Name: ________________________ (   ) **CT Group: 23S0** ____

RAFFLES INSTITUTION

2022 YEAR 5 JULY COMMON TEST

H2 PHYSICS

Section B

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section B in the spaces provided in this booklet.

For Examiner's Use		
Section A	MCQ	/ 15
Section B	16	/ 9
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Deductions		
Total		/ 95

There are 18 printed pages, inclusive of the cover page, in this booklet.

16 Drag coefficient is a quantity used to quantify the drag force acting on an object in a fluid environment. A smaller drag coefficient indicates that an object has less aerodynamic drag.

The drag coefficient C_d of a steel ball of diameter d and mass m when it falls through a fluid of density ρ at terminal speed v is given by the expression

$$C_d = \frac{8mg}{\pi \rho v^2 d^2}$$

where g is the acceleration of free fall.

(a) Determine the SI base units of C_d.

SI base units of C_d = ... [2]

(b) In an experiment to determine the drag coefficient of a steel ball falling through air, the following measurements are made:

d = (9.6 ± 0.1) mm
m = (3.64 ± 0.01) g
g = (9.81 ± 0.03) m s^{-2}
ρ_{air} = (1.23 ± 0.02) kg m^{-3}
v = (39.8 ± 0.1) m s^{-1}

(i) State the instrument that was used to measure d.

.... [1]

(ii) Determine C_d, with its actual uncertainty. Give your answer to an appropriate number of significant figures.

C_d = ... ± .... [4]

(iii) Suggest two methods to reduce the uncertainty in the measurement of the diameter of the steel ball.

1 ....

....

2 ....

.... [2]

17 In an attempt to chase his enemy, Captain America rides his motorbike up a ramp inclined at an angle of 30° to jump over 14 identical crates of length 1.5 m and height 1.5 m as shown in Fig. 17.1.

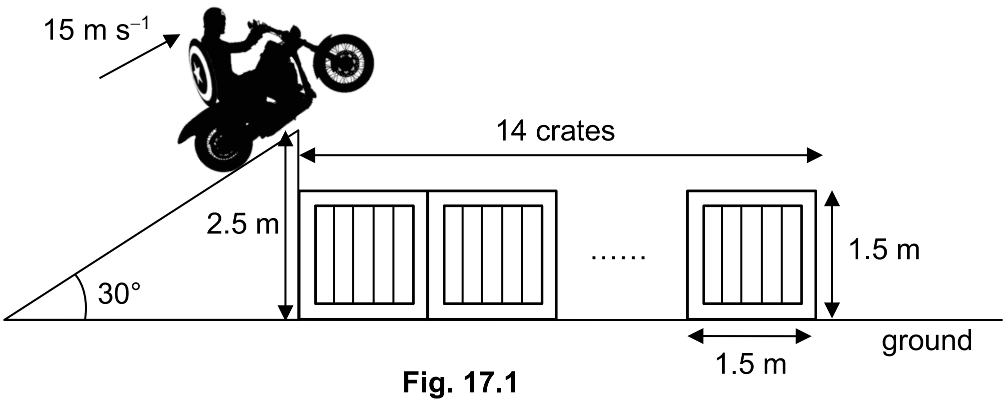

Fig. 17.1

The motorbike leaves the ramp at a speed of 15 m s^{-1}.

(a) Determine the horizontal and vertical components of the initial velocity of the motorbike.

horizontal component of initial velocity = ... m s^{-1}

vertical component of initial velocity = ... m s^{-1} [2]

(b) Show that the motorbike will be able to go over all the 14 crates without hitting the crates.

[3]

(c) Determine the velocity of the motorbike just before it lands on the ground.

magnitude of velocity = ... m s^{-1}

direction of velocity = ... [3]

(d) In another chase, Captain America rides his motorbike up another ramp that is inclined at a greater angle of 35° as shown in Fig. 17.2. He leaves the ramp with a velocity that has the same horizontal component as calculated in **(a)**.

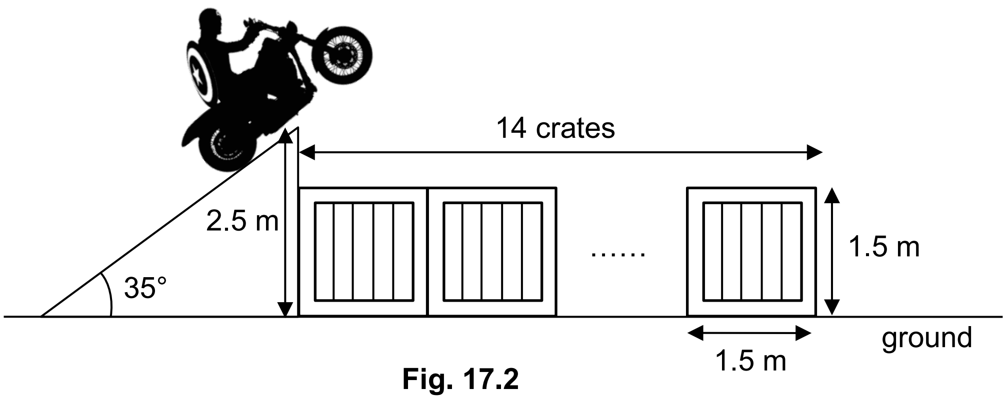

Fig. 17.2

Without any calculation, state and explain whether the horizontal displacement of the motorbike when it lands on the ground is greater than, smaller than or equal to that of the first chase.

....

....

....

.... [2]

18 A metal sphere A of mass 0.050 kg is suspended from a fixed point. It is pulled aside and released so that it swings and collides head-on with another identical metal sphere B at its lowest point as shown in Fig. 18.1.

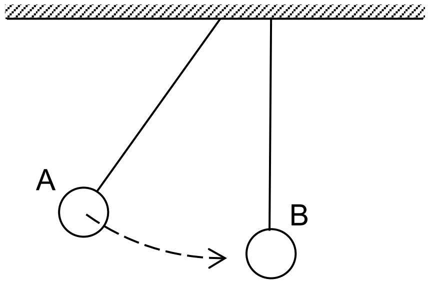

Fig. 18.1

(a) Identify the external forces acting on the system of the two spheres during their collision. You may ignore air resistance.

.... [1]

(b) Explain why, despite the presence of external forces, the principle of conservation of momentum may still be applied to determine the speeds of the two spheres immediately after the collision.

....

....

....

.... [2]

(c) The variation with time *t* of the force exerted by sphere A on sphere B during the collision is shown in Fig. 18.2.

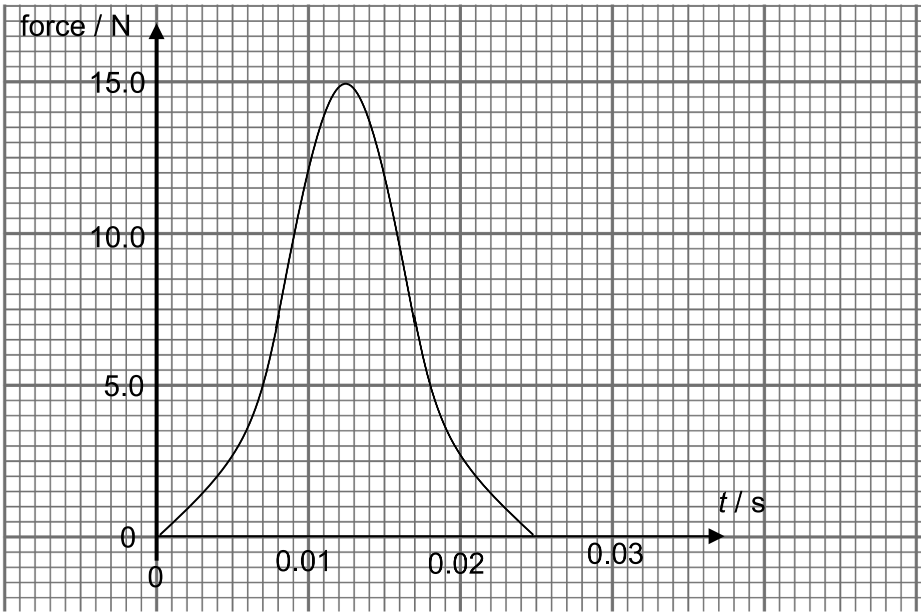

Fig. 18.2

Estimate the impulse exerted by sphere A on sphere B during the collision.

impulse = ... N s [2]

(d) The velocity of sphere A just before collision is 4.0 m s^{-1}.

Determine the speeds of the two spheres immediately after the collision.

speed of sphere A = ... m s^{-1}

speed of sphere B = ... m s^{-1} [2]

(e) **(i)** With reference to Fig. 18.2, state the value of *t* during the collision at which the two spheres move with a common speed.

t = ... s [1]

(ii) Determine the value of this common speed.

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

19 Fig. 19.1 shows a window panel that is hinged at its top end to a wall and supported by a rod.

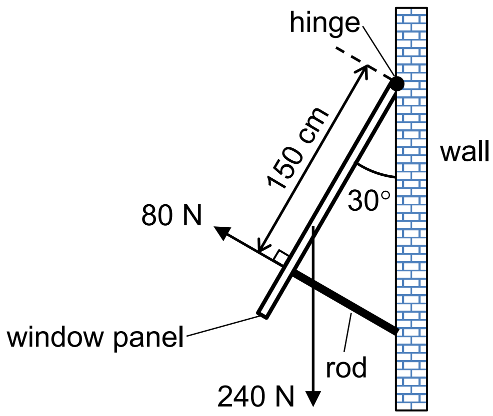

Fig. 19.1

The window panel of weight 240 N is at an angle of 30° to the vertical. The rod exerts a force of 80 N perpendicular to the window panel at a distance of 150 cm from the hinge.

(a) Explain two conditions required for the window panel to be in a state of equilibrium.

1 ....

....

2 ....

.... [2]

(b) State what is meant by the centre of gravity of the window panel.

....

.... [1]

(c) Use the principle of moments to determine the distance between the centre of gravity of the window panel and the hinge.

distance = ... cm [2]

(d) On Fig. 19.1, draw an arrow to indicate the direction of the force on the window panel at the hinge.

[2]

(e) Determine the magnitude of the force acting on the window panel at the hinge.

magnitude of force = ... N [3]

20 **(a)** A box of mass m is moving horizontally with an initial speed u as shown in Fig. 20.1. It is acted on by a constant horizontal force F. The body accelerates uniformly to a final speed v over a distance s.

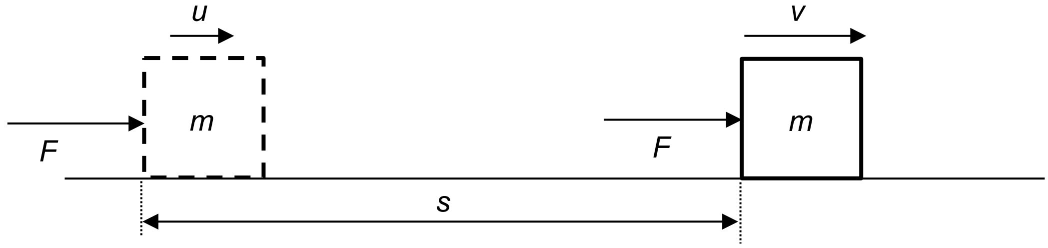

Fig. 20.1

Assuming no resistive forces, start from the definition of work done and use the equations for uniformly accelerated motion in a straight line to derive an expression in terms of m, u and v for the increase in kinetic energy of the box after moving a distance s.

[2]

(b) The box of mass 5.0 kg is now placed on a slope at an angle of 20° to the horizontal as shown in Fig. 20.2. A constant force F of 25 N acts on the box that is initially at rest at the bottom of the slope, causing it to move a distance of 3.0 m up the slope to a point P. There is a constant frictional force of 4.0 N between the box and the slope.

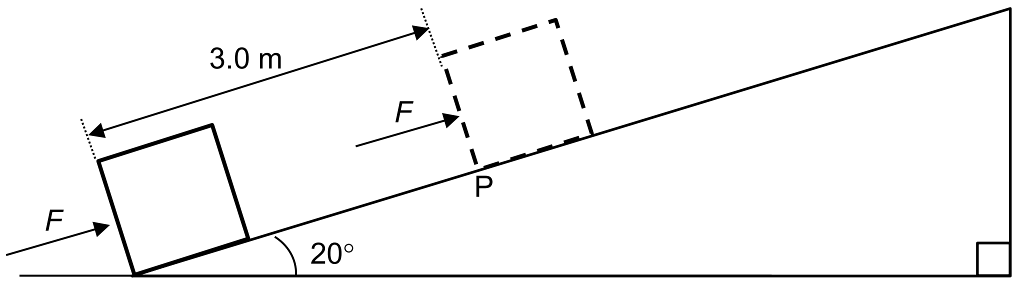

Fig. 20.2

(i) Determine the speed v of the box at point P.

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

(ii) The force stops acting on the box at point P. The box continues to move up the slope for a short distance before sliding down to the same starting point at the bottom of the slope.

A student states that the total work done by friction is zero as the net displacement is zero.

Discuss whether this statement is correct.

....

....

....

.... [2]

(iii) On Fig. 20.3, sketch lines to show the variation of the kinetic energy of the box with displacement s from the bottom of the slope where s = 0 to the highest point on the slope reached by the box.

1. when it is moving up the slope

2. when it is moving down the slope.

Use solid and dotted lines for **(1.)** and **(2.)** respectively. [2]

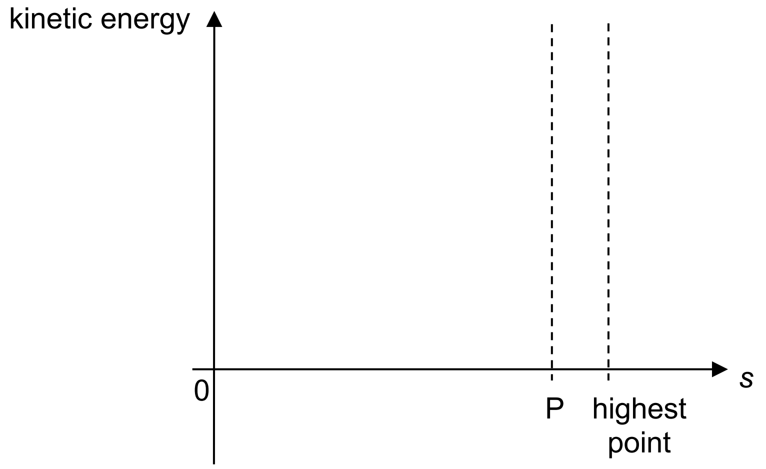

Fig. 20.3

(iv) When the box moves from the bottom of the slope where s = 0 to point P, the increase in kinetic energy is E_K and the work done by F is W.

Without any further calculation, state and explain how the ratio $\frac{E_K}{W}$ changes when the angle of slope is increased to 23° for the same distance moved along the slope.

....

.... [1]

21 **(a)** Explain why a body travelling at a constant speed in a circle has an acceleration.

....

....

....

.... [2]

(b) A small smooth ring R, of mass m, is threaded through an inextensible string of length L. The ends of the string are tied securely to both ends of a light horizontal rod AB of length r as shown in Fig. 21.1.

Rod AB is rotated in the horizontal plane about the end A. At a particular constant angular speed ω, the ring lies a distance b vertically below end B. In this position, the string is at an angle θ to the vertical.

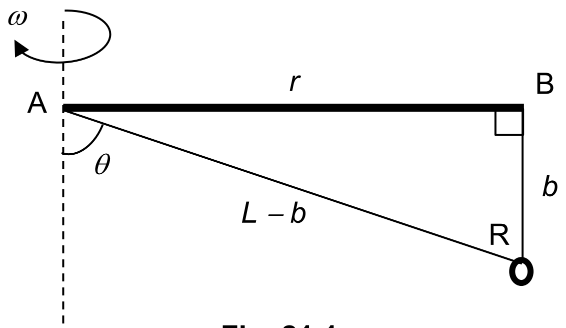

Fig. 21.1

(i) The tension in the string is constant throughout the string and has a magnitude of T.

On Fig. 21.1, draw arrows, and label with the letter T, to represent the tension in the sections AR and BR acting at the point R.

[1]

(ii) By considering the forces acting on the ring in the vertical and horizontal directions separately, show that

$$\omega^2 = \frac{g}{L}.$$

[4]

(iii) The length L of the string is 0.83 m and the distance b is 0.25 m.

1. Determine the frequency of rotation f.

f = ... Hz [2]

2. Rod AB stops rotating and the whole system comes to a rest.

Determine the new angle θ.

θ = ... ° [2]

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

A hovercraft is an amphibious craft capable of travelling over land, water, mud, ice, and other surfaces. The first practical design for the hovercraft was derived from a British invention in the 1950s. They are now used throughout the world as specialised transport in disaster relief, coastguard, military, and survey applications, as well as for sports or passenger services. In civilian applications, very large versions are used to transport hundreds of people and vehicles across the English Channel. Similarly, in military applications, they are used to transport tanks, soldiers and large equipment in hostile environments and terrains.

A hovercraft uses a fan to produce a large volume of air below the hull, around which there is a skirting to form an air cushion, as shown in Fig. 22.1. The pressure difference between the higher pressure of the air cushion and lower pressure of the ambient air above it allows the hull to float above a surface.

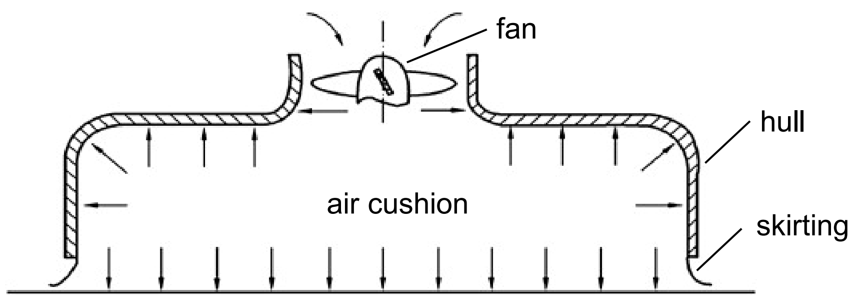

Fig. 22.1

To move forward, hovercrafts use propellers to push air backwards. This produces a forward horizontal thrust, as shown in Fig. 22.2. Steering of a hovercraft is achieved using a rudder that is located behind the propeller. The rudder can rotate left or right to redirect the air from the propeller and turn the hovercraft.

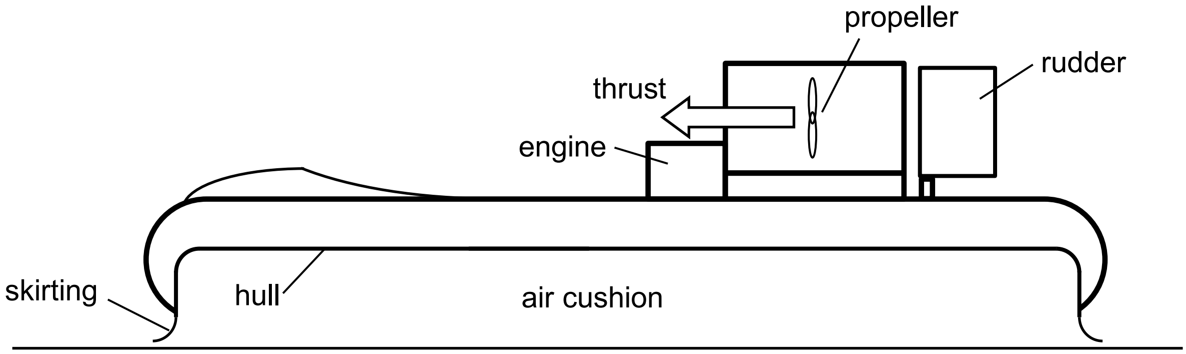

Fig. 22.2

With many hovercrafts, the propeller is driven by a separate engine from the one used to produce the air cushion. For some other hovercrafts, the same engine is used to produce both the thrust and air cushion.

The maximum speed at which a hovercraft can travel depends on the surface it is travelling over. For example, a hovercraft will have a higher maximum speed over smooth ice than over calm water. For different surfaces, a hovercraft will have a speed at which it can travel most efficiently, and this is called “cruising speed”.

A four passenger hovercraft designed for rescue services has a single engine. When it is moving, 30% of the power of the engine is used to produce the air cushion while the rest is used to produce thrust.

The data for this hovercraft is given in Table 22.1.

Table 22.1

Maximum speed over calm water	72 km h^{-1}
Maximum speed over land	64 km h^{-1}
Maximum speed over smooth ice	80 km h^{-1}
Maximum speed over firm snow	72 km h^{-1}
Cruising speed over calm water	56 km h^{-1}
Fuel consumption at cruising speed	13.3 litres h^{-1}
Maximum power output of engine	40.5 kW
Mass of empty hovercraft	230 kg
Maximum load	350 kg
Length	4200 mm
Width	2100 mm
Height	1300 mm
Diameter of propeller	0.71 m
Fuel capacity	49 litres

(a) Explain how the pressure difference between the air cushion and ambient air allows the hovercraft to float above a surface.

....

.... [1]

(b) The horizontal area of the air cushion is 8.5 m^2. Determine the average pressure in the air cushion in excess of atmospheric pressure when the hovercraft is carrying its maximum load.

pressure = ... Pa [2]

(c) (i) Suggest why the maximum speed of the hovercraft is the greatest when it is travelling over smooth ice.

....

.... [1]

(ii) Calculate the thrust of the hovercraft when it is travelling at its maximum speed over ice.

thrust = ... N [3]

(d) When the hovercraft is at rest over calm water, the propeller accelerates air horizontally from rest to a velocity v. The thrust produced is 630 N.

The density of air is 1.2 kg m^{-3}.

(i) Show that the mass of air that passes through the propeller in 1.0 s is 0.475v. Assume that the air moves horizontally in a cylindrical shape with the same diameter as the fan.

[1]

(ii) Hence, calculate the value of v.

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

(iii) Calculate the acceleration of a fully loaded hovercraft.

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

(e) The resistive force acting on the hovercraft is proportional to the square of its velocity when it is travelling over calm water.

(i) Determine the power output of the engine when the hovercraft is travelling over water at cruising speed.

power output = ... kW [3]

(ii) On the axes of Fig. 22.3, sketch the variation with time t of the acceleration a of the hovercraft as it accelerates from rest to its maximum speed over water at maximum power.

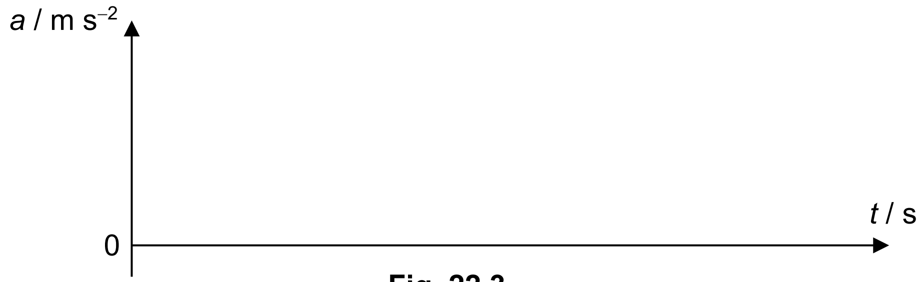

Fig. 22.3

[1]

(iii) Fuel efficiency is measured by the distance travelled per litre of fuel. Explain why fuel efficiency of the hovercraft decreases with higher speeds.

....

....

....

.... [2]

(f) In Singapore, the Changi Airport Emergency Service uses hovercrafts for rescue missions in both shallow and deep water up to 20 km away.

State and explain two reasons why a hovercraft is preferred as compared to a typical propellor driven boat.

1 ....

....

2 ....

.... [2]