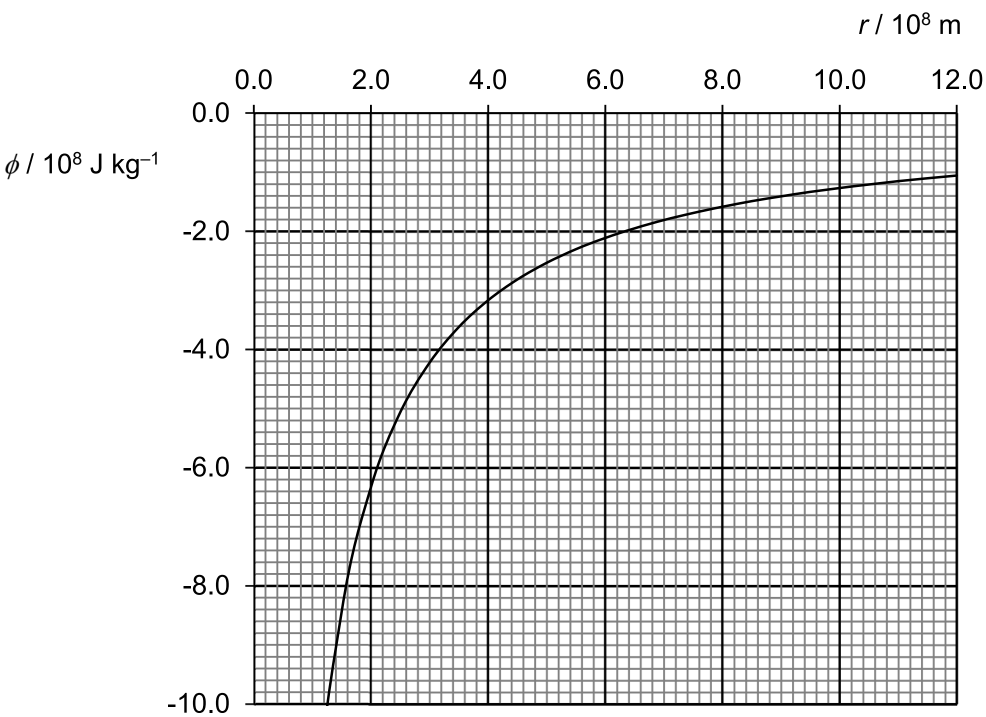

Fig. 6.1

(i) Using Fig. 6.1, show that the mass of the planet is 1.9×10^{27} kg.

[1]

(ii) Fig. 6.2 shows the planet and two points, X and Y, in its gravitational field. Points X and Y are 8.0×10^{8} m and 2.0×10^{8} m from the centre of the planet respectively.

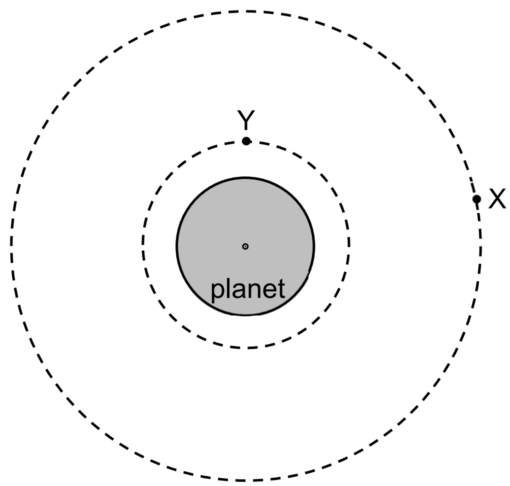

Fig. 6.2

1. Determine the orbital speed of an object that is orbiting the planet with a radius of 2.0×10^{8} m.

Explain your working.

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

2. As a space stone approaches the planet, it passes through point X with a speed of 3.5×10^4 m s^{-1} and continues to pass through point Y.

The direction in which the space stone passes through point Y is parallel to a tangent to the planet's surface as shown in Fig. 6.3.

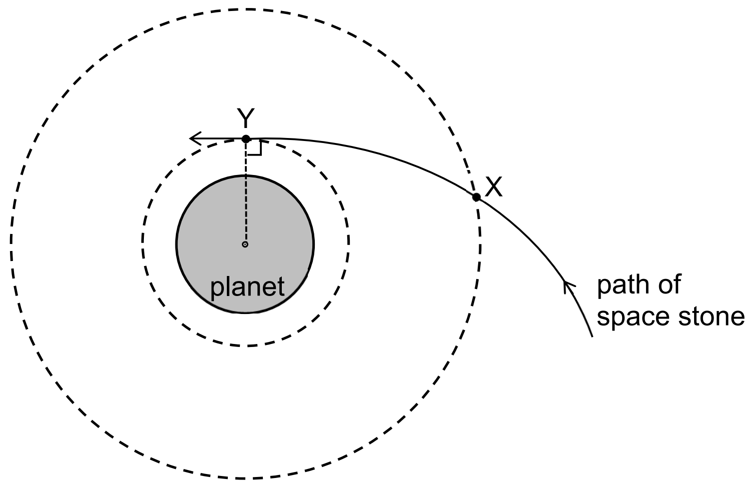

Fig. 6.3

Explain why the space stone will not move in a circular orbit around the planet when it reaches point Y.

Support your explanation with appropriate calculations and with reference to your answer in **(b)(ii)1.**

....

....

.... [4]

3. If the mass of the space stone is 1.5×10^5 kg, calculate the total energy of the space stone.

total energy = ... J [2]

4. Deduce if the space stone will escape the gravitational field of the planet after it passes through point Y.

State your reason.

....

....

.... [2]

7 A hyperloop is a potential super speed transportation system that consists of a system of tubes with vacuum interiors that makes it very energy efficient. People can travel in a hovering pod inside these vacuum tubes at speeds close to the speed of sound in air. Fig. 7.1 shows what a hovering pod in a hyperloop may look like.

A proposed route runs from Los Angeles to San Francisco Bay. It takes about half an hour to cover this 500 km route. This is considerably shorter than current rail or air times.

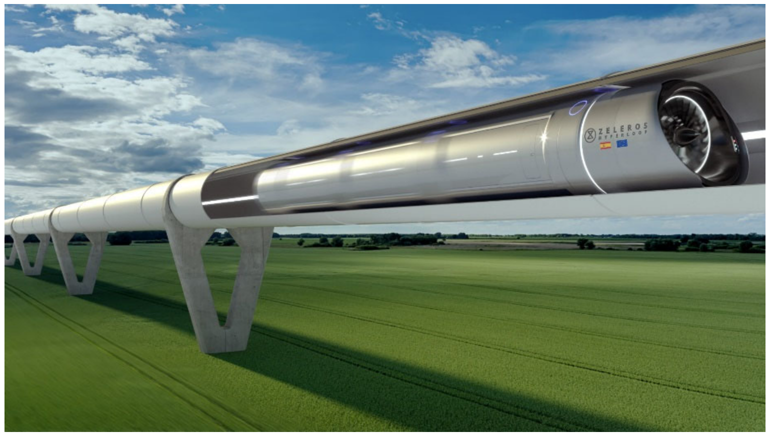

Fig. 7.1

Groups of engineers from different companies have conceptualised the idea and worked on prototypes of the hyperloops. The first stage of testing is to use computer simulations and compare it with experiments to see whether there are differences in the theoretical and actual results.

(a) In one computer simulation, the pod in the hyperloop starts from rest, accelerates uniformly before travelling at a constant speed, then finally decelerates uniformly to rest. Theoretical values of the distance *s* travelled by the pod at various times *t* are obtained. Fig. 7.2 shows the values of *s* for part of the journey from $t = 0.0$ min to $t = 3.0$ min.

t / min	*s* / m	*t* / min	*s* / m
0.0	0.000	1.6	13 310
0.2	209	1.8	16 440
0.4	835	2.0	19 570
0.6	1 879	2.2	22 700
0.8	3 341	2.4	25 830
1.0	5 220	2.6	28 960
1.2	7 517	2.8	32 090
1.4	10 230	3.0	35 220

Fig. 7.2

(i) Using kinematics equation(s) and relevant data from Fig. 7.2, show that the acceleration of the pod during the initial part of the journey is 2.9 m s^{-2}.

[1]

(ii) Estimate the time taken for the pod to accelerate to its constant speed. Explain your working.

time taken = ... min [3]

(iii) The technology of the hyperloop can actually accelerate the pod at accelerations much greater than $2.9\ \text{m s}^{-2}$.

Suggest a reason for not doing so despite potentially saving transport time.

....

....

.... [1]

(b) The engineers also studied the motion of objects that are dropped in the pod while it travels in the hyperloop. This study serves to inform them whether the high speed at which the pod travels may cause potential danger to passengers when objects are dropped in front of or behind them.

Fig. 7.3 shows a pod within a hyperloop tube travelling to the right at constant speed when a passenger in the pod releases a box from rest.

Fig. 7.4 shows the pod and passenger a while later when the box hits the floor of the pod.

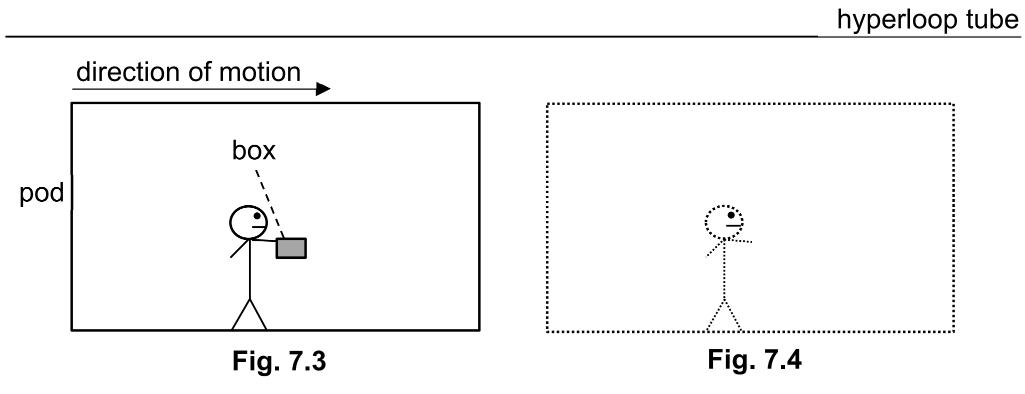

Fig. 7.3 **Fig. 7.4**

(i) **1.** On Fig. 7.4, draw the position of the box when it hits the floor of the pod. [1]

2. Draw the path of the box from the moment the box is released in Fig. 7.3 to the moment the box hits the floor in Fig. 7.4, as seen by an observer outside the pod. [1]

(ii) The pod now decelerates uniformly. The passenger repeats the experiment again by releasing the box just before the pod starts to decelerate and observes the motion of the box until it hits the floor.

Describe the motion of the box as observed by the passenger in the pod and compare the position of the box where it hits the floor with the position you have drawn in **(b)(i)1.**

....

....

....

.... [2]

(c) **(i)** In an experiment, a scaled-down prototype of the hyperloop is made with a straight tube that contains air. The engineers used this to study the effects of resistive forces on the motion of the pod travelling in such a hyperloop.

The known specifications of the prototype are such that the variation with the pod's speed v of the total resistive force F_R experienced by the pod is as shown in Fig. 7.5.

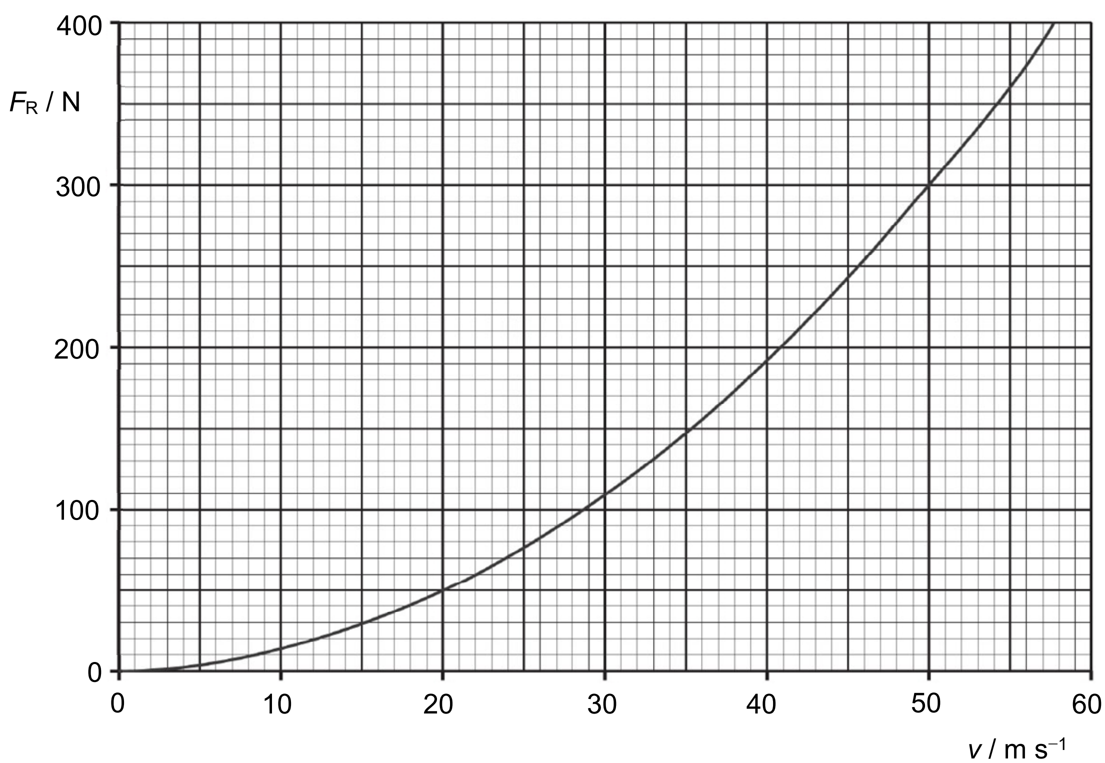

Fig. 7.5

During a test run, a constant driving force of 390 N is exerted on pod P in the forward direction. The variation with time t of pod P's speed v for the first 70 s is as shown in Fig. 7.6.

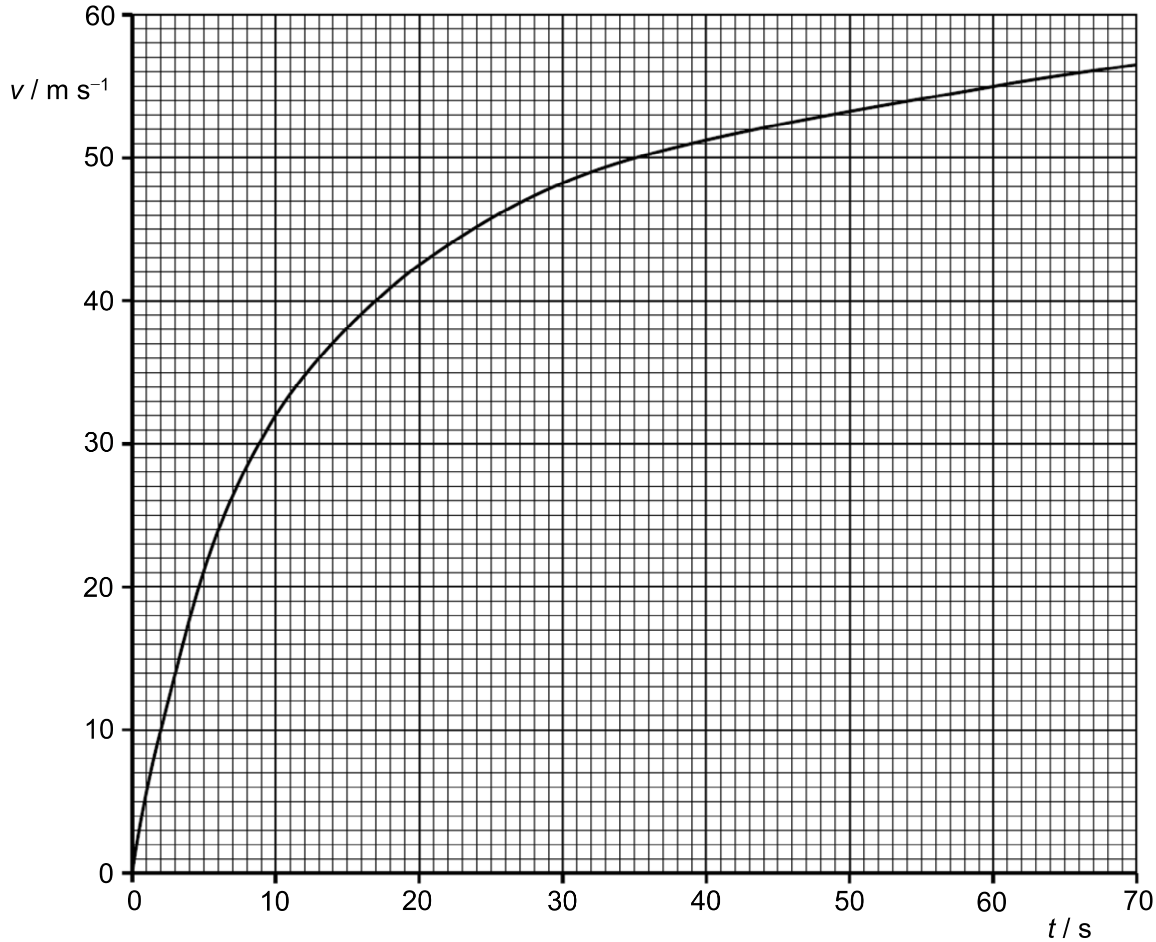

Fig. 7.6

1. Using Fig. 7.6, determine the acceleration of pod P at $t = 20$ s.

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

2. Hence, determine the mass of pod P.

mass = ... kg [2]

(ii) In another experiment, a second scaled-down prototype of the hyperloop is made with a straight vacuum tube, such that the pod experiences negligible resistive forces.

A constant driving force is exerted on pod Q, which is initially at rest in the vacuum tube. After 70 s, it reaches the same speed as pod P in **(c)(i)**.

1. On Fig. 7.6, shade an area that is equal to the difference in the distances travelled by pod P and pod Q during the first 70 s of their motion. [1]

2. A student states that although pod P and pod Q have travelled different distances in the same amount of time, the two pods have the same average acceleration during the first 70 s of their motion.

   State and explain if the student's statement is correct.

   ....

   ....

   ....

   .... [2]

END OF SECTION C