## Paper 1 Q1

The equation $y = P\cos(Qx - Rt)$ describes the motion of an object, where $x$ is displacement and $t$ is time. If the equation is homogeneous, what must the units be for $P$, $Q$, and $R$?

| | $P$ | $Q$ | $R$ |
|---|---|---|---|
| **A** | m | s | m |
| **B** | m s | s | m |
| **C** | m $s^{-1}$ | s $m^{-1}$ | dimensionless |
| **D** | m | $m^{-1}$ | $s^{-1}$ |

(Q x – R t) is an angle → dimensionless

→ [Q] [x] = [R] [t] = 1

Ans: D

## Paper 1 Q2

The density of a plastic cylinder is determined by measuring its mass, length and diameter. The mass, length and diameter are measured with an uncertainty of 2%, 1% and $y$% respectively. The uncertainty in the calculated density of the cylinder is 7%. What is the value of $y$?

**A** 2 **B** 4 **C** 5 **D** 10

$\rho = M / V$

where $V = L \pi d^2 / 4$

$\Delta\rho/\rho = \Delta M/M + \Delta L/L + 2\,\Delta d/d$

Ans: A

## Paper 1 Q3

An experiment was carried out to determine the acceleration of free fall. The experiment was repeated five times. Which of the following sets of results shows an accuracy of ± 0.1 m $s^{-2}$, and a precision of ± 0.3 m $s^{-2}$ ?

**A** {9.73, 9.64, 9.84, 9.86, 10.20}

**B** {10.01, 9.75, 9.98, 9.82, 10.15}

**C** {9.65, 9.93, 9.72, 9.80, 9.74}

**D** {9.80, 9.91, 9.97, 10.10, 9.86}

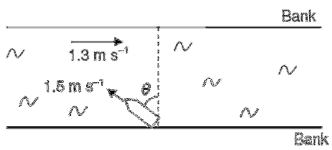
Average = 9.8 ± 0.1

(Max – Min) / 2 ≤ 0.3

Ans: C

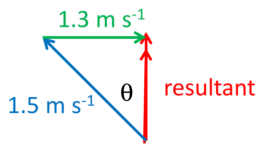
## Paper 1 Q4

The diagram below shows a boat that is about to cross the river heading in a direction $\theta$ from the dotted line at a speed of 1.5 m $s^{-1}$. The current flows at 1.3 m $s^{-1}$ in the direction shown.




What should the value of $\theta$ be, such that the actual path of the boat is along the dotted line?

**A** 30° **B** 50° **C** 60° **D** 70°




Ans: C

## Paper 1 Q5

Which of the following is ***incorrect*** in describing the motion of a body if the acceleration is not zero?

**A** It can be instantaneously at rest.

**B** Its velocity is constant.

**C** It is moving.

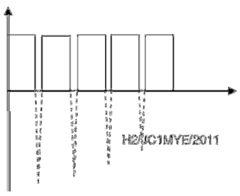
**D** It is turning.

Velocity constant → Acceleration = 0

Ans: B

## Paper 1 Q6

The motion of a ball rebounding from a horizontal surface after being released from a point above the surface is described in the graph below. Ignore the presence of air resistance.



1 H2/JC1MYE/2011 NYJC

The y-axis represents the ball's

**A** weight **B** velocity **C** acceleration **D** displacement

Acceleration is g except when ball is in contact with ground.

Ans: C

## Paper 1 Q7

A motorist travelling at 10 m s$^{-1}$ can bring his car to rest in a braking distance of 10 m. In what distance could he bring the car to rest from a speed of 30 m s$^{-1}$ using the same braking force?

A 17 m  B 30 m  C 52 m  D 90 m

$v^2 = u^2 + 2as$

→ $0 = 10^2 + 2a(10)$

→ $0 = 30^2 + 2aD_{30}$

Ans: D

## Paper 1 Q8

A tennis ball is struck such that it leaves the racket horizontally with a speed of 30 m s$^{-1}$. The ball hits the court at a horizontal distance of 20 m from the racket. What is the height of the tennis ball when it leaves the racket? Assume air resistance is negligible.

A 2.2 m  B 4.4 m  C 7.4 m  D 46 m

$u_x = 0$  $s_x = 20$ m  → $s_x = u_x t$

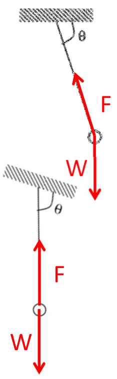
$u_y = 0$  $a_y = 9.8$ m s$^{-2}$  $s_y = h$  → $s_y = u_y t + \frac{1}{2} a_y t^2$

Ans: A

## Paper 1 Q9

A pendulum is hanging from the ceiling of a train. Passengers sitting in the train observe that the pendulum is at rest and is making a constant angle with the ceiling as shown in the figure on the right. Which of the following deduction is ***definitely incorrect***?

A The train is accelerating with a increasing rate.
B The train is decelerating with a constant rate.
C The train is moving in a circle with a constant speed.
D The train is travelling uphill with a constant velocity.




Constant velocity → acceleration = 0

Ans: A

## Paper 1 Q10

A block with a spring attached with a total mass M collides elastically with another block of m as shown in Fig.10. Which of the following response is correct?

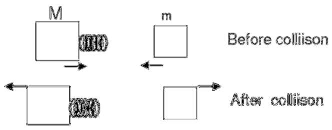



Fig. 10

| | Total Momentum of M and m is conserved | Total Kinetic Energy of M and m is conserved |
|---|---|---|
| A | before, during and after the collision | before and after the collision only |
| B | before and after the collision only | before, during and after the collision |
| C | before, during and after the collision | before, during and after the collision |
| D | before and after the collision only | before and after the collision only |

Ans: A

## Paper 1 Q11

A car is accelerating up a slope as shown in Fig 11. Ignoring air resistance, which of the following force diagrams (not to scale) is correct?

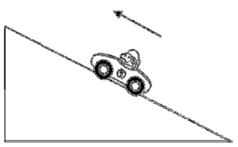
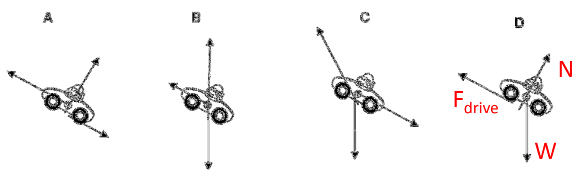


Fig. 11

Ans: D




## Paper 1 Q12

A football moving with kinetic energy K and momentum p, hits the wall of a building perpendicularly and rebounds along its original path. The collision is inelastic. Which of the following correctly shows the kinetic energy of the ball and the system as a whole, and the magnitude of the momentum of the ball and the system as a whole, after this collision?

| | Kinetic energy | | Momentum | |
|---|---|---|---|---|
| | of ball | of system | of ball | of system |
| A | K | 0 | p | p |
| B | < K | K | <p | p |
| C | <K | <K | <p | p |
| D | < K | < K | <p | <p |

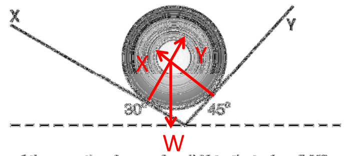
Momentum of system is conserved.

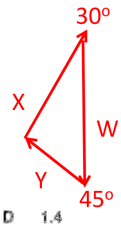
Kinetic energy of system decreased.

Ans: C

Paper 1 Q13

A bowling ball rests against the frictionless walls X and Y, of a groove as shown in the diagram below.




What is the ratio of the reaction force of wall X to that of wall Y?

A 0.71 B 0.82 C 1.0 D 1.4

Ans: D

Paper 1 Q14

Fig. 14 shows an object B of weight 5.0 N on a uniform light bridge, held in equilibrium by two supports. Calculate the downward force on support X.

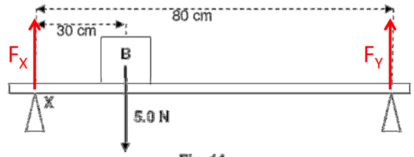



Fig. 14

A 1.9 N B 3.1 N C 5.0 N D 10 N

Sum moments about right pivot:

$F_X$ 0.80 + (-5.0 x 0.50) = 0

Ans: B

Paper 1 Q15

An incompressible liquid of density $\rho$ is contained in a vessel of uniform cross-sectional area $A$. The atmospheric pressure is $P$.

What is the force acting on a horizontal plane of area $S$, in a depth h in the liquid?

A $\frac{P}{A} + \frac{\rho g h}{S}$ B $A(\rho g h + P)$ C $S(\rho g h + P)$ D $S \rho g h + A P$

Pressure at depth p = h ρ g + P

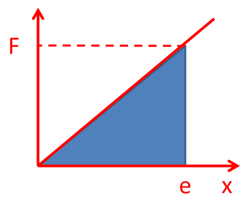
Force on plane = p S

Ans: C

Paper 1 Q16

A wire is stretched by a force $F$ which causes an extension $e$. The energy stored in the wire is ½ $F e$ only if

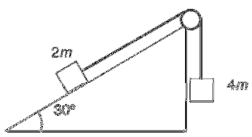
- **A** The weight of the wire is negligible.
- **B** The gravitational field strength is constant.
- **C** The extension is done slowly.
- **D** The extension of the wire is proportional to the force being applied.




Ans: D

Paper 1 Q17

The diagram shows a system of 2 objects of mass $2m$ and $4m$ connected by light strings over a light, free-running pulley. When the objects are released from rest, the object of mass $2m$ moves on a frictionless plane inclined at 30° to the horizontal.




When the object of mass $2m$ has travelled distance $x$ along the slope from rest, what will be the total kinetic energy of the system?

A $mgx$ B $2mgx$ C $3mgx$ D $4mgx$

Total change in energy = Work done on system

gain in KE of A&B + gain in GPE of A – loss in GPE of B = 0

Ans: C

Paper 1 Q18

A vehicle of mass 650 kg starts from rest at the top of a slope, and, without application of driving power, moves down the slope. It acquires a speed of 20 m $s^{-1}$ by the time it moves through a height of 60 m. Determine the total energy dissipated by frictional forces during the whole process.

A $1.2 \times 10^5$ J B $2.5 \times 10^5$ J C $3.8 \times 10^5$ J D $4.4 \times 10^5$ J

Total change in energy = Work done on system

+ gain in KE – loss in GPE = work done by friction *(negative)*

Ans: B

## Paper 1 Q19

It is estimated that $4.5 \times 10^6$ kg of water falls over the Niagara Falls each second. The height of the Niagara Falls is about 50 m. Assuming that mechanical energy is converted into electrical energy at an efficiency of 90 %, determine the number of 100 W bulbs it can fully light up in 1 second.

**A** $1.9 \times 10^7$ **B** $2.0 \times 10^7$ **C** $1.9 \times 10^8$ **D** $2.0 \times 10^9$

In 1 s:

Loss in GPE of water = E = m g h

Electrical energy produced = E' = 0.90 E

No of light bulbs = E' / 100

Ans: B

## Paper 1 Q20

A car of mass $m$ has an engine which can deliver power $P$. What is the minimum time in which the car can be accelerated from rest to a speed $v$?

**A** $\frac{mv}{P}$ **B** $\frac{mv^2}{P}$ **C** $\frac{mv^2}{2P}$ **D** $\frac{2P}{mv^2}$

Energy gain = E = ½ m $v^2$

Time taken = E / P

Ans: C

## Paper 2 Q2

Fig. 2.1 shows a jet of water coming out of a water hose which was held at an angle above the horizontal.

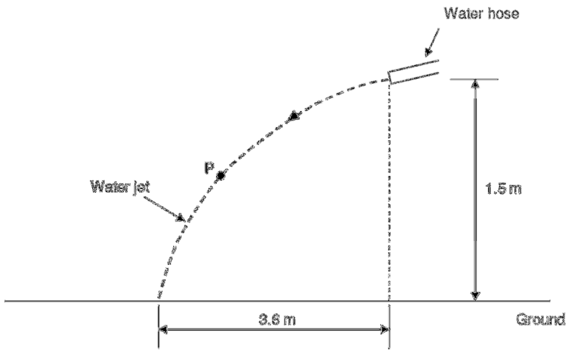
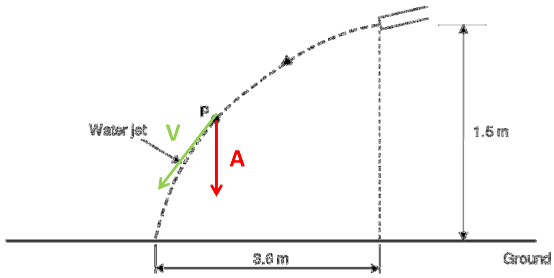



Fig. 2.1

## Paper 2 Q2




The water hose is at a height of 1.5 m from the ground. The initial horizontal component of velocity of the water is 7.0 m $s^{-1}$. The horizontal distance from the end of the water hose to the point where the water hits the ground is 3.6 m. The water jet passes through the point **P** as it hits the ground. You may assume that air resistance has negligible effect on the motion of the water jet.

(a) On Fig. 2.1, draw an arrow to show the direction of the acceleration of the water at point **P**. (Mark this arrow **A**) [1]

## Paper 2 Q2a

Explain why the horizontal component of the velocity remains constant at 7.0 m $s^{-1}$.

Acceleration has no horizontal component

→ Horizontal velocity will not change.

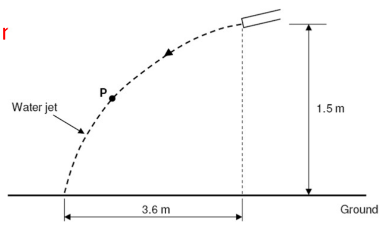
## Paper 2 Q2b

Show that the water takes about 0.51 s to travel from the end of the pipe to the ground. [1]

$u_x$ = 7.0 m $s^{-1}$ $s_x$ = 3.6 r

→ $s_x = u_x t$

→ t = 0.51 s



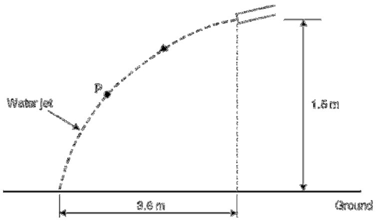
Paper 2 Q2c

Calculate $u_y$, the initial vertical component of velocity of the water jet.

↓ + : $u_y$ = ?  $s_y$ = 1.5 m  $a_y$ = 9.81 m $s^{-2}$  t = 0.51 s

→ $s_y = u_y t + ½ a_y t^2$

→ $u_y$ = 0.44 m $s^{-1}$

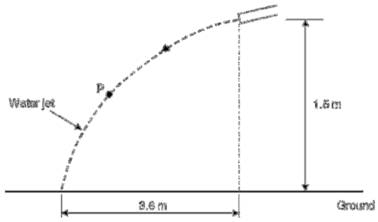



Paper 2 Q2d

Calculate the velocity of the water jet as it hits the ground.

↓ + : $u_y$ = 0.44 m $s^{-1}$  $v_y$ = ?  $a_y$ = 9.81 m $s^{-2}$  t = 0.51 s

→ $v_y = u_y + a_y t$




$v_x = u_x$ = 7.0 m $s^{-1}$

$v = \sqrt{(v_x^2 + v_y^2)}$

$\theta = \tan^{-1} (v_y / v_x)$

Final velocity = 8.9 m $s^{-1}$ at angle of 38° below horizontal

Paper 2 Q3a

A soldier tests a helmet by firing a bullet toward the helmet which is lying on a smooth surface as shown in Fig. 3.1.


Fig 3.1

(a) If the mass of the gun is 7.00 kg, the mass and speed of bullet is 0.0100 kg and 600 m $s^{-1}$, calculate the recoiling velocity of the gun as the bullet is fired.

Conservation of Momentum:

→ + :  $0 = 7.00\ v_1 + 0.0100 \times 600$

→ $v_1$ = - 0.857 m $s^{-1}$

Paper 2 Q3b


If the rifle is stopped by the shoulder of the shooter in 0.1 s, estimate the average force on his shoulder.

Force <u>by</u> shoulder <u>on</u> rifle F = dp / dt

momentum of rifle after firing = 7.00 x (-0.857)

= -6.00 kg m $s^{-1}$

dp = 0 – (-6.00) = 6.00 kg m $s^{-1}$

→ F = 60.0 N →

→ Force <u>on</u> shoulder <u>by</u> rifle = 60.0 N ←

Paper 2 Q3c


The butt of such a gun is sometimes fitted with a thick rubber pad. Discuss the effect of such a design.

Rubber pad allows more space for rifle to recoil

→ Time for deceleration is longer

→ Force on shoulder smaller

Paper 2 Q3d

The bullet moves along a line that passes through the centre of mass of the helmet and hits the helmet perpendicularly to its surface. The collision is *head-on* and *perfectly elastic*. The mass of the helmet is 2.00 kg and the velocities of the bullet and the helmet immediately after the collision are $v_B$ and $v_H$ respectively as shown in Fig 3.2.

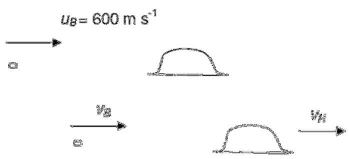
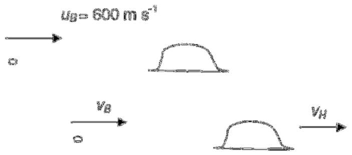



Fig 3.2

## Paper 2 Q3di




Express, in terms $v_B$ and $v_H$, two equations on the conservation of two physical quantities in this collision. (Do not attempt to solve the equations.) [2]

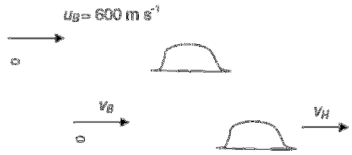
by C.O.M.

$0.0100 \times 600 = 0.0100\, v_B + 2.00\, v_H$

KE conserved in elastic collision

$\frac{1}{2}\, 0.0100 \times 600^2 = \frac{1}{2}\, 0.0100\, v_B^2 + \frac{1}{2}\, 2.00\, v_H^2$

## Paper 2 Q3dii

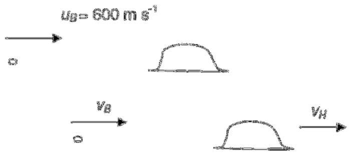



Express another equation, in terms $v_B$ and $v_H$, relating the relative speeds of the bullet and helmet before and after the collision. [1]

relative speed of approach = relative speed of separation

$600 = v_H - v_B$

## Paper 2 Q3diii




State a danger involved in doing such an experiment.

Bullet may ricochet / rebound with a high speed,

injuring firer or people around.

## Paper 2 Q4a

State the conditions for the equilibrium of a body which is acted upon by a number of forces.

Body initial at rest

Sum of forces equals to zero

Sum of torque equals to zero

## Paper 2 Q4b

The force diagram for the spine of a person bending over, with his back horizontal, is shown in Fig. 4.1 below. Consider the spine to be a rod pivoted at its base. The various muscles of the back are equivalent to a single muscle exerting a force *T* as shown on Fig. 4.1. *W* is the force the upper body produces on the spine.

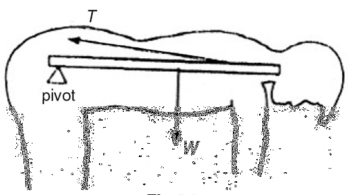
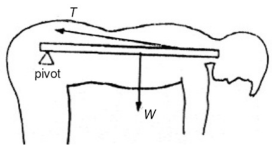



Fig 4.1

## Paper 2 Q4b




(i) Explain why, if the person is in equilibrium in this position, the value of *T* is typically several times of *W*.

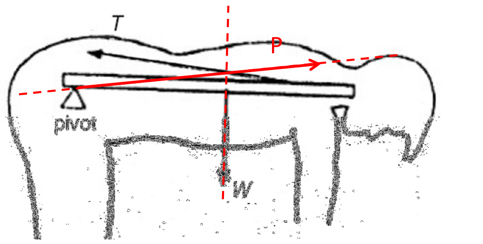
Taking moments about pivot:

CW moment due to W = ACW moment due to T

Because T is almost horizontal, perpendicular distance to pivot is very much smaller than that of W.

Thus T is many times larger than W.

## Paper 2 Q4b




(ii) Draw, on Fig. 4.1, the third force *P* acting on the spine. The point of exertion and the line of action must be clearly shown. [1]

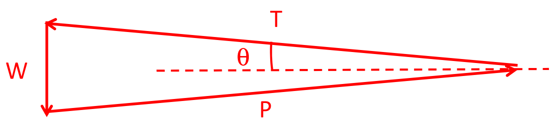
## Paper 2 Q4b

(iii) Suggest the nature of force P.

Force of base of spine on spine

## Paper 2 Q4b

(iv) Sketch a triangle of forces showing the equilibrium of the spine under the action of the forces *T*, *W* and *P*, as well as the positions of angle *θ*. [3]




## Paper 2 Q7a

(i) Define *acceleration*.

Rate of change of velocity

(ii) State *Newton's second law of motion*.

Resultant force on a body is directly proportional to its rate of change of momentum in the direction of the force

## Paper 2 Q7b

Two blocks, **A** and **B**, of masses 0.30 kg and 0.50 kg respectively, are connected by a string that passes over the pulley as shown in Fig. 7.1. The tabletop and pulley are frictionless and the string is inelastic. The system is released from rest. Block **A** moves along the tabletop and strikes a spring with negligible mass that is firmly attached to the tabletop. The spring has a force constant of 360 N m$^{-1}$.

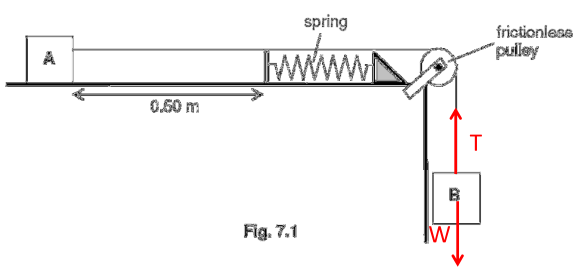
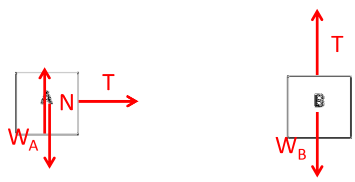



Fig. 7.1

(i) On the free-body diagrams of block **A** and **B** in Fig. 7.2 below, draw and label all the forces acting on blocks **A** and **B**. [3]

## Paper 2 Q7b

(i) On the free-body diagrams of block **A** and **B** in Fig. 7.2 below, draw and label all the forces acting on blocks **A** and **B**. [3]



Paper 2 Q7b

**(ii)** Show that the magnitude of the acceleration of block **A** is 6.13 m $s^{-2}$ before striking the spring. [2]

For A : (→+) $\Sigma F = m a$ → $T = m_A a$

For B : (↓+) $\Sigma F = m a$ → $W + (-T) = m_B a$

Solving simultaneously, $a = 6.13$ m $s^{-2}$

Paper 2 Q7b

**(iii)** Calculate the tension in the string before block **A** strikes the spring.

For A : (→+) $\Sigma F = m a$ → $T = m_A a$

For B : (↓ +) $\Sigma F = m a$ → $W + (-T) = m_B a$

Solving simultaneously, $T = 1.84$ N

Paper 2 Q7b

**(iv)** Calculate the velocity of block **B** just before block **A** strikes the spring.

$u = 0$ $v = ?$ $a = 6.13$ m $s^{-2}$ $s = 0.50$ m

Using $v^2 = u^2 + 2 a s$,

$v = 2.48$ m $s^{-1}$

Paper 2 Q7b

**(v)** Calculate the time taken for block **A** to reach the spring.

$u = 0$ $v = 2.48$ $a = 6.13$ m $s^{-2}$ $t = ?$

Using $v = u + a t$,

$t = 0.403$ s

Paper 2 Q7b

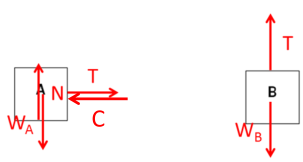
**(vi)** When block **A** strikes the spring, the spring will exert a force on block **A**. Determine the compression of the spring when the resultant force on block **A** is 0 N.

For A : (→+) $\Sigma F = m a$ → $T + (-C) = 0$

For B : (↑+) $\Sigma F = m a$ → $W + (-T) = 0$

Solving simultaneously, $C = 4.91$ N

$C = k x$ → $x = 0.0136$ m




Paper 2 Q7b

**(vii)** Determine the maximum compression of the spring after block **A** strikes the spring.

By conservation of energy:

work done on system = Total change in energy of system

For A: $\Delta K = -\frac{1}{2} m_A u^2$ For A: $\Delta K = 0$

For B: $\Delta K = -\frac{1}{2} m_B u^2$ For B: $\Delta K = 0$

$\Delta G = -m_B g x$ $\Delta G = -m_B g (0.50 + x)$

For spring: $\Delta E = \frac{1}{2} k x^2$ For spring: $\Delta E = \frac{1}{2} k x^2$

work done by external forces = 0

Solving: $x = 0.131$ m

Paper 2 Q7b

(viii) Describe the subsequent motion of block **A**.

A will move leftwards (and B upwards)

back to (their respective) initial positions.

The entire cycle of motion will repeat itself.

**1** **(a)** Estimate the number of breaths taken during an average human life span, showing clearly how you arrived at your estimate.

A person takes an average of 25 breaths per minute.
The average human life span is 70 years.
Hence number of breaths taken during an average human life span
= (70 x 365 x 24 x 60) (25) = $9 \times 10^8$

Note:

1. Accepted answer in the order of $10^8 - 10^9$ (1 s.f. will suffice for estimates but no marks deducted for more than 1 s.f. in this case)
2. No marks awarded if no logical reasoning is given at all

number of breaths = ................................ [2]

**(b)** **(i)** The rate of heat energy loss through an insulated rod is given by the equation

$$\frac{E}{t} = \lambda A(\frac{\Delta T}{x})$$ , where

*E* is the loss in heat energy,
*t* the time taken for the loss,
*ΔT* is the temperatures difference between the hotter and colder ends of the rod,
*x* is the length of the rod,
*A* is the cross-sectional area of the rod, and
*λ* is a constant for a given material of the rod; it is also known as the thermal conductivity of the material.

Given that the unit of $\lambda$ is kg m $s^{-3}$ $K^{-1}$, show that the above equation is dimensionally homogeneous. [3]

$[\frac{E}{t}]$ = [force][displacement]/[time]
= [mass][acceleration][displacement]/[time]
= (kg . m $s^{-2}$ . m) / s = kg $m^2$ $s^{-3}$

$[\lambda A(\frac{\Delta T}{x})]$ = (kg m $s^{-3}$ $K^{-1}$ . $m^2$ . K) / m
= kg $m^2$ $s^{-3}$

Since $[\frac{E}{t}] = [\lambda A(\frac{\Delta T}{x})]$, the equation is dimensionally homogeneous.

Note:

1. Do not equate units of $[\frac{E}{t}]$ and $[\lambda A(\frac{\Delta T}{x})]$ first; you need to PROVE that they are the same
2. Do not equate physical quantities with units

**(ii)** A lagged copper rod has length (20.0 ± 0.3) cm and diameter (11.0 ± 0.1) mm. When steady state is attained, the temperature of one end of the rod is 120.0 °C and the other end is 0.0 °C. The temperature at each end of the rod is measured with an uncertainty of 0.5 °C.

**1.** Determine the temperature difference between the two ends of the rod, with its associated uncertainty.

$T_1$ = (0.0 ± 0.5) °C
$T_2$ = (120.0 ± 0.5) °C

$T_2 - T_1$ = (120 ± 1) °C

Note :

1. Uncertainty in temperature difference expressed in 1 s.f. = 1 °C, not 1.0 °C
2. Actual temp difference rounded off to nearest °C = 120 °C, not 120.0 °C

temperature difference = .................................... °C [1]

**2.** Given that the rate of heat flow through the copper rod is determined to be (22 ± 1) W, calculate the thermal conductivity of copper, expressing your answer with its associated uncertainty.

Rate of heat flow = $\frac{E}{t}$ = (22 ± 1) W

Area of rod, $A = \pi r^2$

$$\lambda = \frac{\frac{E}{t}x}{\pi r^2 (T_2 - T_1)} = \frac{(22)(0.200)}{\pi(0.0055^2)(120)} = 385.83 \text{ kg m s}^{-3}\text{ K}^{-1}$$

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta\frac{E}{t}}{\frac{E}{t}} + \frac{\Delta x}{x} + 2(\frac{\Delta r}{r}) + \frac{\Delta(T_2 - T_1)}{(T_2 - T_1)}$$
$$= \frac{1}{22} + \frac{0.3}{20.0} + 2(\frac{0.1}{11.0}) + \frac{1}{120}$$
$$= 0.0870$$

$\Delta\lambda$ = 33.6 = 30 kg m s$^{-3}$ K$^{-1}$ (1 s.f.)

Hence $\lambda$ = (390 ± 30) kg m s$^{-3}$ K$^{-1}$

thermal conductivity of copper = .................................. kg m s$^{-3}$ K$^{-1}$ [3]

**5** A 3.00 kg mass with an initial velocity of 1.00 m $s^{-1}$ slides down a frictionless 30.0° incline as shown in Fig. 5.1. While sliding, it comes into contact with an unstretched spring of negligible mass with a spring constant of 400 N $m^{-1}$.

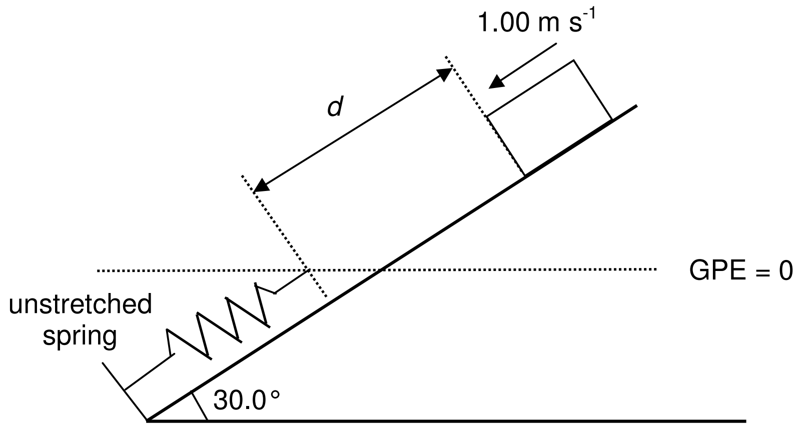



**Fig 5.1**

The initial separation between the mass and the unstretched spring is *d*. The mass slides an additional 0.200 m as it is brought momentarily to rest by compression of spring. The gravitational potential energy is taken to be zero at the level shown in the Fig. 5.1.

**(a)** Find the restoring force in the spring when it is compressed by 0.200 m.

F = k x= (400) (0.20) = 80.0 N

restoring force = .............................. N [1]

**(b)** Find the energy stored in the spring when it is compressed by 0.200 m.

EPE = ½ F x or
EPE = ½ k $x^2$
= ½ (400) $(0.20)^2$
= 8.00 J

energy stored = .............................. J [2]

**(c)** Find the initial kinetic energy and gravitational potential energy of the mass in terms of *d* when necessary.

$E_K = ½ m v^2 = ½ (3.00) (1.00)^2 = 1.50$ J

$E_P = m g d \sin 30^0$
$= (3.00)(9.81) d \sin 30^0$
$= 14.7d$ J

initial kinetic energy = ................................ J

initial gravitational potential energy = .................................. J [3]

**(d)** Find the initial separation *d* between the mass and the unstretched spring.

Initial $(E_P + E_K)$ = Final $(E_P + E_K)$
Initial (GPE + EPE + KE) = Final (GPE + EPE + KE)
$14.715\ d + 0 + 1.50 = -(3.00)(9.81)(0.20) \sin 30^0 + 8.00 + 0$
$d = 0.242$ m

*d* = .................................. m [3]

**6** Solids can be classified as crystalline, polymeric or amorphous. All these materials are widely used in engineering and industry. In the question, we will look at how materials deform when subjected to loads of varying amounts.

When a load $F$ is applied to the end of a wire of unstretched length $l$ and cross sectional $A$, it extends by a length $e$. Some technical terms used in the subject of elasticity of wires include:

$$\text{Tensile stress} = \text{force per unit area} = \frac{F}{A}$$

$$\text{Tensile strain} = \text{extension per unit length} = \frac{e}{l}$$

$$\text{Young Modulus } E = \frac{\text{Stress}}{\text{Strain}} = \frac{Fl}{Ae}$$

**(a)** Determine the base units of $E$, the Young Modulus.

$$[E] = [\frac{Fl}{Ae}] = [\frac{F}{A}] = [\frac{ma}{A}] = kg\,m\,s^{-2}m^{-2} = kg\,s^{-2}m^{-1}$$

base units of $E$ = ..................................... [2]

A specimen fibre of glass has the same dimensions as a specimen of copper wire. The length of each specimen is 1.50 m and the radius of each is 0.15 mm. Both specimens are loaded slowly until they break. The force-extension graphs of both specimens are shown in Fig. 6.1.

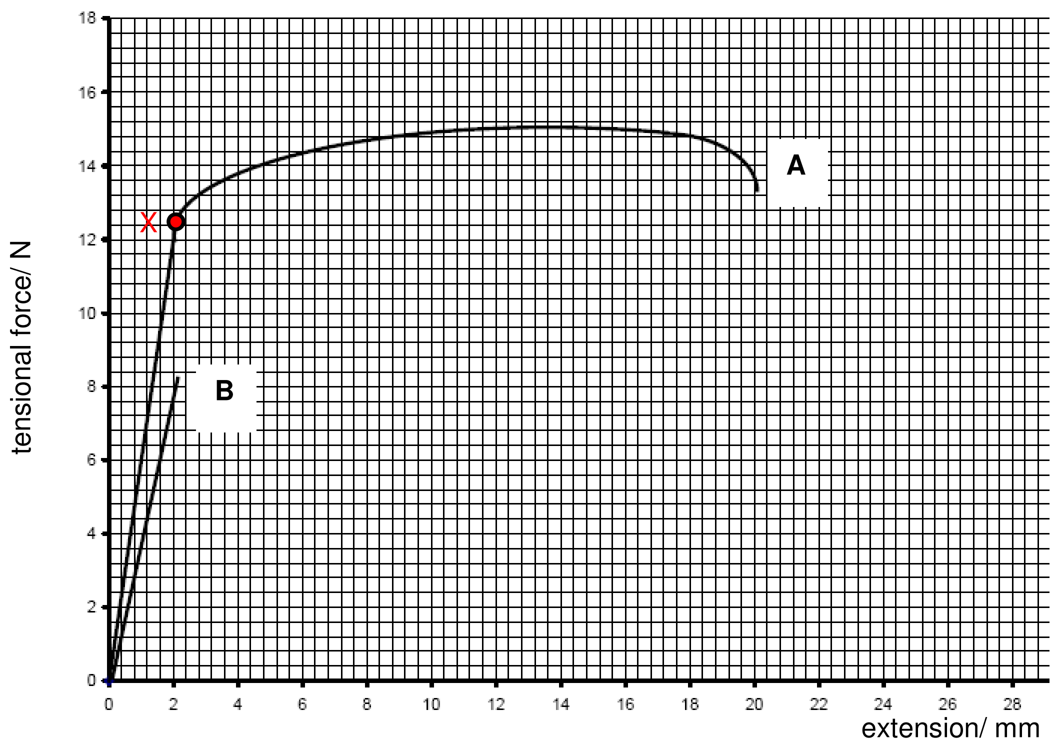



**Fig. 6.1**

**(b)** **(i)** State Hooke's law.

Within the proportionality limit, the magnitude of the applied force is proportional to the amount of extension or compression it produces.

**(ii)** Label, on Fig. 6.1, the point of limit of proportionality for material A with ***X***. [1]

**(iii)** Glass is known to be a brittle material. Suggest, with a reason, which material is likely to be glass.

Material B could be glass. Brittle material is unlikely to undergo extended stretching beyond its limit of proportionality before its breaking point

[2]

**(iv)** Suggest what happens to material A after it is loaded beyond 14 mm.

Material A extends without an increase in applied force beyond 14 mm. This happens when the deformation is too great. The area of the material becomes smaller due to the extension.

[2]

**(c)** Using the graphs and data given, determine

**(i)** the Young modulus *E* of B.

$$E = \frac{Fl}{Ae} = \frac{(6.0)(1.50)}{\pi(0.15\times10^{-3})^2(1.6\times10^{-3})} = 7.96\times10^{10}\ kg\ m^{-1}\ s^{-2}$$

Accept (7.16 – 8.76) x $10^{10}$ kg $m^{-1}$ $s^{-2}$

Young modulus *E* = .................................. [2]

**(ii)** the approximate value of work done to stretch material A to its breaking point.

Work done = Area under the force-extension graph

$$= \frac{1}{2}(12)(0.002) + \frac{1}{2}(12+14.4)(0.0036) + 14.8(0.0148) = 0.278J$$

Accept (0.264 J - 0.292 J)

work done = ...................................... J [2]

**(d)** In a separate experiment, three rods were set up as shown in Fig. 6.2 for the loading test. All rods are of the same dimensions as in the previous experiment. Rods X and Y are made of material B and Rod Z is made of material A. Rod Z is at the midpoint of the support rod.

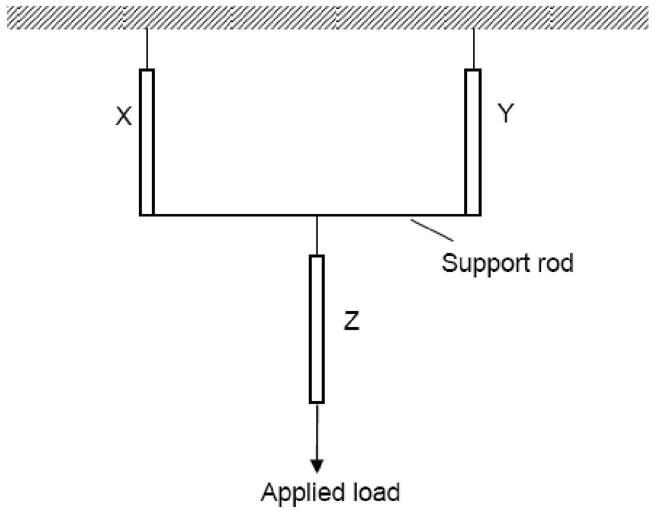



**Fig. 6.2**

**(d)** State, with a reason, which rod(s) will break first as the load increases slowly.

At any time, rod z will experience 2 times the tensional force compare to both X and Y. The largest force material A can withstand before breaking is 15 N, and the largest force material B can withstand before breaking is 8.2 N. Therefore **rod Z will break first** when the applied load is 15 N.