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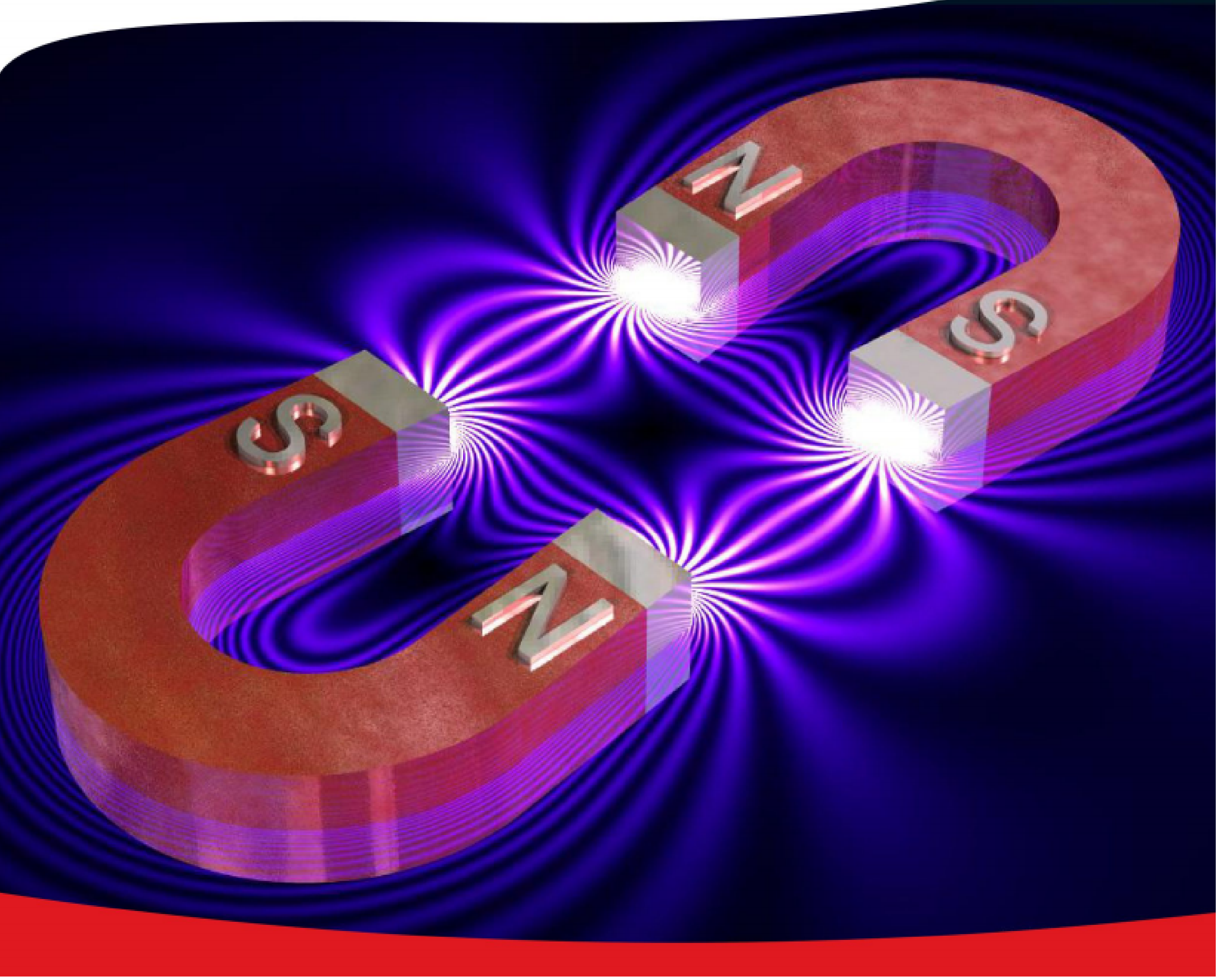
Cambridge International AS & A Level

PHYSICS (9702) P2

TOPIC WISE QUESTIONS + ANSWERS | COMPLETE SYLLABUS



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Chapter 5

Forces, density and pressure

5.1 Types of force

43. 9702_s18_qp_21 Q: 3

(a) State what is meant by the *mass* of a body.

....

....[1]

(b) Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 3.1.

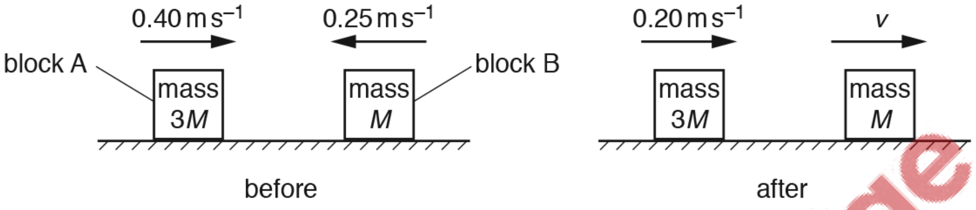

Fig. 3.1

Block A has mass $3M$ and block B has mass M.
Before the collision, block A moves to the right with speed $0.40\,\mathrm{m\,s^{-1}}$ and block B moves to the left with speed $0.25\,\mathrm{m\,s^{-1}}$.
After the collision, block A moves to the right with speed $0.20\,\mathrm{m\,s^{-1}}$ and block B moves to the right with speed v.

(i) Use Newton's third law to explain why, during the collision, the change in momentum of block A is equal and opposite to the change in momentum of block B.

....

....

....

....[2]

(ii) Determine speed v.

v = ... $\mathrm{m\,s^{-1}}$ [3]

(iii) Calculate, for the blocks,

1. the relative speed of approach,

relative speed of approach = ... $m\,s^{-1}$

2. the relative speed of separation.

relative speed of separation = ... $m\,s^{-1}$
[2]

(iv) Use your answers in **(b)(iii)** to state and explain whether the collision is elastic or inelastic.

....

....[1]

[Total: 9]

44. 9702_m17_qp_22 Q: 1

(a) Complete Fig. 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

quantity	scalar	vector
acceleration		
force		
kinetic energy		
momentum		
power		
work		

Fig. 1.1 [2]

(b) A floating sphere is attached by a cable to the bottom of a river, as shown in Fig. 1.2.

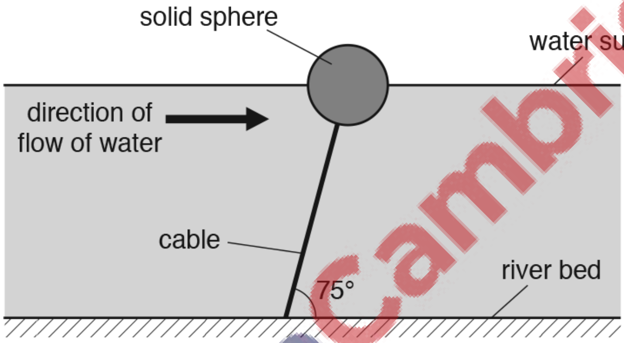

Fig. 1.2

The sphere is in equilibrium, with the cable at an angle of 75° to the horizontal. Assume that the force on the sphere due to the water flow is in the horizontal direction.

The radius of the sphere is 23 cm. The sphere is solid and is made from a material of density 82 kg m^{-3}.

(i) Show that the weight of the sphere is 41 N.

[2]

(ii) The tension in the cable is 290 N.

Determine the upthrust acting on the sphere.

upthrust = ... N [2]

(iii) Explain the origin of the upthrust acting on the sphere.

....

....

....[1]

[Total: 7]

45. 9702_s16_qp_21 Q: 3

A ball of mass 150 g is at rest on a horizontal floor, as shown in Fig. 3.1.

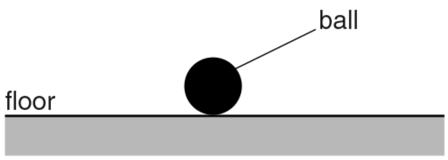

Fig. 3.1

(a) **(i)** Calculate the magnitude of the normal contact force from the floor acting on the ball.

force = ... N [1]

(ii) Explain your working in **(i)**.

....

....

....[1]

(b) The ball is now lifted above the floor and dropped so that it falls vertically, as illustrated in Fig. 3.2.

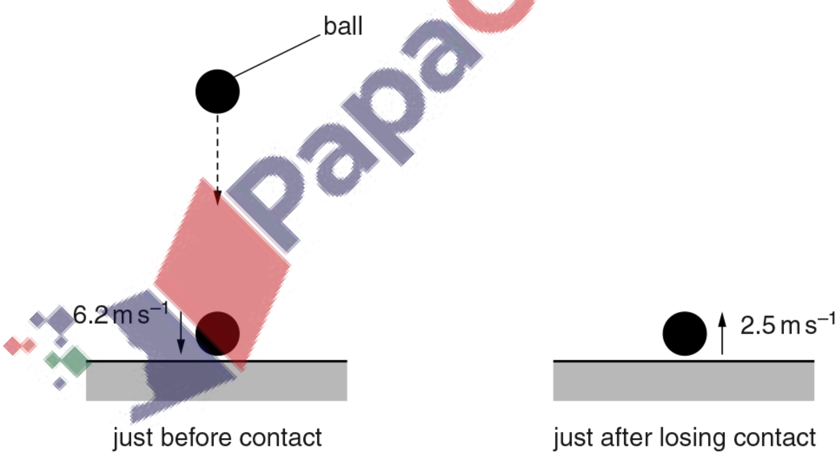

Fig. 3.2

Just before contact with the floor, the ball has velocity 6.2 m s^{-1} downwards. The ball bounces from the floor and its velocity just after losing contact with the floor is 2.5 m s^{-1} upwards. The ball is in contact with the floor for 0.12 s.

(i) State Newton's second law of motion.

....

....[1]

(ii) Calculate the average resultant force on the ball when it is in contact with the floor.

magnitude of force = ... N

direction of force ....
[3]

(iii) State and explain whether linear momentum is conserved during the collision of the ball with the floor.

....

....

....

....[2]

[Total: 8]

5.2 Turning effects of forces

46. 9702_w19_qp_22 Q: 4

(a) A sphere in a liquid accelerates vertically downwards from rest. For the viscous force acting on the moving sphere, state:

(i) the direction

.... [1]

(ii) the variation, if any, in the magnitude.

.... [1]

(b) A man of weight 750 N stands a distance of 3.6 m from end D of a horizontal uniform beam AD, as shown in Fig. 4.1.

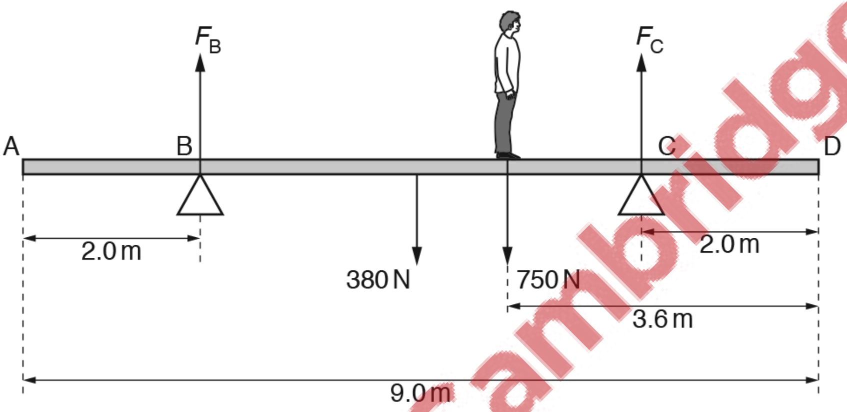

Fig. 4.1 (not to scale)

The beam has a weight of 380 N and a length of 9.0 m. The beam is supported by a vertical force F_B at pivot B and a vertical force F_C at pivot C. Pivot B is a distance of 2.0 m from end A and pivot C is a distance of 2.0 m from end D. The beam is in equilibrium.

(i) State the principle of moments.

....

....

.... [2]

(ii) By using moments about pivot C, calculate F_B.

F_B = ... N [2]

(iii) The man walks towards end D. The beam is about to tip when F_B becomes zero.

Determine the minimum distance x from end D that the man can stand without tipping the beam.

x = ... m [2]

[Total: 8]

47. 9702_w19_qp_23 Q: 1

(a) Determine the SI base units of the moment of a force.

SI base units .... [1]

(b) A uniform square sheet of card ABCD is freely pivoted by a pin at a point P. The card is held in a vertical plane by an external force in the position shown in Fig. 1.1.

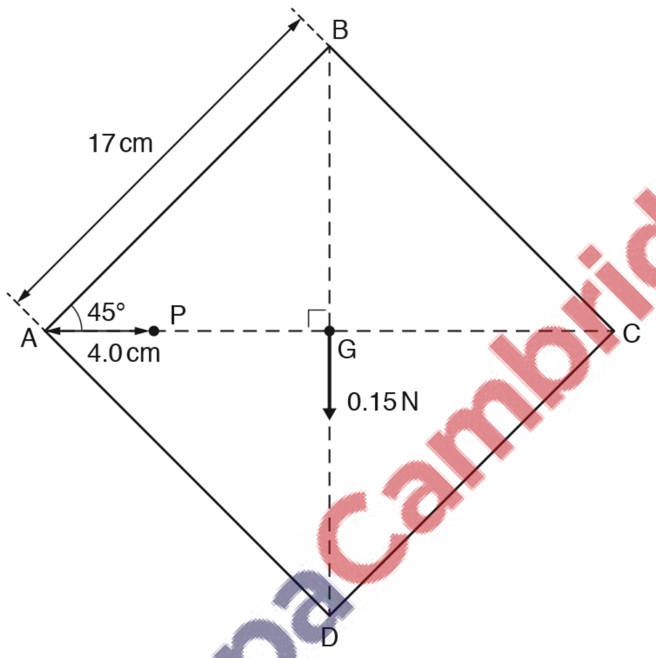

Fig. 1.1 (not to scale)

The card has weight 0.15 N which may be considered to act at the centre of gravity G. Each side of the card has length 17 cm. Point P lies on the horizontal line AC and is 4.0 cm from corner A. Line BD is vertical.

The card is released by removing the external force. The card then swings in a vertical plane until it comes to rest.

(i) Calculate the magnitude of the resultant moment about point P acting on the card immediately after it is released.

moment = ... N m [2]

(ii) Explain why, when the card has come to rest, its centre of gravity is vertically below point P.

....

....

....

.... [2]

[Total: 5]

48. 9702_w17_qp_22 Q: 2

(a) Define the *moment* of a force.

....

....[1]

(b) A thin disc of radius *r* is supported at its centre O by a pin. The disc is supported so that it is vertical. Three forces act in the plane of the disc, as shown in Fig. 2.1.

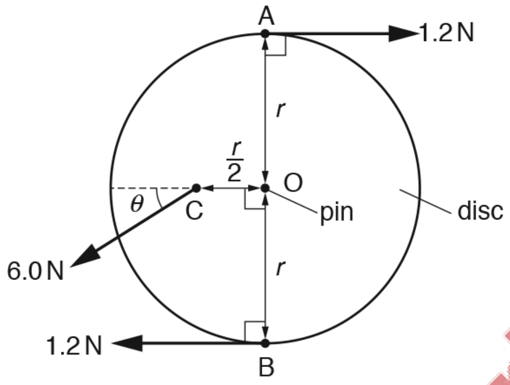

Fig. 2.1

Two horizontal and opposite forces, each of magnitude 1.2 N, act at points A and B on the edge of the disc. A force of 6.0 N, at an angle θ below the horizontal, acts on the midpoint C of a radial line of the disc, as shown in Fig. 2.1. The disc has negligible weight and is in equilibrium.

(i) State an expression, in terms of *r*, for the torque of the couple due to the forces at A and B acting on the disc.

....[1]

(ii) Friction between the disc and the pin is negligible.
Determine the angle θ.

θ = ... ° [2]

(iii) State the magnitude of the force of the pin on the disc.

force = ... N [1]

[Total: 5]

5.3 Equilibrium of forces

49. 9702_s20_qp_23 Q: 2

(a) State Newton's first law of motion.

....

.... [1]

(b) A skier is pulled in a straight line along horizontal ground by a wire attached to a kite, as shown in Fig. 2.1.

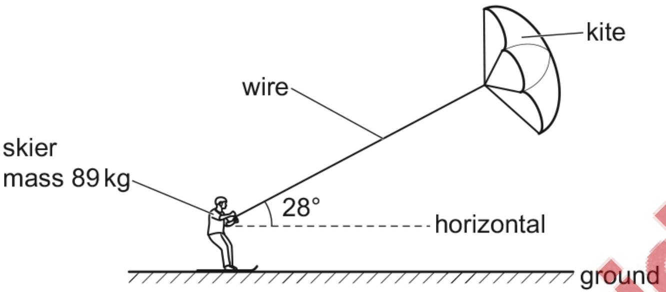

Fig. 2.1 (not to scale)

The mass of the skier is 89 kg. The wire is at an angle of 28° to the horizontal. The variation with time *t* of the velocity *v* of the skier is shown in Fig. 2.2.

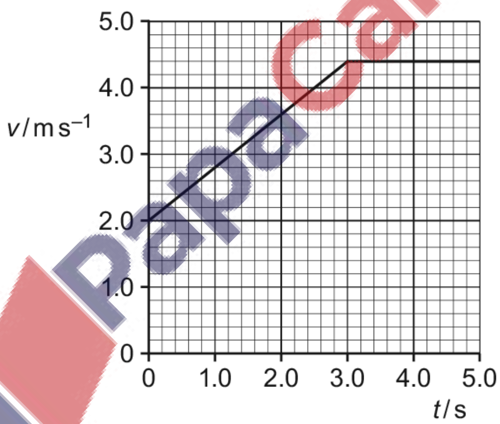

Fig. 2.2

(i) Use Fig. 2.2 to determine the distance moved by the skier from time $t = 0$ to $t = 5.0$ s.

distance = ... m [2]

(ii) Use Fig. 2.2 to show that the acceleration a of the skier is $0.80\,\text{m s}^{-2}$ at time $t = 2.0\,\text{s}$.

[2]

(iii) The tension in the wire at time $t = 2.0\,\text{s}$ is 240 N.

Calculate:

1. the horizontal component of the tension force acting on the skier

horizontal component of force = ... N [1]

2. the total resistive force R acting on the skier in the horizontal direction.

R = ... N [2]

(iv) The skier is now lifted upwards by a gust of wind. For a few seconds the skier moves horizontally through the air with the wire at an angle of 45° to the horizontal, as shown in Fig. 2.3.

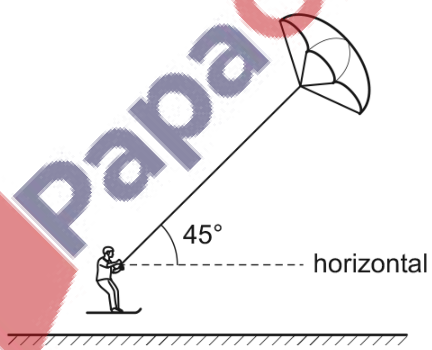

Fig. 2.3 (not to scale)

By considering the vertical components of the forces acting on the skier, determine the new tension in the wire when the skier is moving horizontally through the air.

tension = ... N [2]

[Total: 10]

50. 9702_w20_qp_22 Q: 4

A rigid plank is used to make a ramp between two different horizontal levels of ground, as shown in Fig. 4.1.

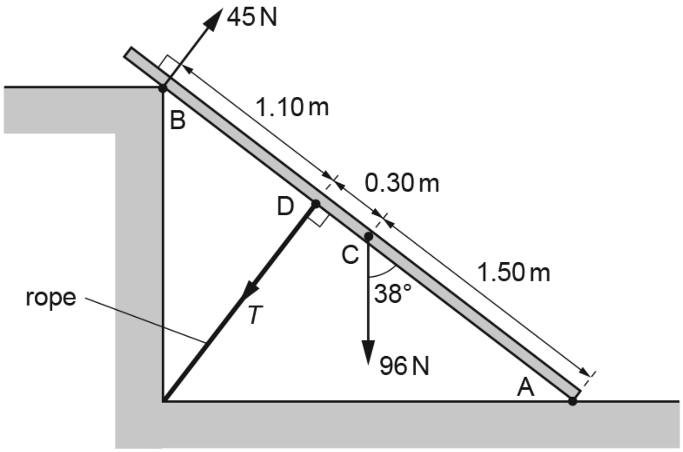

Fig. 4.1 (not to scale)

Point A at one end of the plank rests on the lower level of the ground. A force acts on, and is perpendicular to, the plank at point B. The plank is held in equilibrium by a rope that connects point D on the plank to the ground. The plank has a weight that may be considered to act from its centre of gravity C.

The rope is perpendicular to the plank and has tension *T*. The plank is at an angle of 38° to the vertical.

The forces and the distances along the plank of points A, B, C and D are shown in Fig. 4.1.

(a) Show that the component of the weight that is perpendicular to the plank is 59 N.

[1]

(b) By taking moments about end A of the plank, calculate the tension *T*.

T = ... N [3]

[Total: 4]

51. 9702_w20_qp_23 Q: 2

(a) State what is meant by the *centre of gravity* of a body.

....

....

.... [2]

(b) A uniform wooden post AB of weight 45 N stands in equilibrium on hard ground, as shown in Fig. 2.1.

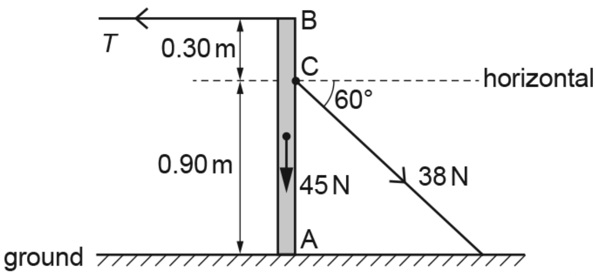

Fig. 2.1 (not to scale)

End A of the vertical post is supported by the ground. A horizontal wire with tension *T* is attached to end B of the post. Another wire, attached to the post at point C, is at an angle of 60° to the horizontal and has tension 38 N. The distances along the post of points A, B and C are shown in Fig. 2.1.

(i) Calculate the horizontal component of the force exerted on the post by the wire connected to point C.

horizontal component of force = ... N [1]

(ii) By considering moments about end A, determine the tension *T*.

T = ... N [2]

(iii) Calculate the vertical component of the force exerted on the post at end A.

force = ... N [1]

[Total: 6]

52. 9702_w18_qp_22 Q: 2

(a) The kilogram, metre and second are all SI base units.

State two other SI base units.

1. ....

2. ....
[2]

(b) A uniform beam AB of length 6.0 m is placed on a horizontal surface and then tilted at an angle of 31° to the horizontal, as shown in Fig. 2.1.

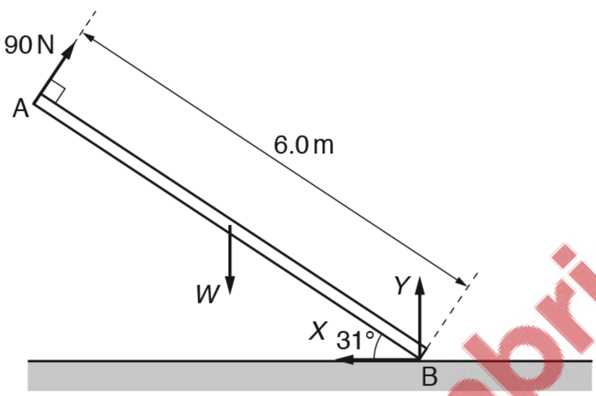

Fig. 2.1 (not to scale)

The beam is held in equilibrium by four forces that all act in the same plane. A force of 90 N acts perpendicular to the beam at end A. The weight *W* of the beam acts at its centre of gravity. A vertical force *Y* and a horizontal force *X* both act at end B of the beam.

(i) State the name of force *X*.

....[1]

(ii) By taking moments about end B, calculate the weight *W* of the beam.

W = ... N [2]

(iii) Determine the magnitude of force *X*.

magnitude of force *X* = ... N [1]

[Total: 6]

53. 9702_s15_qp_22 Q: 3

A rod PQ is attached at P to a vertical wall, as shown in Fig. 3.1.

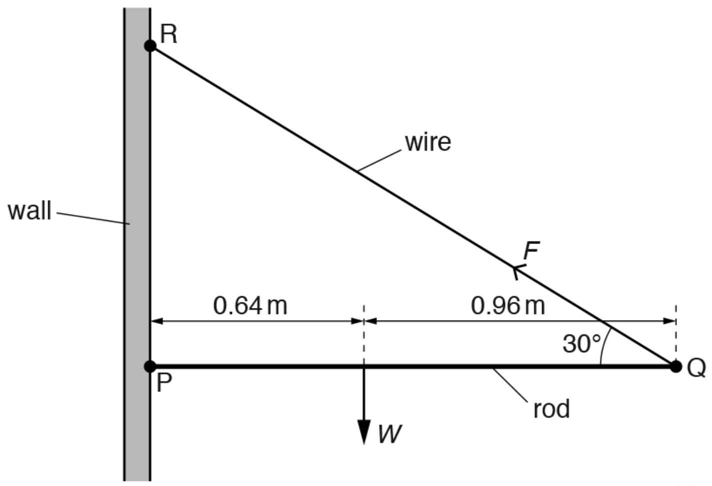

Fig. 3.1

The length of the rod is 1.60 m. The weight W of the rod acts 0.64 m from P. The rod is kept horizontal and in equilibrium by a wire attached to Q and to the wall at R. The wire provides a force F on the rod of 44 N at 30° to the horizontal.

(a) Determine

(i) the vertical component of F,

vertical component = ... N [1]

(ii) the horizontal component of F.

horizontal component = ... N [1]

(b) By taking moments about P, determine the weight W of the rod.

W = ... N [2]

(c) Explain why the wall must exert a force on the rod at P.

....

....

.... [1]

(d) On Fig. 3.1, draw an arrow to represent the force acting on the rod at P. Label your arrow with the letter S. [1]

54. 9702_w15_qp_22 Q: 4

(a) Define *moment of a force*.

....

....[1]

(b) An arrangement for lifting heavy loads is shown in Fig. 4.1.

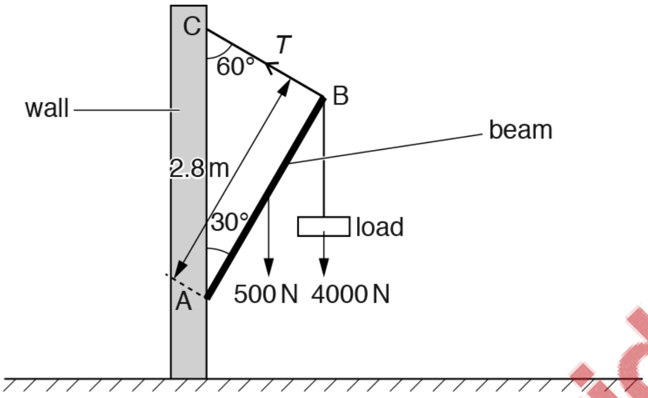

Fig. 4.1

A uniform metal beam AB is pivoted on a vertical wall at A. The beam is supported by a wire joining end B to the wall at C. The beam makes an angle of 30° with the wall and the wire makes an angle of 60° with the wall.

The beam has length 2.8 m and weight of 500 N. A load of 4000 N is supported from B. The tension in the wire is *T*. The beam is in equilibrium.

(i) By taking moments about A, show that *T* is 2.1 kN.

[2]

(ii) Calculate the vertical component T_v of the tension *T*.

T_v = ... N [1]

(iii) State and explain why T_v does not equal the sum of the load and the weight of the beam although the beam is in equilibrium.

....

....[2]

5.4 Density and pressure

55. 9702_w20_qp_21 Q: 1

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

....

.... [1]

(ii) Determine the SI base units of the moment of a force.

base units .... [1]

(b) A uniform rigid rod of length 2.4 m is shown in Fig. 1.1.

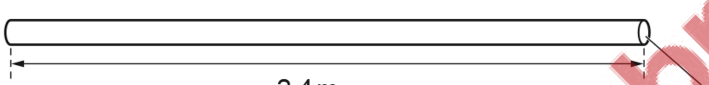

Fig. 1.1

The rod has a weight of 5.2 N and is made of wood of density 790 kg m^{-3}.

Calculate the cross-sectional area *A*, in mm^2, of the rod.

A = ... mm^2 [3]

(c) A fishing rod AB, made from the rod in **(b)**, is shown in Fig. 1.2.

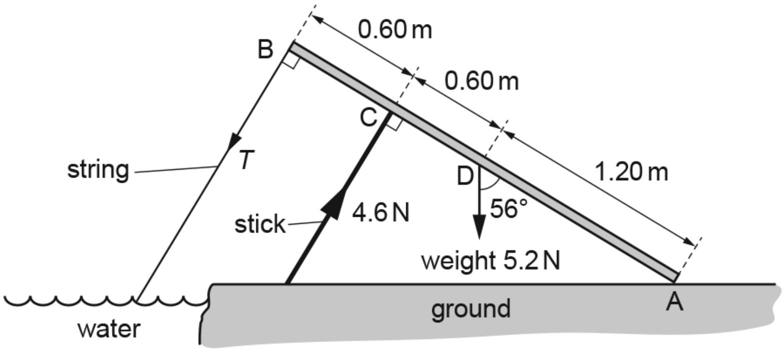

Fig. 1.2 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension *T* in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 1.2.

(i) Show that the component of the weight that is perpendicular to the rod is 4.3 N.

[1]

(ii) By taking moments about end A of the rod, calculate the tension *T*.

T = ... N [3]

[Total: 9]

56. 9702_w20_qp_22 Q: 2

(a) A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

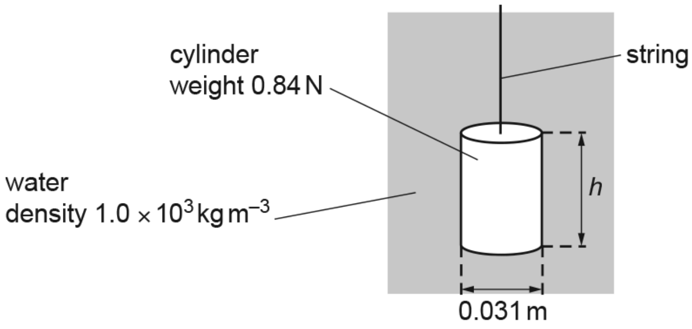

Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is $1.0 \times 10^3\,\text{kg}\,\text{m}^{-3}$. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

(i) Calculate the height h of the cylinder.

h = ... m [2]

(ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

(iii) Calculate the tension T in the string.

T = ... N [1]

(b) The string is now used to move the cylinder in **(a)** vertically upwards through the water. The variation with time t of the velocity v of the cylinder is shown in Fig. 2.2.

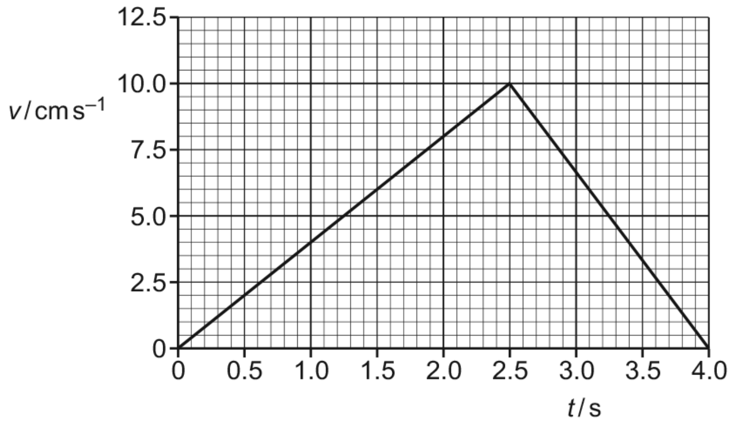

Fig. 2.2

(i) Use Fig. 2.2 to determine the acceleration of the cylinder at time t = 2.0 s.

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

(ii) The top face of the cylinder is at a depth of 0.32 m below the surface of the water at time t = 0.

Use Fig. 2.2 to determine the depth of the top face below the surface of the water at time t = 4.0 s.

depth = ... m [2]

(c) The cylinder in **(b)** is released from the string at time t = 4.0 s. The cylinder falls, from rest, vertically downwards through the water. Assume that the upthrust acting on the cylinder remains constant as it falls.

(i) State the name of the force that acts on the cylinder when it is moving and does not act on the cylinder when it is stationary.

.... [1]

(ii) State and explain the variation, if any, of the acceleration of the cylinder as it falls downwards through the water.

....

....

.... [2]

[Total: 12]

57. 9702_w18_qp_22 Q: 3

(a) State the principle of conservation of momentum.

....

....

....[2]

(b) The propulsion system of a toy car consists of a propeller attached to an electric motor, as illustrated in Fig. 3.1.

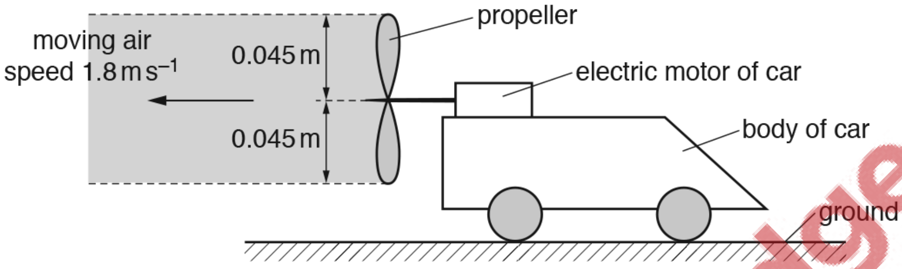

Fig. 3.1

The car is on horizontal ground and is initially held at rest by its brakes. When the motor is switched on, it rotates the propeller so that air is propelled horizontally to the left. The density of the air is 1.3 kg m^{-3}.

Assume that the air moves with a speed of 1.8 m s^{-1} in a uniform cylinder of radius 0.045 m. Also assume that the air to the right of the propeller is stationary.

(i) Show that, in a time interval of 2.0 s, the mass of air propelled to the left is 0.030 kg.

[2]

(ii) Calculate

1. the increase in the momentum of the mass of air in **(b)(i)**,

increase in momentum = ... N s

2. the force exerted on this mass of air by the propeller.

force = ... N
[3]

(iii) Explain how Newton's third law applies to the movement of the air by the propeller.

....

....

....[2]

(iv) The total mass of the car is 0.20 kg. The brakes of the car are released and the car begins to move with an initial acceleration of $0.075\,\mathrm{m\,s^{-2}}$.

Determine the initial frictional force acting on the car.

frictional force = ... N [2]

[Total: 11]

58. 9702_w18_qp_23 Q: 3

(a) State Newton's second law of motion.

....

....[1]

(b) A toy rocket consists of a container of water and compressed air, as shown in Fig. 3.1.

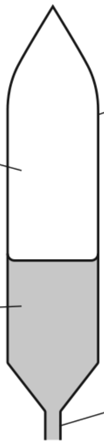

Fig. 3.1

Water is pushed vertically downwards through a nozzle by the compressed air. The rocket moves vertically upwards.

The nozzle has a circular cross-section of radius 7.5 mm. The density of the water is $1000\,\text{kg}\,\text{m}^{-3}$. Assume that the water leaving the nozzle has the shape of a cylinder of radius 7.5 mm and has a constant speed of $13\,\text{m}\,\text{s}^{-1}$ relative to the rocket.

(i) Show that the mass of water leaving the nozzle in the first 0.20 s after the rocket launch is 0.46 kg.

[2]

(ii) Calculate

1. the change in the momentum of the mass of water in **(b)(i)** due to leaving the nozzle,

change in momentum = ... N s

2. the force exerted on this mass of water by the rocket.

force = ... N
[3]

(iii) State and explain how Newton's third law applies to the movement of the rocket by the water.

....

....

....[2]

(iv) The container has a mass of 0.40 kg. The initial mass of water before the rocket is launched is 0.70 kg. The mass of the compressed air in the rocket is negligible. Assume that the resistive force on the rocket due to its motion is negligible.

For the rocket at a time of 0.20 s after launching,

1. show that its total mass is 0.64 kg,

2. calculate its acceleration.

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

[Total: 11]

59. 9702_s17_qp_21 Q: 3

(a) A cylinder is made from a material of density 2.7 g cm^{-3}. The cylinder has diameter 2.4 cm and length 5.0 cm.

Show that the cylinder has weight 0.60 N.

[3]

(b) The cylinder in **(a)** is hung from the end A of a non-uniform bar AB, as shown in Fig. 3.1.

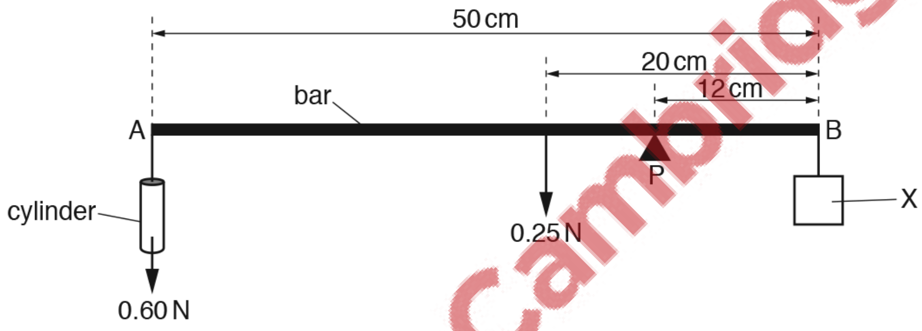

Fig. 3.1

The bar has length 50 cm and has weight 0.25 N. The centre of gravity of the bar is 20 cm from B. The bar is pivoted at P. The pivot is 12 cm from B.

An object X is hung from end B. The weight of X is adjusted until the bar is horizontal and in equilibrium.

(i) Explain what is meant by *centre of gravity*.

....

....[1]

(ii) Calculate the weight of X.

weight of X = ... N [3]

(c) The cylinder is now immersed in water, as illustrated in Fig. 3.2.

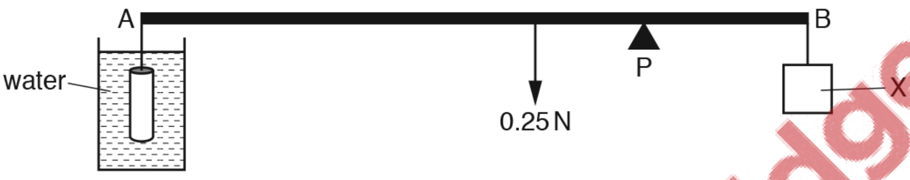

Fig. 3.2

An upthrust acts on the cylinder and the bar is not in equilibrium.

(i) Explain the origin of the upthrust.

....

....

....

....[2]

(ii) Explain why the weight of X must be reduced in order to obtain equilibrium for AB.

....

....

....[1]

[Total: 10]

60. 9702_s16_qp_22 Q: 2

(a) Fig. 2.1 shows a liquid in a cylindrical container.

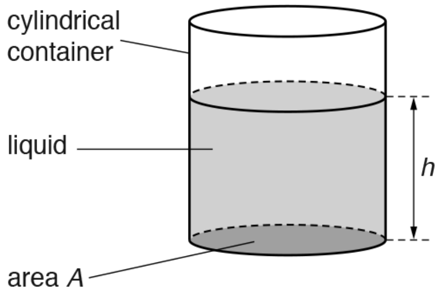

Fig. 2.1

The cross-sectional area of the container is A. The height of the column of liquid is h and the density of the liquid is ρ.

Show that the pressure p due to the liquid on the base of the cylinder is given by

$$p = \rho g h.$$

[3]

(b) The variation with height h of the total pressure P on the base of the cylinder in **(a)** is shown in Fig. 2.2.

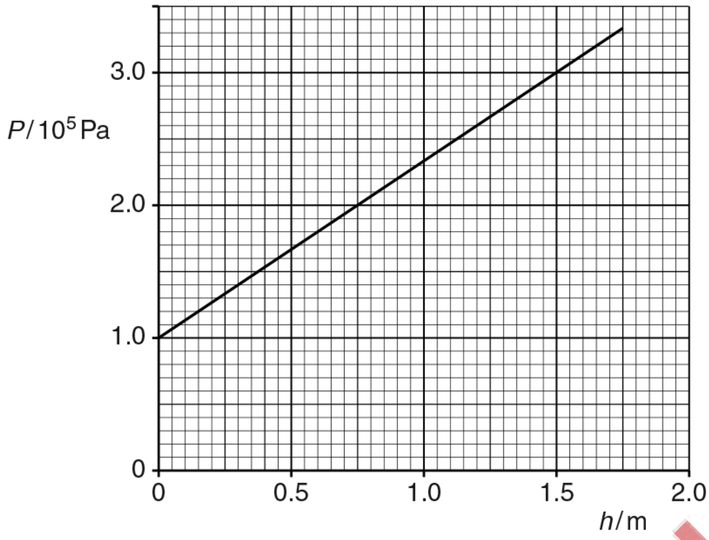

Fig. 2.2

(i) Explain why the line of the graph in Fig. 2.2 does not pass through the origin (0,0).

....

....[1]

(ii) Use data from Fig. 2.2 to calculate the density of the liquid in the cylinder.

density = ... $kg\,m^{-3}$ [2]

[Total: 6]

61. 9702_s16_qp_23 Q: 4

A spring balance is used to weigh a cylinder that is immersed in oil, as shown in Fig. 4.1.

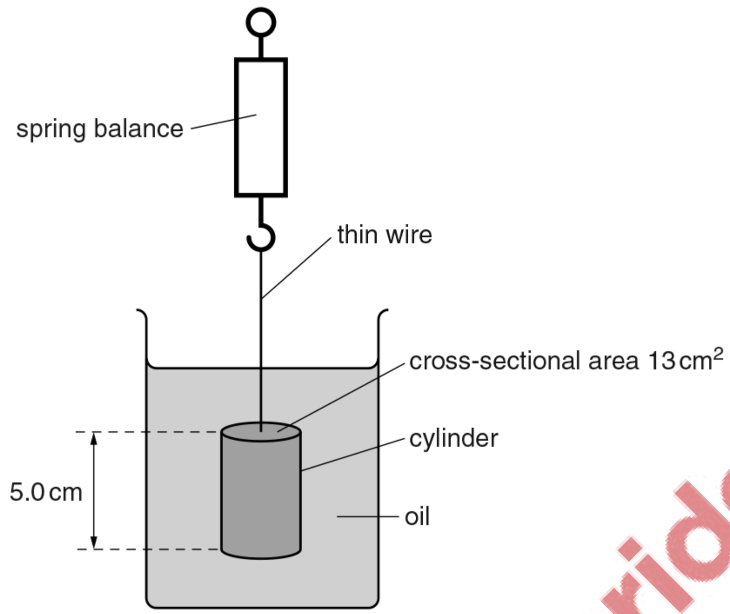

Fig. 4.1

The reading on the spring balance is 4.8 N. The length of the cylinder is 5.0 cm and the cross-sectional area of the cylinder is 13 cm^2. The weight of the cylinder is 5.3 N.

(a) The cylinder is in equilibrium when it is immersed in the oil. Explain this in terms of the forces acting on the cylinder.

....

.... [1]

(b) Calculate the density of the oil.

density = ... kg m^{-3} [3]

[Total: 4]

62. 9702_w16_qp_21 Q: 1

(a) Define *density*.

....

....[1]

(b) The mass m of a metal sphere is given by the expression

$$m = \frac{\pi d^3 \rho}{6}$$

where ρ is the density of the metal and d is the diameter of the sphere.

Data for the density and the mass are given in Fig. 1.1.

quantity	value	uncertainty
ρ m	8100 kg m^{-3} 7.5 kg	± 5% ± 4%

Fig. 1.1

(i) Calculate the diameter d.

d = ... m [1]

(ii) Use your answer in **(i)** and the data in Fig. 1.1 to determine the value of d, with its absolute uncertainty, to an appropriate number of significant figures.

d = ... ± .... m [3]

[Total: 5]

63. 9702_w16_qp_22 Q: 1

(a) **(i)** Define *pressure*.

....

....[1]

(ii) Show that the SI base units of pressure are $\text{kg}\,\text{m}^{-1}\,\text{s}^{-2}$.

[1]

(b) Gas flows through the narrow end (nozzle) of a pipe. Under certain conditions, the mass *m* of gas that flows through the nozzle in a short time *t* is given by

$$\frac{m}{t} = kC\sqrt{\rho P}$$

where *k* is a constant with no units,
C is a quantity that depends on the nozzle size,
ρ is the density of the gas arriving at the nozzle,
P is the pressure of the gas arriving at the nozzle.

Determine the base units of *C*.

base units ....[3]

[Total: 5]

64. 9702_w16_qp_23 Q: 1

(a) Define *density*.

....

....[1]

(b) The mass *m* of a metal sphere is given by the expression

$$m = \frac{\pi d^3 \rho}{6}$$

where ρ is the density of the metal and *d* is the diameter of the sphere.

Data for the density and the mass are given in Fig. 1.1.

quantity	value	uncertainty
ρ m	$8100\,\text{kg}\,\text{m}^{-3}$ 7.5 kg	± 5% ± 4%

Fig. 1.1

(i) Calculate the diameter *d*.

d = ... m [1]

(ii) Use your answer in **(i)** and the data in Fig. 1.1 to determine the value of *d*, with its absolute uncertainty, to an appropriate number of significant figures.

d = ... ± .... m [3]

[Total: 5]

65. 9702_s15_qp_22 Q: 4

(a) A gas molecule has a mass of 6.64×10^{-27} kg and a speed of $1250\,\mathrm{m\,s^{-1}}$. The molecule collides normally with a flat surface and rebounds with the same speed, as shown in Fig. 4.1.

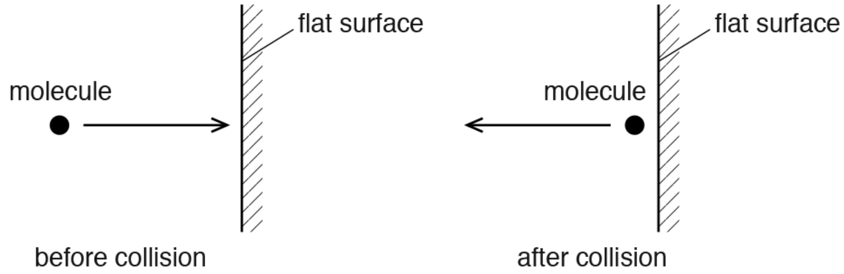

Fig. 4.1

Calculate the change in momentum of the molecule.

change in momentum = ... N s [2]

(b) **(i)** Use the kinetic model to explain the pressure exerted by gases.

....

....

....

....

....

.... [3]

(ii) Explain the effect of an increase in density, at constant temperature, on the pressure of a gas.

....

.... [1]

66. 9702_w15_qp_21 Q: 4

Fig. 4.1 shows a metal cylinder of height 4.5 cm and base area 24 cm^2.

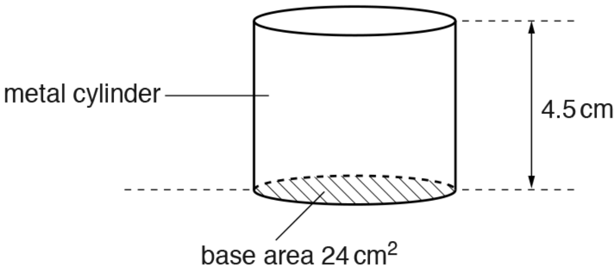

Fig. 4.1

The density of the metal is 7900 kg m^{-3}.

(a) Show that the mass of the cylinder is 0.85 kg.

[2]

(b) The cylinder is placed on a plank, as shown in Fig. 4.2.

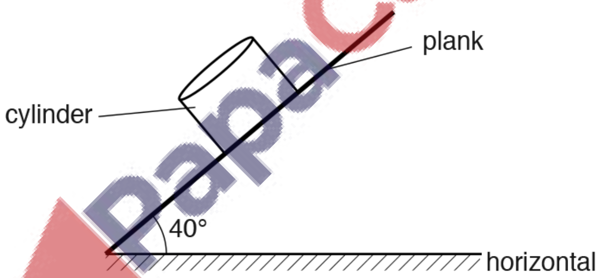

Fig. 4.2

The plank is at an angle of 40° to the horizontal.

Calculate the pressure on the plank due to the cylinder.

pressure = ... Pa [3]

(c) The cylinder then slides down the plank with a constant acceleration of $3.8\,m\,s^{-2}$.
A constant frictional force *f* acts on the cylinder.

Calculate the frictional force *f*.

f = ... N [3]

67. 9702_w15_qp_23 Q: 7

A steel wire of cross-sectional area 15 mm^2 has an ultimate tensile stress of 4.5×10^8 N m^{-2}.

(a) Calculate the maximum tension that can be applied to the wire.

tension = ... N [2]

(b) The steel of the wire has density 7800 kg m^{-3}. The wire is hung vertically.

Calculate the maximum length of the steel wire that could be hung vertically before the wire breaks under its own weight.

length = ... m [3]