Name: ________________________ (   ) CT Group: 25S0 ____

RAFFLES INSTITUTION

2024 YEAR 5 PROMOTION EXAMINATION

H2 PHYSICS

9749

2 h 30 min

Section C

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Name, Index Number and CT Group 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 a 2B pencil for any diagrams or graphs.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
21	/ 17
22	/ 19
Deductions	

There are **11** printed pages, inclusive of the cover page, in this booklet.

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

An earthquake is the shaking of the Earth's surface resulting from a sudden release of energy in the outermost rocky shell of Earth that creates seismic waves. Earthquakes can range in intensity, from those so weak they cannot be felt, to those violent enough to propel objects and people into the air, damage critical infrastructure, and wreak destruction across entire cities.

Earth is made up of several layers, namely, the core, mantle and crust as shown in Fig. 21.1.

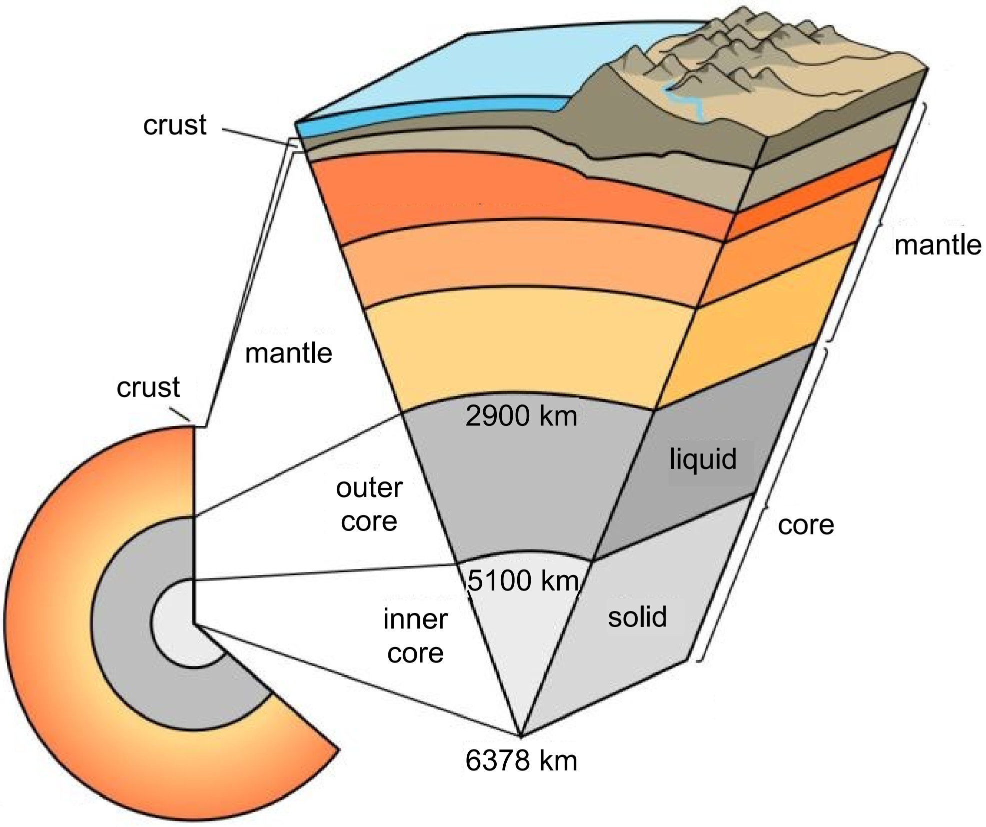

Fig. 21.1 (not to scale)

The core is made of two layers, i.e., the inner core and the outer core. The inner core at the centre of Earth is a hot, dense ball of solid iron. The outer core which is sandwiched between the inner core and the mantle is composed of liquid iron and nickel. The mantle is the largest and thickest layer of Earth, making up 84% of the planet's total volume and its structure is mostly silicate. The outermost layer known as the crust is thin and rigid. The crust is mostly made up of rocks.

Earthquakes occur in the mantle or crust. They can occur naturally or be induced by human activities, such as mining, fracking (hydraulic fracturing) and nuclear tests. The initial point of rupture is called the hypocentre or focus while the ground level directly above it is the epicentre. Earthquakes are primarily caused by geological faults but also by volcanic activity, landslides, and other seismic events.

Every earthquake produces different types of seismic waves, which travel through rock with different velocities, i.e., the longitudinal P-waves (also known as shock or pressure waves), the transverse S-waves (shear waves) and surface waves (also known as Rayleigh and Love waves). Propagation velocity of the seismic waves varies depending on the density and elasticity of the medium. In the Earth's interior, the P-waves travel much faster than the S-waves. The differences in travel time from the epicentre to the observatory are a measure of the distance and can be used to image both sources of earthquakes and structures within the Earth. The depth of the hypocentre can also be computed roughly.

(a) Distinguish between a longitudinal wave and a transverse wave.

....

....

....

.... [2]

(b) A large earthquake occurs very near the surface of the Earth at a particular location and both seismic P-waves and S-waves are produced. The P-waves and S-waves travel through the Earth away from the epicentre of the earthquake.

The average speed of the P-waves is 7.98 km s^{-1} and the average speed of the S-waves is 4.75 km s^{-1}. A seismograph which measures and records the vibrations of the earthquake detects the arrival of the S-waves 2 minutes 50 seconds after the arrival of the P-waves.

(i) Calculate the time taken for the S-waves to travel from the epicentre of the earthquake to the seismograph.

time taken = ... s [2]

(ii) Determine the distance of the epicentre of the earthquake from the seismograph.

distance = ... km [1]

(c) Fig. 21.2 shows an epicentre at point A and a seismograph at point B which is located on the opposite side of the Earth.

Fig. 21.2

Explain why the seismograph can detect the P-waves but not the S-waves produced by the earthquake.

....

.... [1]

(d) Peak Ground Acceleration (PGA) is the maximum acceleration of the ground during an earthquake. To gauge the potential damage of earthquakes, the United States Geological Survey measures PGA to create an intensity scale for the effects of earthquakes. This scale is shown in Table 21.1.

Table 21.1

intensity scale	PGA / m s^{-2}	maximum ground velocity / m s^{-1}	perceived shaking	potential damage
I	$<$ 0.017	$<$ 0.001	not felt	none
II–III	0.017 – 0.14	0.001 – 0.011	weak	none
IV	0.14 – 0.38	0.011 – 0.034	light	none
V	0.38 – 0.90	0.034 – 0.081	moderate	very light
VI	0.90 – 1.8	0.081 – 0.16	strong	light
VII	1.8 – 3.3	0.16 – 0.31	very strong	moderate
VIII	3.3 – 6.4	0.31 – 0.60	severe	moderate to heavy
IX	6.4 – 12.2	0.60 – 1.16	violent	heavy
X+	$>$ 12.2	$>$ 1.16	extreme	very heavy

(i) Assuming that the ground movements can be modelled as simple harmonic oscillations, calculate the frequency and the amplitude of the strongest earthquake within the intensity scale of V.

frequency = ... Hz

amplitude = ... m [3]

(ii) Earthquakes can cause the ground to accelerate in three perpendicular directions, x, y and z, as shown in Fig. 21.3.

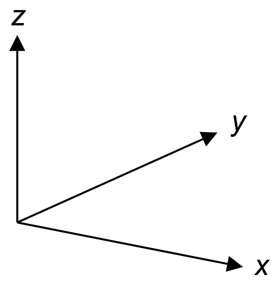

Fig. 21.3

During a particular earthquake, the maximum ground accelerations along x, y and z are:

$$a_x = 8.0 \text{ m s}^{-2},\ a_y = a_z = 1.5 \text{ m s}^{-2}$$

Show that the maximum possible resultant ground acceleration that could be produced by these vibrations is 8.3 m s^{-2}.

[2]

(iii) Explain why, in reality, the maximum resultant ground acceleration might be less than 8.3 m s^{-2}.

....

.... [1]

(e) It is suggested that the Peak Ground Acceleration (PGA) decreases with distance *r* from the epicentre according to the equation:

$$\text{PGA} = \frac{k}{r}$$

where *k* is a constant.

Table 21.2 shows some data from an earthquake.

Table 21.2

distance *r* from epicentre / km	56	84	120	220
PGA / m s^{-2}	0.71	0.60	0.50	0.32

Use the data in Table 21.2 to explain whether the suggested equation is valid.

[2]

(f) During an earthquake, the amplitude of a particular building's oscillation is observed to be much larger than the amplitude of the movements of the ground.

(i) State the name of this phenomenon.

....

.... [1]

(ii) State two properties of the building that will affect how strongly it responds to the earthquake vibrations.

....

....

....

.... [2]

[Total: 17]

22 Springs are commonly used in a vehicle suspension system. A truck is supported by four identical springs. Fig. 22.1 shows the side view of the truck. Assume that the springs obey Hooke's law.

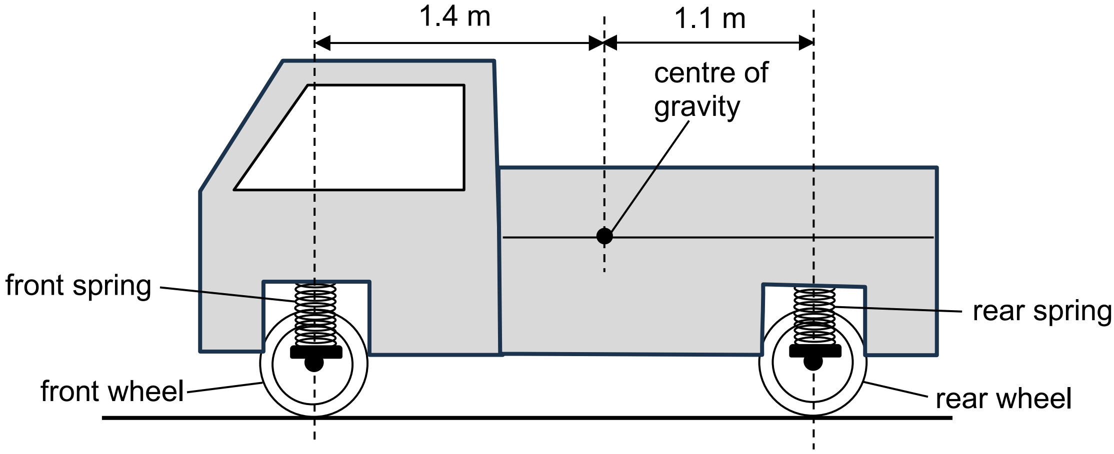

Fig. 22.1 (not to scale)

The body of the truck, which excludes the springs and wheels, has a mass of 1400 kg. The distances from the front wheels and rear wheels to the centre of gravity are 1.4 m and 1.1 m respectively.

(a) Define the moment of a force about a point.

....

.... [1]

(b) The truck is stationary.

(i) Calculate the force exerted on the body of the truck by each of the rear springs.

force = ... N [2]

(ii) The spring constant for each of the springs is 1.0×10^5 N m^{-1}.

Calculate the compression of each of the rear springs.

compression = ... m [2]

(iii) A metal box of weight 2500 N is placed on the truck above the rear springs. There is no change in the compression of the front springs.

Determine the increase in elastic potential energy E_P of each of the rear springs due to the loading of this box.

increase in E_P of each of the rear springs = ... J [3]

(c) The maximum power of the engine of the truck is 70 kW and the truck has a maximum speed of 60 km h^{-1}.

Determine the total resistive force acting on the truck when the truck is moving at its maximum speed.

resistive force = ... N [2]

(d) The engine of the truck breaks down when the truck is on a slope of inclination 20°, as shown in Fig. 22.2. A recovery vehicle tows the truck from rest at point P up the slope to a service centre, with the tow cable having a constant tension of 9.0×10^3 N.

The total weight of the truck including the wheels, the springs and the metal box is 1.8×10^4 N. The ratio of the frictional force f on the truck to the normal contact force N on the truck is given by:

$$\frac{f}{N} = 0.030\,.$$

Assume air resistance is negligible.

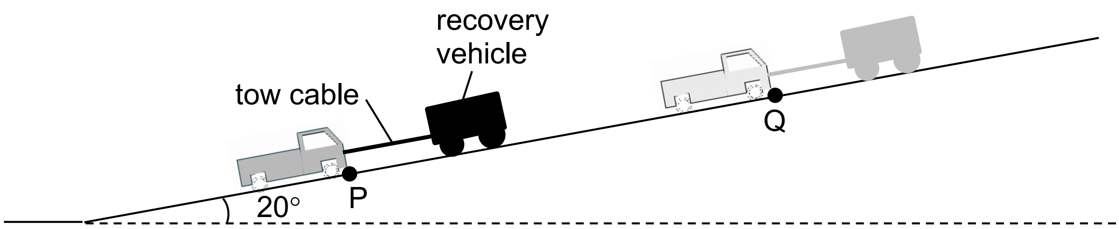

Fig. 22.2

(i) Determine the acceleration of the truck.

acceleration = ... m s^{-2} [3]

(ii) At time t = 0, the truck moves off from point P. At $t = t_Q$, the truck is at point Q when the tow cable suddenly breaks.

1. Determine the magnitude of the acceleration of the truck immediately after the tow cable breaks.

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

2. At $t = t_P$, the truck is back at point P.

On the axes of Fig. 22.3, sketch a graph to show the variation with time t of the kinetic energy E_K of the truck for values of t from t = 0 to $t = t_P$.
Label t_P and t_Q.

Fig. 22.3

[4]

[Total: 19]