Name: ____________________________ (   ) CT Group: 22S0 _______

RAFFLES INSTITUTION

2021 YEAR 5 TERM 3 COMMON TEST

30 June 2021

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 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		
Section A	MCQ	/ 15
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Deductions		
Total		/ 95

This document consists of **19** printed pages.

Section B (80 marks)

1 An equation that governs gas-flow through a cylindrical tube is given by

$$Z = \frac{cr^3\left(p_1 - p_2\right)}{L}\sqrt{\frac{m}{RT}},$$

where c is a unitless constant,
r is the internal radius of the tube,
p_1 and p_2 are the pressures at the ends of the tube,
L is the length of the tube,
m is the molar mass of the gas (in kg mol^{-1}),
R is the molar gas constant (in kg m^2 s^{-2} K^{-1} mol^{-1}), and
T is the thermodynamic temperature of the gas.

(a) Show that the SI base unit of pressure is kg m^{-1} s^{-2}.

[1]

(b) Determine the SI base unit of the quantity Z.

base unit = ... [2]

(c) Experiments on gas-flow through a cylindrical tube are conducted. The pressure difference ($p_1 - p_2$) between two points along the tube is recorded as 800 101 Pa by a pressure gauge as shown in Fig.1.1. However, the manufacturer of the pressure gauge states that its measurements have a percentage uncertainty of 2.5%.

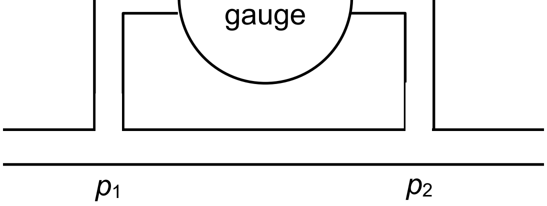

Fig. 1.1

(i) Determine the absolute uncertainty in the value of ($p_1 - p_2$).

absolute uncertainty = ... Pa [2]

(ii) Hence, state ($p_1 - p_2$), with its uncertainty, to an appropriate number of significant figures in terms of MPa.

($p_1 - p_2$) = ... ± .... MPa [1]

(d) In addition to the information given in **(c)**, the internal diameter d is found to be (3.34 ± 0.03) mm and the length L is found to be (0.153 ± 0.001) m. It is estimated that the percentage uncertainties in temperature T and molar mass m are 2.8% and 1.7%, respectively, due to random errors.

(i) Distinguish between *systematic errors* and *random errors* in the measurement of a physical quantity.

....

....

....

....

....

.... [2]

(ii) Determine the percentage uncertainty in the value of Z.

percentage uncertainty = ... % [2]

2 **(a)** In the 1992 Barcelona Olympics opening ceremony, an archer stood at a distance of 60 m from the base of a tower. The archer shot a flaming arrow at an angle θ from the horizonal to light the Olympic cauldron on top of the tower that is 24 m above him. The flaming arrow lit the cauldron at the peak of its trajectory as shown in Fig. 2.1.

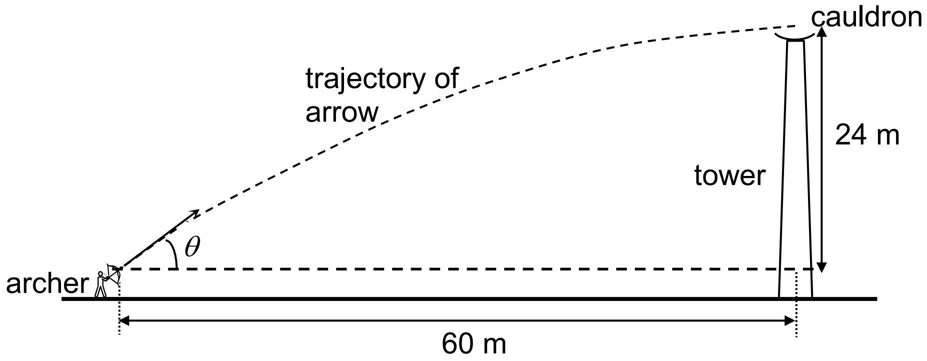

Fig. 2.1

(i) Show that the arrow took 2.2 s to reach the cauldron. Ignore air resistance.

[3]

(ii) Calculate the initial horizontal speed of the arrow.

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

(iii) Determine the angle θ.

θ = ... ° [2]

(b) A cart carrying a ball accelerates down a long plane inclined at an angle ϕ to the horizontal as shown in Fig. 2.2. The cart then launches the ball such that the ball's initial velocity with respect to the cart is perpendicular to the motion of the cart. The ball is under free fall after it was launched from the cart.

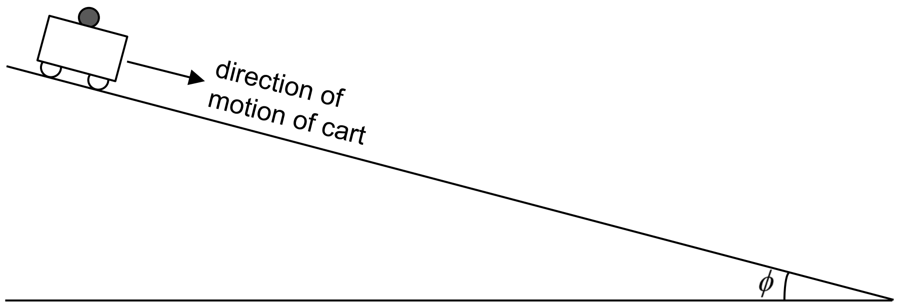

Fig. 2.2

(i) On Fig. 2.2, sketch the trajectory of the ball after it was launched from the cart, as viewed by a person on the ground.

[1]

(ii) Express the cart's acceleration along the plane in terms of ϕ and the acceleration of free fall *g*.

acceleration = ... [1]

(iii) By comparing the component of the ball's acceleration that is parallel to the plane with your answer in **(b)(ii)**, state and explain whether the ball will land back on the cart.

....

....

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....

.... [2]

3 Balls A and B are two identical balls, each of mass 0.22 kg and radius 0.030 m. The initial distance between the centres of the balls is 0.950 m.

The balls then move towards each other head on with an initial speed of 0.20 m s^{-1} as shown in Fig. 3.1.

All surfaces are assumed to be frictionless.

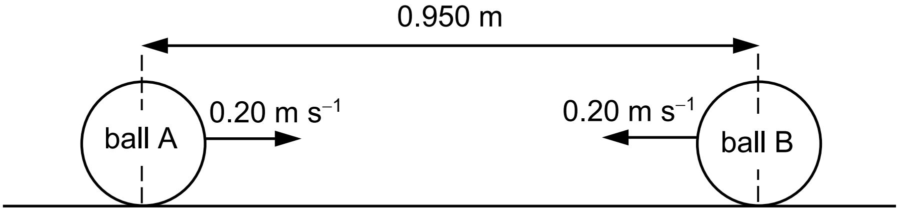

Fig. 3.1

(a) Determine the time taken for the balls to come in contact.

time taken = ... s [2]

(b) The balls collide and are in contact for 0.070 s before they reverse their direction of motion and move off with the same speed as each other. During the collision, 20% of the kinetic energy of the balls is lost as thermal energy.

(i) State with a reason the type of collision the balls underwent.

....

.... [1]

(ii) Calculate the speed of the balls after collision.

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

(iii) Calculate the magnitude of the average force acting on ball A during its collision with ball B.

magnitude of average force = ... N [2]

(iv) **1.** On Fig 3.2, sketch separate graphs for ball A and ball B to show the variation with time t of each ball's acceleration a.

Your graphs should be for the duration when balls A and B were initially 0.950 m apart at t = 0 to after they collide and move off.

Include appropriate values of t and label your graphs A and B for balls A and B respectively.

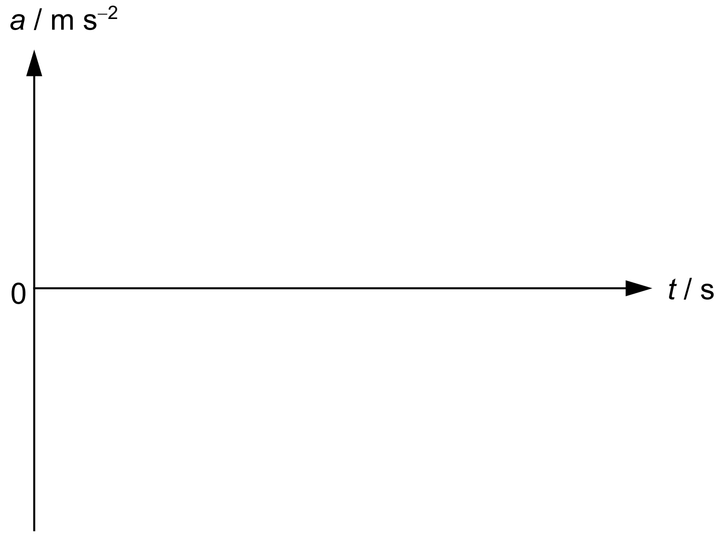

Fig 3.2

[2]

2. If the mass of ball A is now greater than the mass of ball B, sketch on Fig. 3.3, a new set of graphs to show the variation with time t of each ball's acceleration a, over the same duration as in **(b)(iv)1.**

Include appropriate values of t and label your graphs A' and B' for balls A and B respectively.

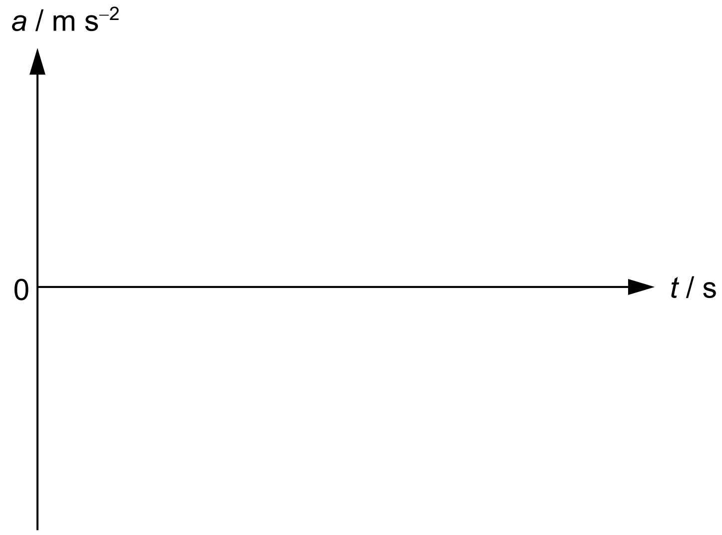

Fig 3.3

Using Newton's laws of motion, explain how your graphs A' and B' compare with each other.

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....

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....

.... [2]

4 **(a)** State the two conditions necessary for a system to be in equilibrium.

....

....

....

.... [2]

(b) A uniform awning of mass 200 kg and length 2.00 m is hinged to a vertical wall at A and is supported by a steel cable at S and a steel beam at R.

The steel cable and steel beam are fixed to the wall at P and Q respectively. The steel beam exerts a force *F* of 400 N normal to the awning as shown in Fig. 4.1. A signboard of mass 20 kg hangs from the end of the awning at B.

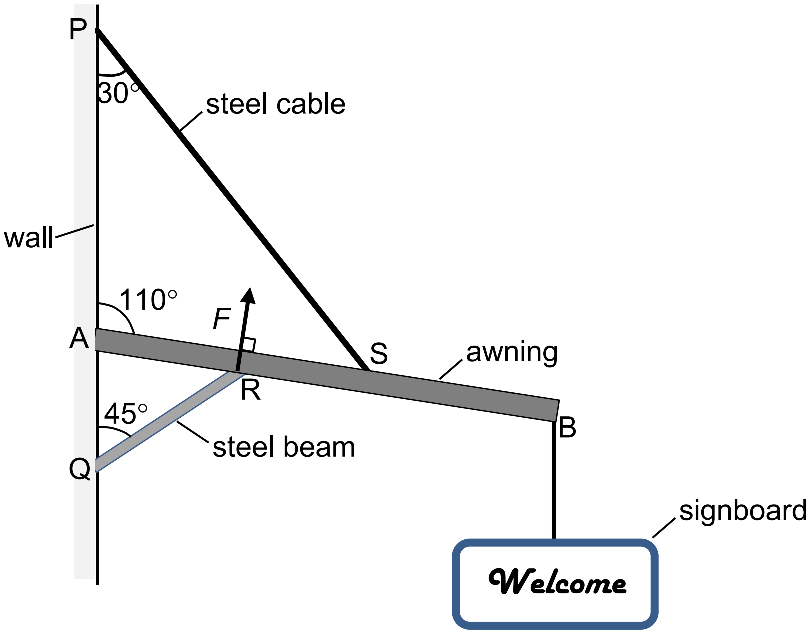

Fig. 4.1

The angles that the steel cable, awning and the steel beam make with the wall are 30°, 110° and 45° respectively. The distances AR and AS along the length of the awning are 0.80 m and 1.20 m respectively. The entire structure is in equilibrium.

Calculate

(i) the tension in the steel cable,

tension = ... N [2]

(ii) the magnitude and direction of the resultant force that the wall exerts on the awning at A.

resultant force = ... N

direction = ... [5]

(iii) The tension in the steel cable needs to be reduced so that it does not exceed the maximum allowable tension.

To reduce the tension in the steel cable, state and explain whether the position S on the awning where the steel cable is attached to should be shifted towards A or B.

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....

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....

....

.... [2]

5 Fig. 5.1 shows a movable trolley on a smooth table, attached to a brick by means of a light elastic rope. The elastic rope is supported by a smooth pulley.

The masses of the trolley and brick are 2.50 kg and 1.50 kg respectively. The elastic rope obeys Hooke's Law and has a force constant of 75.0 N m^{-1}.

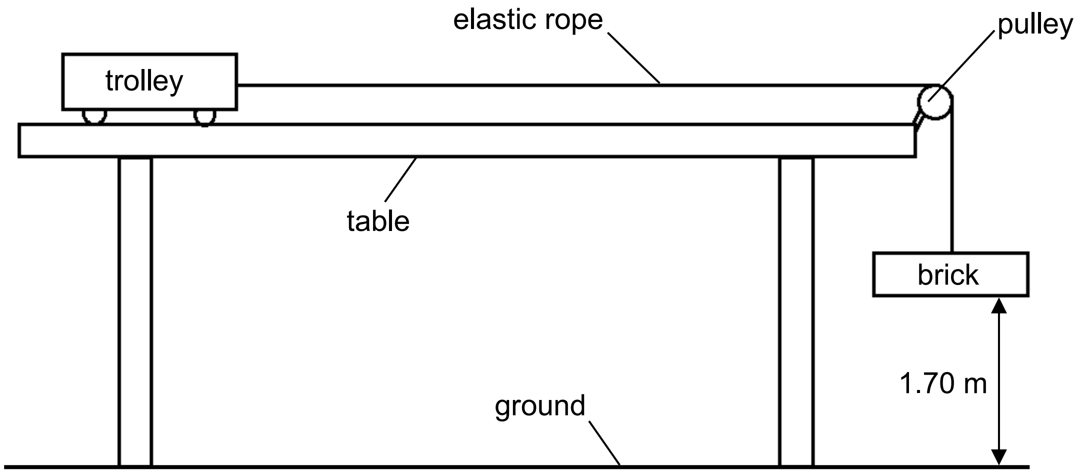

Fig. 5.1

(a) Initially, the trolley is held in place such that the trolley and the brick are both at rest, and the brick is 1.70 m above the ground.

(i) Show that the extension of the elastic rope is 0.196 m.

[1]

(ii) Calculate the elastic potential energy stored in the elastic rope.

elastic potential energy = ... J [1]

(b) The trolley is then released from rest and the extension of the elastic rope decreases during the initial part of the motion.

After the brick has fallen through a distance of 0.50 m, the accelerations of the trolley and the brick are both 3.68 m s^{-2} and the length of the elastic rope stops changing.

Thereafter for the remaining distance of 1.20 m, the speeds of the trolley and brick are equal at all times until the brick hits the ground.

(i) After the length of the elastic rope stops changing,

1. determine the resultant force on the brick,

resultant force = ... N [1]

2. calculate the work done on the brick by the resultant force as it falls through the remaining distance of 1.20 m,

work done = ... J [1]

3. state the increase in the kinetic energy of the brick after it falls through the remaining distance of 1.20 m,

increase in kinetic energy = ... J [1]

4. calculate the instantaneous rate of increase in kinetic energy of the brick when it is falling at a speed of 2.80 m s^{-1}.

rate of increase in kinetic energy = ... J s^{-1} [2]

(ii) The tension in the elastic rope remains at 9.20 N after its length stops changing and until the brick hits the ground.

From the time the trolley is released to the time the brick hits the ground, calculate

1. the decrease in the elastic potential energy of the rope,

decrease in elastic potential energy = ... J [3]

2. the total final kinetic energy of the trolley and the brick.

total final kinetic energy = ... J [2]

6 A ball is initially travelling along a smooth horizontal ground with a speed of 4.0 m s^{-1} as shown in Fig. 6.1.

It then slides up a hill and passes by the highest point P, which is 0.50 m above the ground. It continues to slide down into a valley and passes by the lowest point Q, which is 0.50 m below the ground.

The radii of curvature of the hill and the valley are both 1.5 m.

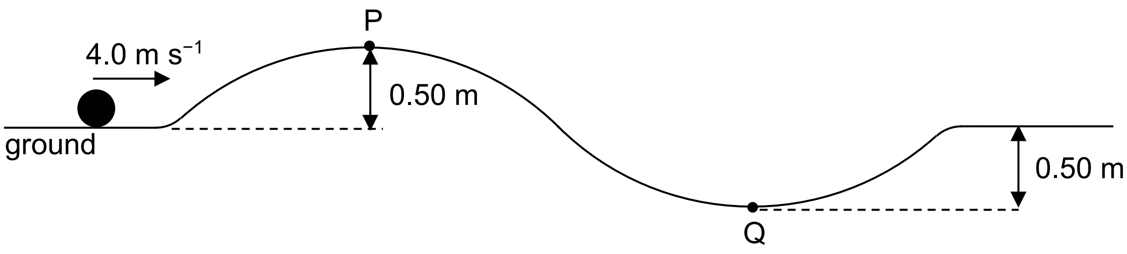

Fig. 6.1

(a) **(i)** Define *angular velocity*.

....

.... [1]

(ii) Determine the angular velocity of the ball at point Q.
Assume that the ball is in contact with the ground, hill and valley at all times.

angular velocity = ... rad s^{-1} [3]

(iii) State and explain if the magnitude of the centripetal acceleration experienced by the ball at point P is lesser than, greater than, or equal to the magnitude of the centripetal acceleration experienced by the ball at point Q.

....

....

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....

....

.... [3]

(b) A second ball travels along the same ground with a different initial speed. It was observed that this ball just loses contact with the hill at point P.

(i) Determine the speed of the second ball at point P.

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

(ii) A student suggests that a third ball with four times the mass of the second ball will not lose contact at point P if it slides up the hill and passes by point P with twice the speed of the second ball found in **(b)(i)**.

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

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....

....

.... [2]

7 When a structural engineer is designing a building there will be occasions when a beam is used to bridge a gap. The width of the gap is called the span. The engineer makes calculations to ensure that the beam is strong enough to withstand any force applied to it, and to ensure that there is not too much sag in the beam. This question concerns how the choice of beam is made.

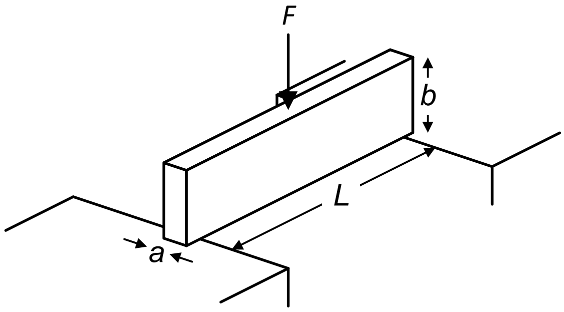

Fig. 7.1

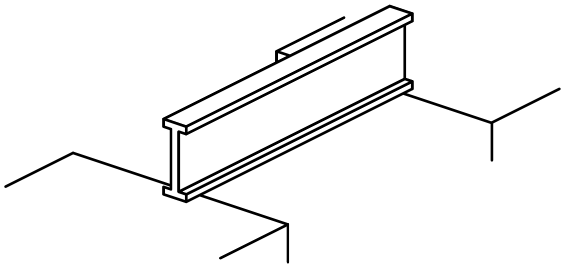

Fig. 7.2

When the loading is small, a plain wooden beam is sufficient, as shown in Fig. 7.1. A beam such as this, loaded at its centre, will sag and undergo a maximum depression x given by

$$x = \frac{FL^3}{kab^3}$$

where F is the load at the centre, L is the span, a is the width and b is the depth of the beam and k is a constant.

When greater loads or greater spans are required, a steel beam may be used. In order to minimise the amount of steel required the shape of the beam used is as shown in Fig. 7.2.

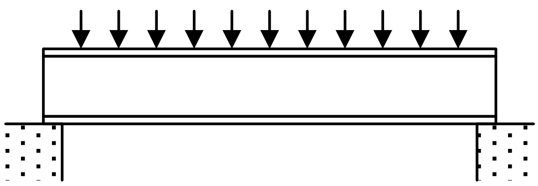

Fig. 7.3

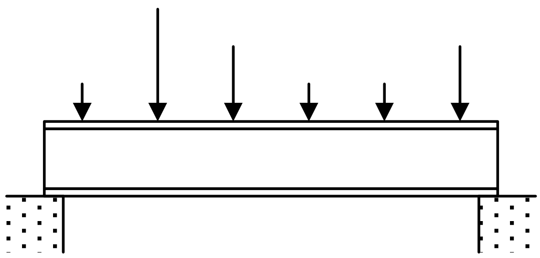

Fig. 7.4

Sometimes, the loading of the beam is uniform, along its length, as shown in Fig. 7.3.

Sometimes, with complex loading, as shown in Fig. 7.4, the moments of the forces must be calculated.

(a) The cross-sectional area of the beams S and T shown in Fig. 7.5 are the same. The beams are made of the same material.

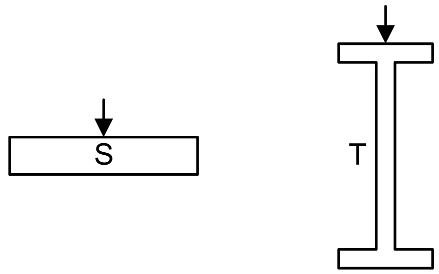

Fig. 7.5

State and explain, for beams of the same length in the orientation shown in Fig. 7.5, which beam would sag more when loaded from the top.

....

....

....

.... [2]

(b) A wooden beam has width 0.050 m, depth 0.10 m and spans 3.0 m.

Calculate the maximum load which the beam can support at its centre for a maximum depression of 0.010 m. Take k to be 3.6×10^{10} Pa for this wood.

maximum load = ... N [2]

(c) A steel beam, loaded uniformly as in Fig. 7.3, is allowed to sag by a maximum of 1/360 of the gap it is spanning. A particular beam is used to carry a load of 33 000 N and to span a gap of 4.20 m. A quantity B, known as the bending moment for this loading pattern is given by

$$B = \frac{FL}{8}$$

and the depression x at the centre is given by

$$x = \frac{BL^3}{c}$$

where $c = 3.35 \times 10^8$ N m^3.

Calculate

(i) the maximum depression by which the beam is allowed to sag,

maximum depression = ... m [1]

(ii) the bending moment *B*,

B = ... N m [2]

(iii) the actual depression of the steel beam.

actual depression = ... m [2]

(d) A beam across a gap is shown in Fig. 7.6, together with values of the forces acting on it and their distances from point X.

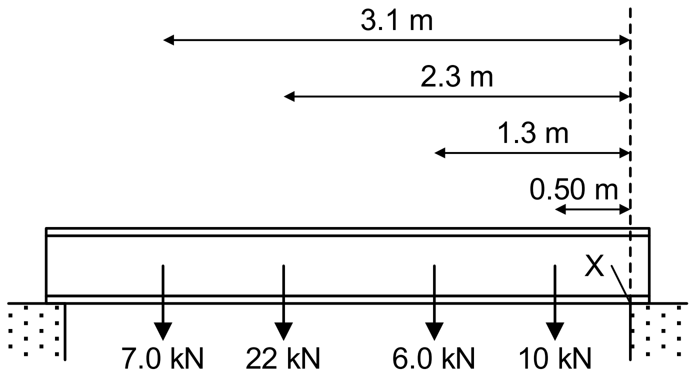

Fig. 7.6

Calculate the total moment of the forces shown about point X.

total moment = ... N m [2]

(e) The final check on the suitability of any beam is to ensure that it is strong enough.

The allowable bending stress in MPa is determined from Fig. 7.7 using two constants *P* and *Q*, without units.

These constants are found from the dimensions of the beam and the gap it is spanning.

(i) For the beam in **(c)**, $P = 21$ and $Q = 170$.

Use Fig. 7.7 to estimate the allowable bending stress.

Q \ P	15	20	25	30
160	111	96	88	82
170	106	93	83	77
180	102	89	80	73

Fig. 7.7

allowable bending stress = ... MPa [1]

(ii) The beam is safe to use if

$$\frac{\text{bending moment}}{\text{allowable bending stress}} < 2.0 \times 10^{-4}\ \text{m}^3$$

Use this relationship to determine whether the beam is safe under these conditions.

....

.... [2]

END OF SECTION B