FORCES, DENSITY AND PRESSURE
AS LEVEL WORKSHEET

1 The drag force F_D acting on an object falling through air is given by **MJ2024/21/Q1**

$$F_D = \frac{1}{2} C\rho A v^2$$

where A is the cross-sectional area of the object,
v is the velocity of the object in the air,
ρ is the density of the air and
C is a constant called the drag coefficient.

(a) Use SI base units to show that the drag coefficient has no units.

[3]

(b) Fig. 1.1 shows a sphere falling at terminal velocity in air.

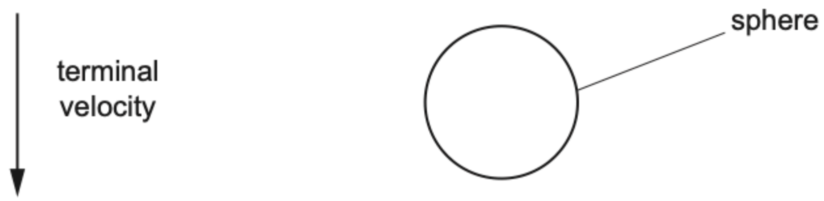

Fig. 1.1

Assume that the upthrust on the sphere is negligible.

On Fig. 1.1, draw and label arrows to show the directions of the **two** forces acting on the sphere. [2]

(c) The mass of the sphere is 49 g.

Calculate the drag force F_D acting on the sphere.

F_D = ... N [2]

(d) The sphere is falling in air at a terminal velocity of 25 in SI base units.
The density of the air is 1.2 in SI base units.
The diameter of the sphere is 0.060 in SI base units.

Use your answer in **(c)** to calculate the drag coefficient *C* for the sphere.

C = ... [3]

[Total: 10]

MJ2024/23/Q1

2 The drag force F_D acting on a sphere falling through a liquid is given by

$$F_D = 6\pi\eta r v$$

where *r* is the radius of the sphere,
v is the speed of the sphere in the liquid and
η is a property of the liquid called the viscosity.

(a) Show that the SI base units of viscosity are $kg\,m^{-1}\,s^{-1}$.

[2]

(b) The sphere has a radius of 3.0 cm and is falling vertically downwards at a terminal velocity of $2.0\,m\,s^{-1}$ through the liquid. The drag force acting on the sphere is 0.096 N.

Calculate the viscosity of the liquid.

viscosity = ... $kg\,m^{-1}\,s^{-1}$ [2]

(c) The sphere is shown in Fig. 1.1.

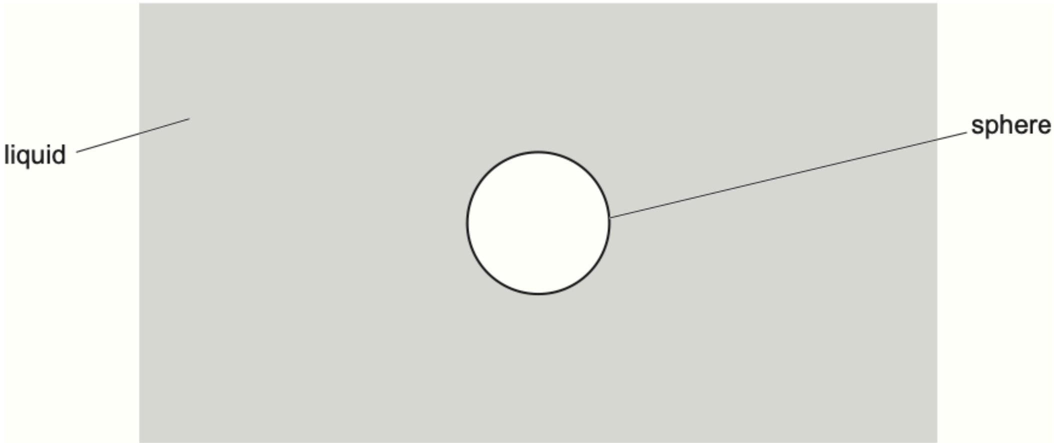

Fig. 1.1

On Fig. 1.1, draw and label arrows to represent the directions of the **three** forces acting on the sphere as it falls at terminal velocity through the liquid. [2]

(d) (i) The density of the liquid is $920\,kg\,m^{-3}$.

Show that the upthrust acting on the sphere is 1.0 N.

[2]

(ii) Calculate the mass of the sphere.

mass = ... kg [2]

[Total: 10]

ON2023/23/Q3

3 **(a)** State the conditions for a system to be in equilibrium.

....

....

.... [2]

(b) Fig. 3.1 shows an airship in flight. The airship is propelled by identical fans that can be angled to control the motion of the airship.

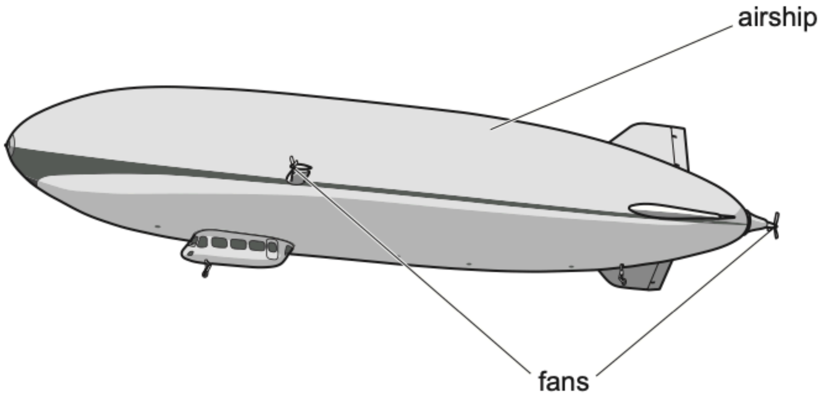

Fig. 3.1

The upthrust on the airship is 93 000 N.
The density of the surrounding air is $1.2\,kg\,m^{-3}$.

(i) Calculate the volume of air displaced by the airship.

volume = ... m^3 [1]

(ii) When fully loaded, the weight of the airship is greater than the upthrust.
To maintain horizontal flight, the fans provide a total vertical force of 3.0×10^3 N upwards on the airship.

Calculate the mass of the airship.

mass = ... kg [2]

(c) At a certain time, the airship in **(b)** is stationary. The thrust force exerted by a fan on the airship is 2800 N.

To produce this force, a mass of 64 kg of air is propelled through the blades of the fan in a time of 0.50 s. Assume that this air is initially stationary at the entrance to the fan.

Calculate:

(i) the change in momentum Δp of the air propelled through the fan blades in this time

Δp = ... $kg\,m\,s^{-1}$ [2]

(ii) the speed of the air as it leaves the fan

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

(iii) the total kinetic energy of this air due to its movement through the fan.

kinetic energy = ... J [2]

[Total: 11]

4 **(a)** State what is meant by the centre of gravity of an object.

....

.... [1]

(b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

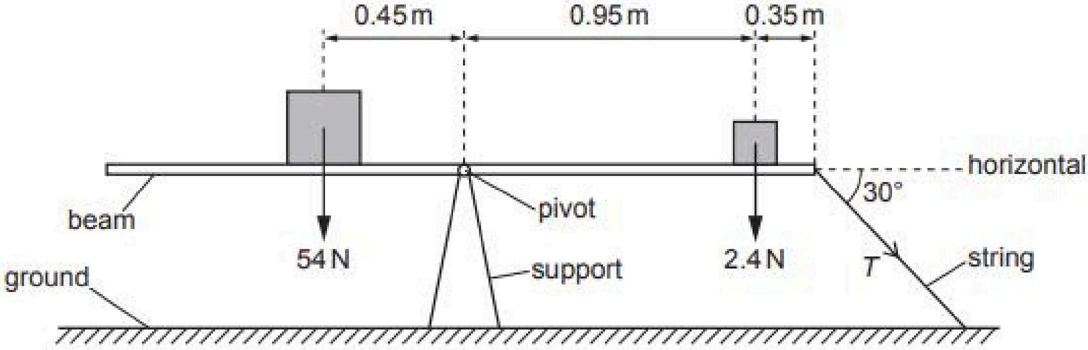

Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

(i) By taking moments about the pivot, calculate the tension *T* in the string.

T = ... N [3]

(ii) The string is cut so that the beam is no longer in equilibrium.

Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut.

resultant moment = ... N m [1]

(c) The beam in **(b)** rotates when the string is cut and the small block of weight 2.4 N is projected through the air. Fig. 2.2 shows the last part of the path of the block before it hits the ground at point Y.

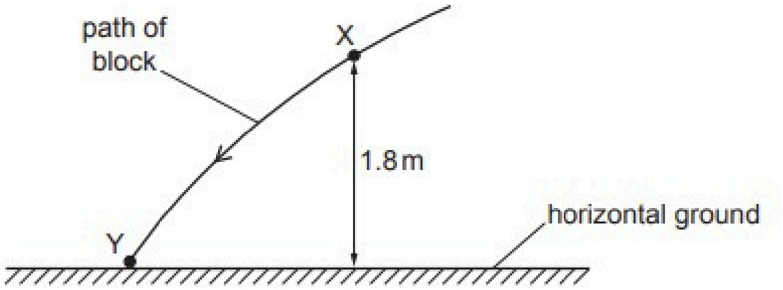

Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of $3.4\,\text{m}\,\text{s}^{-1}$ and is at a height of 1.8 m above the horizontal ground. Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from X to Y.

decrease in gravitational potential energy = ... J [2]

(ii) Use your answer to **(c)(i)** and conservation of energy to determine the kinetic energy of the block at Y.

kinetic energy = ... J [3]

(iii) State the variation, if any, in the direction of the acceleration of the block as it moves from X to Y.

.... [1]

(iv) The block passes point X at time t_X and arrives at point Y at time t_Y.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the horizontal component of the velocity of the block with time from t_X to t_Y.
Numerical values are not required.

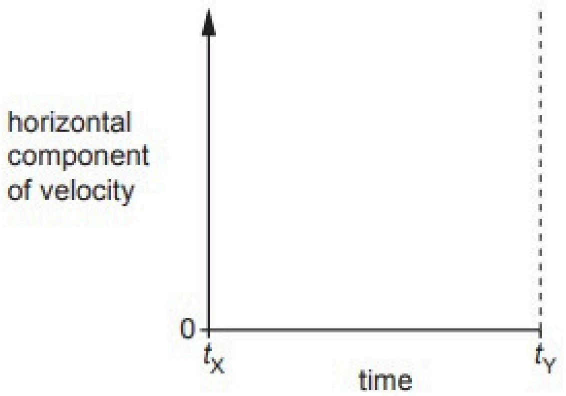

Fig. 2.3

[1]

[Total: 12]

5 A beaker in air contains a liquid. The base of the beaker is in contact with the liquid and has area A, as shown in Fig. 4.1.

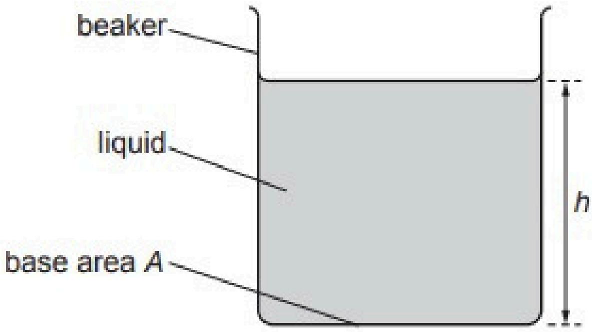

Fig. 4.1

The liquid has density ρ and fills the beaker to a depth h.

(a) By using the definitions of pressure and density, show that

$$p = \rho g h$$

where p is the pressure due to the liquid that is exerted on the base of the beaker and g is the acceleration of free fall.

[3]

(b) Suggest why the equation in **(a)** does not give the total pressure on the base of the beaker.

....

.... [1]

(c) Fig. 4.2 shows the variation of the total pressure inside the liquid with depth x below the surface.

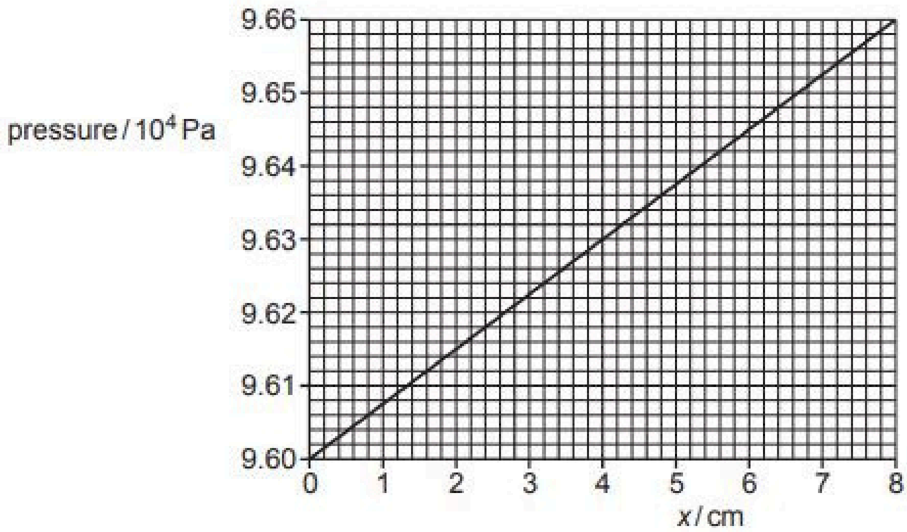

Fig. 4.2

Determine the density of the liquid.

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

(d) A solid cylinder is held stationary by a wire so that the base of the cylinder is level with the surface of the liquid, as shown in Fig. 4.3.

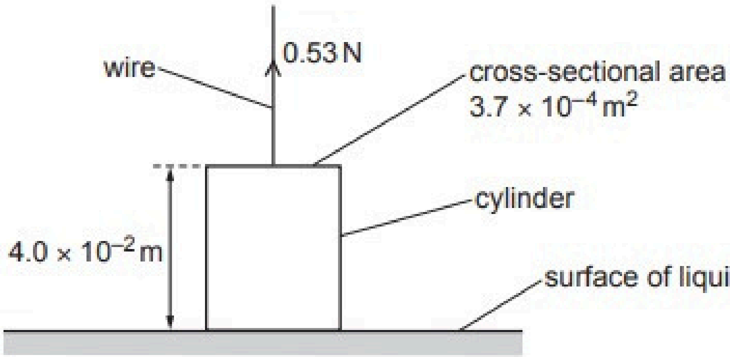

Fig. 4.3 (not to scale)

The cylinder has length 4.0×10^{-2} m and cross-sectional area 3.7×10^{-4} m^2. The tension in the wire is 0.53 N.

The cylinder is now lowered and then held stationary by the wire so that the top of the cylinder is level with the surface of the liquid.

Calculate the new tension in the wire.

tension = ... N [2]

[Total: 8]

6 A uniform beam AB is attached by a hinge to a wall at end A, as shown in Fig. 3.1.

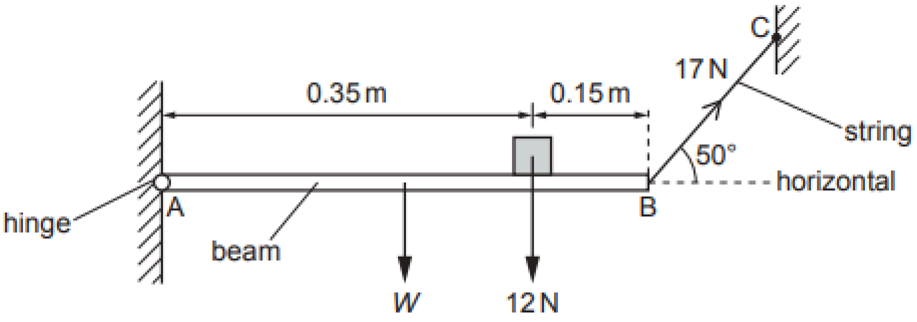

Fig. 3.1 (not to scale)

The beam has length 0.50 m and weight *W*. A block of weight 12 N rests on the beam at a distance of 0.15 m from end B.

The beam is held horizontal and in equilibrium by a string attached between end B and a fixed point C. The string has a tension of 17 N and is at an angle of 50° to the horizontal.

(a) State **two** conditions for an object to be in equilibrium.

1 ....

....

2 ....

....

[2]

(b) Show that the vertical component of the tension in the string is 13 N.

[1]

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

W = ... N [2]

(d) Calculate the magnitude of the vertical component of the force exerted on the beam by the hinge.

force = ... N [1]

(e) The block is now moved closer to end A of the beam. Assume that the beam remains horizontal.

State whether this change will increase, decrease or have no effect on the horizontal component of the force exerted on the beam by the hinge.

.... [1]

[Total: 7]

7 (a) State what is meant by the centre of gravity of an object.

....

.... [1]

(b) A non-uniform rod XY is pivoted at point P, as shown in Fig. 2.1.

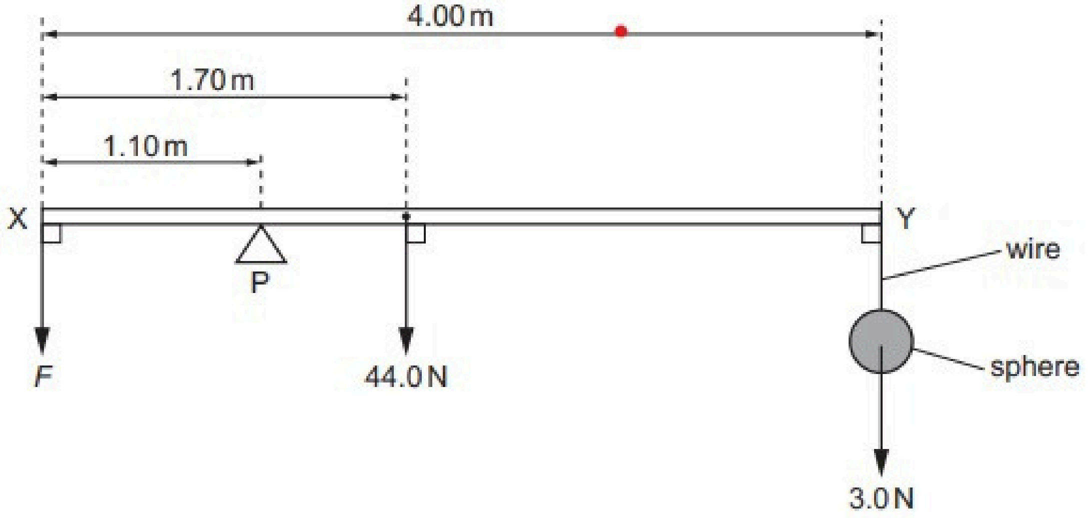

Fig. 2.1 (not to scale)

The rod has length 4.00 m and weight 44.0 N. The centre of gravity of the rod is 1.70 m from end X of the rod. Point P is 1.10 m from end X.

A sphere hangs by a wire from end Y of the rod. The weight of the sphere is 3.0 N. The weight of the wire is negligible.

A force *F* is applied vertically downwards at end X so that the horizontal rod is in equilibrium.

(i) By taking moments about P, calculate *F*.

F = ... N [3]

(ii) Calculate the force exerted on the rod by the pivot.

force = ... N [1]

(c) The sphere in **(b)** is now immersed in a liquid in a container, as shown in Fig. 2.2.

Fig. 2.2

The density of the liquid is $1100\,\mathrm{kg\,m^{-3}}$. The upthrust acting on the sphere due to the liquid is 2.5N. The magnitude of F is unchanged so that the horizontal rod is **not** in equilibrium.

(i) Use Archimedes' principle to determine the radius r of the sphere.

r = ... m [3]

(ii) Calculate the magnitude and direction of the resultant moment of the forces on the rod about P.

magnitude of resultant moment = ... N m

direction of resultant moment ....
[2]

[Total: 10]

8 A sphere is attached by a metal wire to the horizontal surface at the bottom of a river, as shown in Fig. 2.1.

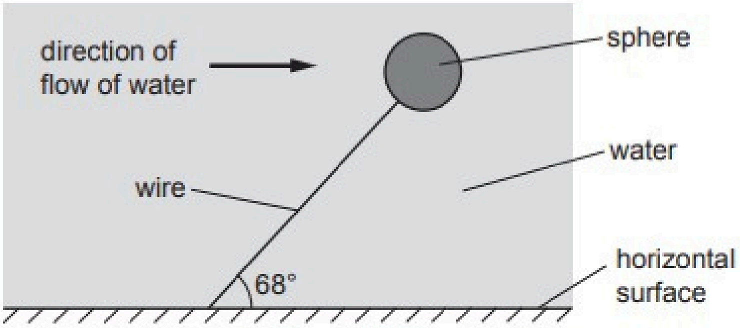

Fig. 2.1 (not to scale)

The sphere is fully submerged and in equilibrium, with the wire at an angle of 68° to the horizontal surface. The weight of the sphere is 32 N. The upthrust acting on the sphere is 280 N. The density of the water is $1.0 \times 10^3\,kg\,m^{-3}$.

Assume that the force on the sphere due to the water flow is in a horizontal direction.

(a) By considering the components of force in the vertical direction, determine the tension in the wire.

tension = ... N [2]

(b) For the sphere, calculate:

(i) the volume

volume = ... m^3 [1]

(ii) the density.

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

9 **(a)** State what is meant by the centre of gravity of an object.

....

.... [1]

(b) A uniform beam AB is attached by a frictionless hinge to a vertical wall at end A. The beam is held so that it is horizontal by a metal wire CD, as shown in Fig. 3.1.

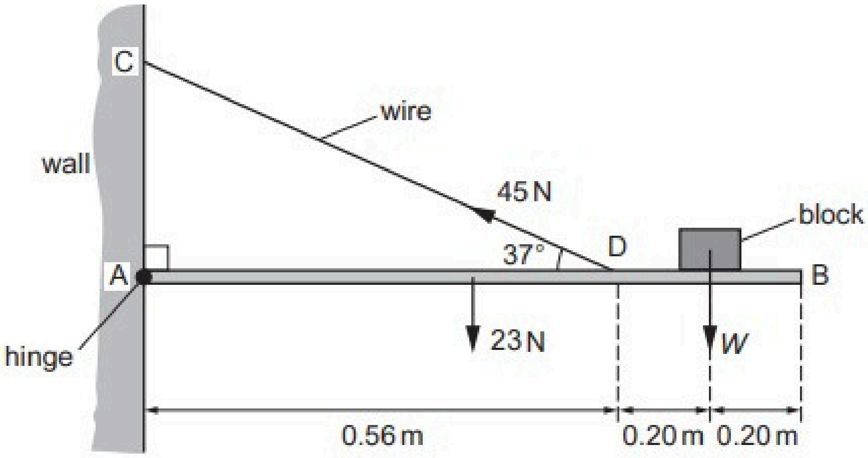

Fig. 3.1 (not to scale)

The beam is of length 0.96 m and weight 23 N. A block of weight *W* rests on the beam at a distance of 0.20 m from end B. The wire is attached to the beam at point D which is a distance of 0.40 m from end B. The wire exerts a force on the beam of 45 N at an angle of 37° to the horizontal. The beam is in equilibrium.

(i) Calculate the vertical component of the force exerted by the wire on the beam.

vertical component of the force = ... N [1]

(ii) By taking moments about A, calculate the weight *W* of the block.

W = ... N [3]

(iii) The hinge exerts a force on the beam at end A.

Calculate the horizontal component of this force.

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

(iv) The block is now placed closer to point D on the beam.

State whether this change will increase, decrease or have no effect on the tension in the wire.

.... [1]

(v) The stress in the wire is 5.3×10^7 Pa. The wire is now replaced by a second wire that has a radius which is three times greater than that of the original wire. The tension in the wire is unchanged.

Calculate the stress in the second wire.

stress = ... Pa [2]

[Total: 9]

10

(c) One end of the spring is attached to a fixed point. A cylinder that is submerged in a liquid is now suspended from the other end of the spring, as shown in Fig. 3.2.

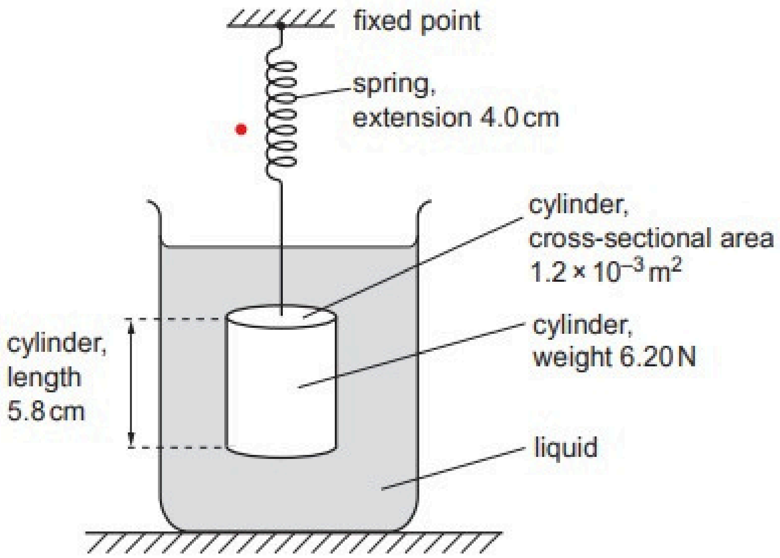

Fig. 3.2

The cylinder has length 5.8 cm, cross-sectional area $1.2 \times 10^{-3}\,m^2$ and weight 6.20 N. The cylinder is in equilibrium when the extension of the spring is 4.0 cm.

(i) Show that the upthrust acting on the cylinder is 0.60 N.

[1]

(ii) Calculate the difference in pressure between the bottom face and the top face of the cylinder.

difference in pressure = ... Pa [2]

(iii) Calculate the density of the liquid.

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

(d) The liquid in **(c)** is replaced by another liquid of greater density.

State the effect, if any, of this change on:

(i) the upthrust acting on the cylinder

.... [1]

(ii) the extension of the spring.

.... [1]

[Total: 12]

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

....

....

.... [2]

(b) Fig. 3.1 shows a type of balance that is used for measuring mass.

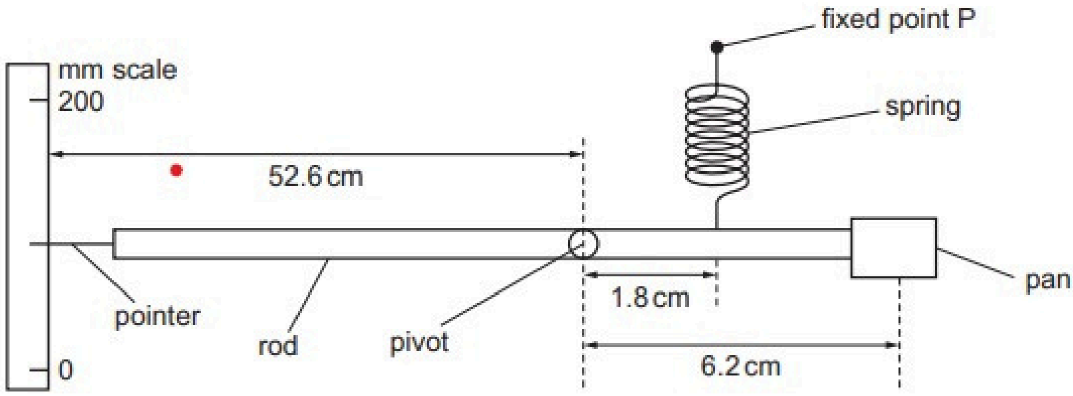

Fig. 3.1 (not to scale)

A rigid rod is pivoted about a point 6.2 cm from the centre of a pan which is attached to one end. The object being measured is placed on the centre of this pan.

A spring, attached to the rod 1.8 cm from the pivot, is attached at its other end to a fixed point P. The spring obeys Hooke's law over the full range of operation of the balance.

A pointer, on the other side of the pivot, is set against a millimetre scale which is a distance 52.6 cm from the pivot.

When the system is in equilibrium with no mass on the pan, the rod is horizontal and the pointer indicates a reading on the scale of 86 mm.

An object of mass 0.472 kg is now placed on the pan. As a result, the pointer moves to indicate a reading of 123 mm on the scale when the system is again in equilibrium.

(i) Show that the increase in the length of the spring is approximately 1.3 mm.

[2]

(ii) Calculate the magnitude of the moment about the pivot of the weight of the object.

moment = ... N m [2]

(iii) Use your answer in **(b)(ii)** to determine the increase in the tension in the spring due to the 0.472 kg mass.

increase in tension = ... N [2]

(iv) Use the information in **(b)(i)** and your answer in **(b)(iii)** to determine the spring constant *k* of the spring. Give a unit with your answer.

k = ... unit .... [2]

[Total: 10]

12 **(a)** Define *velocity*.

....

.... [1]

(b) A remote-controlled toy aircraft is flying horizontally in a wind. Fig. 3.1 shows the velocity vectors, to scale, of the wind and of the aircraft in still air.

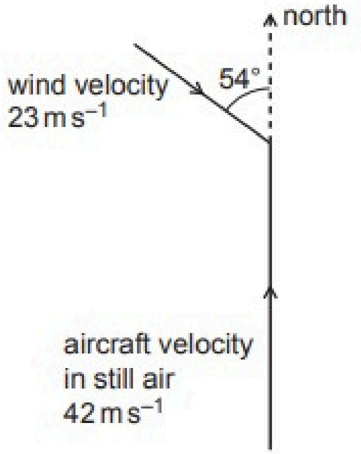

Fig. 3.1

The velocity of the aircraft in still air is 42 m s^{-1} to the north. The velocity of the wind is 23 m s^{-1} in a direction of 54° east of south.

Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... m s^{-1} [2]

(c) The engine of the aircraft in **(b)** stops. The aircraft then glides towards the ground with a constant velocity at an angle θ to the horizontal, as illustrated in Fig. 3.2.

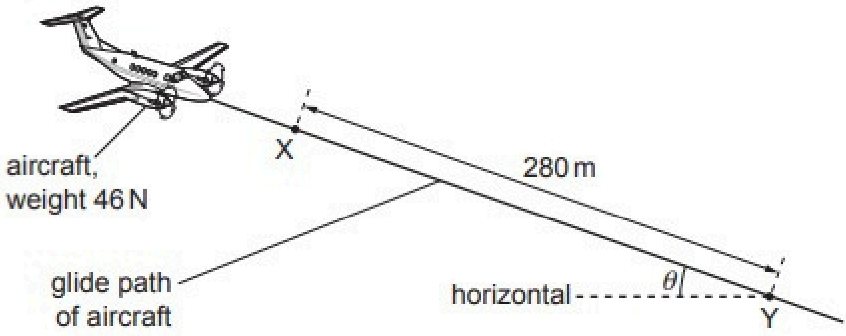

Fig. 3.2 (not to scale)

The aircraft has a weight of 46 N and travels a distance of 280 m from point X to point Y. The change in gravitational potential energy of the aircraft for its movement from X to Y is 6100 J.

Assume that there is now no wind.

(i) Calculate angle θ.

θ = ... ° [3]

(ii) Calculate the magnitude of the force acting on the aircraft due to air resistance.

force = ... N [2]

13 **(a)** State **two** conditions for an object to be in equilibrium.

1. ....

....

2. ....

....
[2]

(b) A sphere of weight 2.4N is suspended by a wire from a fixed point P. A horizontal string is used to hold the sphere in equilibrium with the wire at an angle of 53° to the horizontal, as shown in Fig. 3.1.

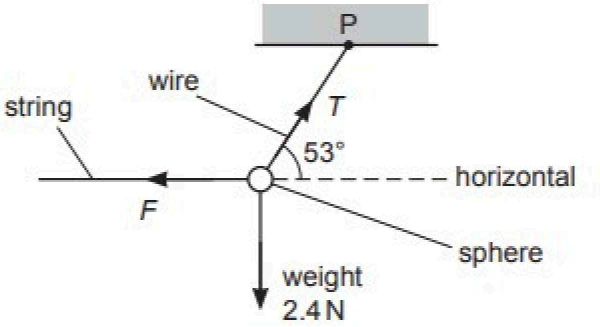

Fig. 3.1 (not to scale)

(i) Calculate:

1. the tension T in the wire

T = ... N

2. the force F exerted by the string on the sphere.

F = ... N
[2]

(ii) The wire has a circular cross-section of diameter 0.50 mm. Determine the stress σ in the wire.

σ = ... Pa [3]

14 **(a)** State the principle of moments.

....

....

.... [2]

(b) In a bicycle shop, two wheels hang from a horizontal uniform rod AC, as shown in Fig. 3.1.

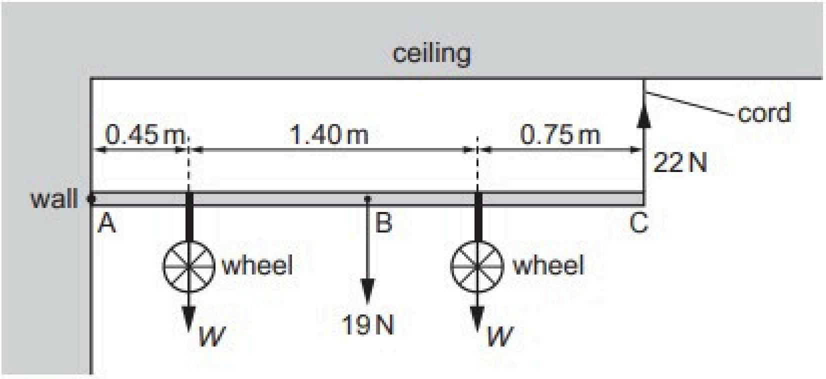

Fig. 3.1 (not to scale)

The rod has weight 19 N and is freely hinged to a wall at end A. The other end C of the rod is attached by a vertical elastic cord to the ceiling. The centre of gravity of the rod is at point B. The weight of each wheel is *W* and the tension in the cord is 22 N.

(i) By taking moments about end A, show that the weight *W* of each wheel is 14 N.

[2]

(ii) Determine the magnitude and the direction of the force acting on the rod at end A.

magnitude = ... N

direction ....

[2]

(c) The unstretched length of the cord in **(b)** is 0.25 m. The variation with length *L* of the tension *F* in the cord is shown in Fig. 3.2.

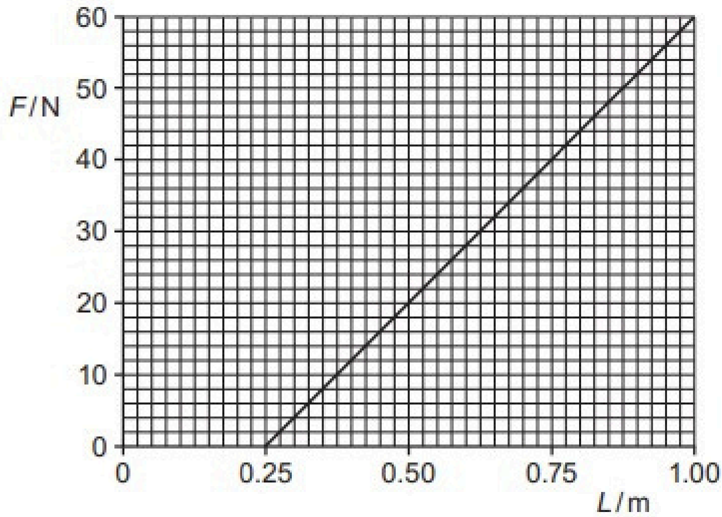

Fig. 3.2

(i) State and explain whether Fig. 3.2 suggests that the cord obeys Hooke's law.

....

....

.... [2]

(ii) Calculate the spring constant *k* of the cord.

k = ... N m^{-1} [2]

(iii) On Fig. 3.2, shade the area that represents the work done to extend the cord when the tension is increased from *F* = 0 to *F* = 40 N. [1]

[Total: 11]

15 **(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.

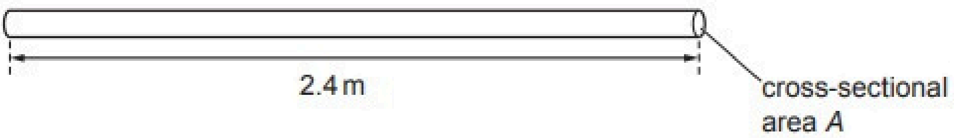

Fig. 1.1

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.

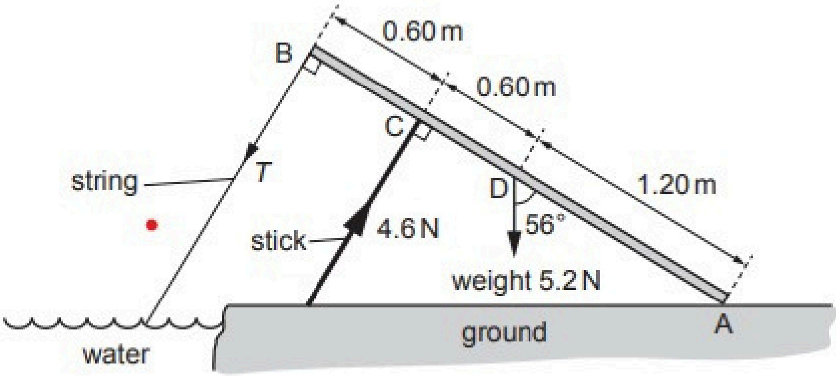

Fig. 1.2 (not to scale)

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]

16 **(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.

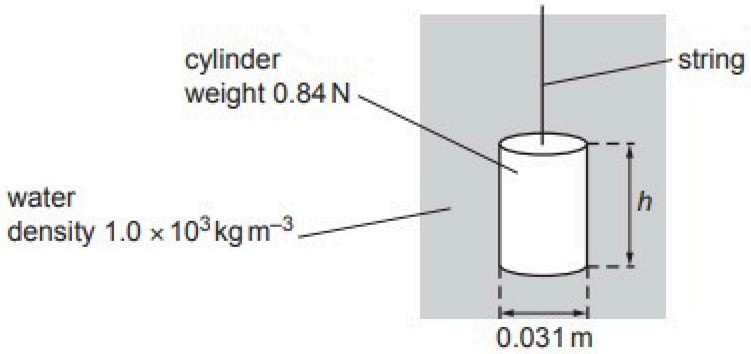

Fig. 2.1 (not to scale)

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.

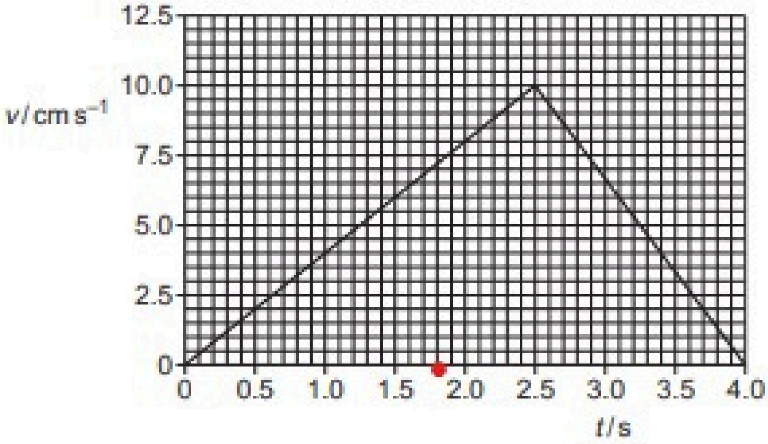

Fig. 2.2

(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]

1	units of F_D: kg m s^{-2}	M1
	units of ρ: kg m^{-3} **and** units of A: m^2 **and** units of v: m s^{-1} **or** units of v^2: m^2 s^{-2}	M1
	kg m s^{-2} = C kg m s^{-2} **and** comment '(so) C has no units' / unit terms cancelled **or** C = kg m s^{-2} / (kg m^{-3} m^2 m^2 s^{-2}) **and** comment '(so) C has no units' / unit terms cancelled	A1
1(b)	one arrow vertically downward labelled weight to within 10° of the vertical	B1
	one arrow vertically upwards labelled drag / drag force / F_D / air resistance / viscous force to within 10° of the vertical	B1
1(c)	(at terminal velocity) $F_D = mg$	C1
	$F_D = 0.049 \times 9.81$ $= 0.48$ N	A1
1(d)	area = $\pi \times (0.060 / 2)^2$	C1
	$0.48 = ½ \times C \times 1.2 \times \pi \times (0.060 / 2)^2 \times 25^2$	C1
	$C = 0.45$	A1

2 (a)	units of F: kg m s^{-2}	C1
	units of r: m and units of v: m s^{-1} units of η: kg m s^{-2} / (m × m s^{-1}) = kg m^{-1} s^{-1}	A1
1(b)	viscosity $= 0.096 / (6 \times \pi \times 0.03 \times 2.0)$	C1
	$= 0.085$ kg m^{-1} s^{-1}	A1
1(c)	one arrow vertically downwards labelled weight / W	B1
	arrow(s) vertically upwards labelled U / upthrust **and** drag / F_D / viscous force	B1
1(d)(i)	$V = (4 / 3)\ \pi r^3$	C1
	upthrust = $(4 / 3) \times \pi \times 0.03^3 \times 920 \times 9.81 = 1.0$ N	A1
1(d)(ii)	weight = 1.0 + 0.096 (= 1.096 N)	C1
	$m = 1.096 / 9.81$ $= 0.11$ kg	A1

3 a)	resultant force (in any direction) is zero	B1
	resultant moment / torque (about any point) is zero	B1
3(b)(i)	$F = \rho Vg$ $V = 93\,000 / (1.2 \times 9.81)$ $= 7900\ m^3$	A1
3(b)(ii)	weight = $93\,000 + 3(.0) \times 10^3$	C1
	$m = (93\,000 + 3.0 \times 10^3) / 9.81$ $= 9800$ kg	A1
3(c)(i)	$(\Delta p) = F(\Delta)t$ **or** $F = \Delta p / (\Delta)t$ **or** F = rate of change of momentum **or** $F = m (v - u) / t$	C1
	$\Delta p = 2800 \times 0.50$ $= 1400$ kg m s^{-1}	A1
3(c)(ii)	$(\Delta p =)\ mv$	C1
	$v = 1400 / 64$ $= 22$ m s^{-1}	A1

3(c)(iii)	$E_K = ½mv^2$	C1
	$= ½ \times 64 \times 22^2$ $= 15\,000$ J	A1
	or	
	$E_K = p^2 / 2m$	(C1)
	$= 1400^2 / (2 \times 64)$ $= 15\,000$ J	(A1)

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Question	Answer	Marks
2(a)	the point where (all) the weight (of the object) is taken to act	B1
2(b)(i)	(54×0.45) **or** (2.4×0.95) **or** $(T \sin 30° \times 1.3)$	C1
	$(54 \times 0.45) = (2.4 \times 0.95) + (T \sin 30° \times 1.3)$	C1
	$T = 34$ N	A1
2(b)(ii)	resultant moment $= (54 \times 0.45) – (2.4 \times 0.95)$ **or** $(34 \sin 30° \times 1.3)$ $= 22$ N m	A1
2(c)(i)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$= 2.4 \times 1.8$ $= 4.3$ J	A1

Question	Answer	Marks
2(c)(ii)	$E = \frac{1}{2}mv^2$	C1
	$= \frac{1}{2} \times (2.4 / 9.81) \times 3.4^2$ $= 1.4$ J (at X)	C1
	kinetic energy at Y $= 4.3 + 1.4$ $= 5.7$ J	A1
	or	
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mg(\Delta)h$	(C1)
	$v^2 = 3.4^2 + 2 \times 9.81 \times 1.8$ $v^2 = 46.9$ so $v = 6.85$ (m s^{-1}) $\text{KE} = \frac{1}{2} \times (2.4 / 9.81) \times 6.85^2$	(C1)
	$= 5.7$ J	(A1)
2(c)(iii)	no variation **or** acceleration is (always) vertically downwards	B1
2(c)(iv)	horizontal straight line at a non-zero value of velocity	B1

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Question	Answer	Marks
4(a)	$\rho = m / V$ **or** $\rho = m / Ah$	B1
	$p = F / A$ **or** $p = W / A$	B1
	appropriate algebra leading to $p = \rho gh$ e.g. $p = \rho Ahg / A$ **or** $\rho Vg / A$ **or** $\rho Vg / (V/h)$ **and** (so) $p = \rho gh$	B1
4(b)	there is atmospheric / air pressure	B1
4(c)	$\Delta p = \rho g \Delta h$ e.g. $(9.66 - 9.60) \times 10^4 / 8.0 \times 10^{-2} = \rho \times 9.81$	C1
	$\rho = 760 - 770\ \text{kg m}^{-3}$	A1
4(d)	$F = \rho gV$ $= 760 \times 9.81 \times 3.7 \times 10^{-4} \times 4.0 \times 10^{-2}$ (= 0.11 N)	C1
	tension = 0.53 – 0.11 = 0.42 N	A1
	or	
	$F = (\Delta)p \times A$ $= (9.63 - 9.60) \times 10^4 \times 3.7 \times 10^{-4}$ (= 0.11 N)	(C1)
	tension = 0.53 – 0.11 = 0.42 N	(A1)

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Question	Answer	Marks
3(a)	resultant force (in any direction) is zero	B1
	resultant moment/torque (about any point) is zero	B1
3(b)	(component =) 17sin50° = 13 (N) **or** 17cos40° = 13 (N)	A1
3(c)	$(W \times 0.25)$ **or** (12×0.35) **or** (13×0.50)	C1
	$(W \times 0.25) + (12 \times 0.35) = (13 \times 0.50)$ $W = 9.2$ N	A1
3(d)	$F = 9.2 + 12 - 13$ = 8 N	A1
3(e)	decrease	B1

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Question	Answer	Marks
2(a)	point where (all) the weight (of the object) is taken to act	B1
2(b)(i)	moments about P are: ($F \times 1.10$), (44.0×0.60) and (3.0×2.90) *1 mark for any one correct moment and 2 marks for two correct moments*	C2
	($F \times 1.10$) = (44.0×0.60) + (3.0×2.90) F = 32 N	A1
2(b)(ii)	force = 32 + 44 + 3 = 79 N	A1
2(c)(i)	($F = \rho g V$) $V = 2.5 / (1100 \times 9.81)$ (= 2.32×10^{-4})	C1
	$V = (4/3)\pi r^3$	C1
	$r = [(3 \times 2.32 \times 10^{-4}) / 4\pi]^{1/3}$ r = 0.038 m	A1
2(c)(ii)	resultant moment = 2.5×2.9 = 7.3 N m **or** resultant moment = $F \times 1.1 - (44 \times 0.6 + 0.5 \times 2.9)$ = 7.3 N m (allow 7.2 N m or 7.4 N m from rounded values of F)	A1
	direction: anticlockwise	A1

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Question	Answer	Marks
2(a)	$T \sin 68° + 32 = 280$	C1
	T = 270 N	A1
2(b)(i)	$F = \rho g V$ $V = 280 / (1.0 \times 10^3 \times 9.81)$ = 0.029 m^3	A1
2(b)(ii)	$\rho = (32 / 9.81) / 0.029$	C1
	= 110 kg m^{-3}	A1

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Question	Answer	Marks
3(a)	point where (all) the weight (of an object) is taken to act	B1
3(b)(i)	vertical component = 45 sin 37° = 27 N	A1
3(b)(ii)	the magnitudes of the three moments about A are (23×0.48), (27×0.56) and ($W \times 0.76$) correct magnitude of any one moment about A	C1
	correct magnitudes of any two moments about A	C1
	$(23 \times 0.48) + (W \times 0.76) = 27 \times 0.56$ $W = 5.4$ N	A1
3(b)(iii)	horizontal component = 45 cos 37° = 36 N	A1
3(b)(iv)	decrease	B1
3(b)(v)	$\sigma = F / A$	C1
	$\sigma = F / \pi r^2$ or $4F / \pi d^2$ so $\sigma = 5.3 \times 10^7 \times \pi r^2 / \pi(3r)^2$ $= 5.3 \times 10^7 / 9$ $= 5.9 \times 10^6$ Pa	A1

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3(c)(i)	(upthrust =) 6.20 – 5.60 = 0.60 (N)	A1
3(c)(ii)	$\Delta p = \Delta F / A$ $= 0.60 / 1.2 \times 10^{-3}$	C1
	$= 500$ Pa	A1
3(c)(iii)	$(\Delta)p = \rho g(\Delta)h$ $\rho = 500 / (9.81 \times 5.8 \times 10^{-2})$	C1
	$= 880$ kg m^{-3}	A1
3(d)(i)	(upthrust) increases	B1
3(d)(ii)	(extension) decreases	B1

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Question	Answer	Marks
3(a)	force × distance	M1
	perpendicular distance of (line of action of) force from the point	A1
3(b)(i)	distance moved by pointer = 123 – 86 (= 37 mm)	C1
	(extension =) 37 × (1.8 / 52.6) = 1.3 (mm) **or** sin or tan θ = 37 / 526 (so θ = 4.0° so extension =) sin or tan θ × 18 = 1.3 (mm)	A1
3(b)(ii)	moment = $0.472 \times 9.81 \times 6.2 \times 10^{-2}$	C1
	= 0.29 N m	A1
3(b)(iii)	$(\Delta)F \times 1.8 \times 10^{-2} = 0.29$	C1
	ΔF = 16 N	A1
3(b)(iv)	$k = F / x$	C1
	$= 16 / (1.3 \times 10^{-3})$ $= 1.2 \times 10^{4}$ N m^{-1}	A1

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Question	Answer	Marks
3(a)	change in displacement / time (taken)	B1
3(b)	by calculation: $v^2 = 42^2 + 23^2 - (2 \times 42 \times 23 \times \cos 54°)$ **or** $v^2 = (42 - 23 \cos 54°)^2 + (23 \sin 54°)^2$ **or** $v^2 = (42 - 23 \sin 36°)^2 + (23 \cos 36°)^2$	C1
	v = 34 m s^{-1}	A1
	or	
	by scale diagram: triangle of vector velocities drawn	(C1)
	v = 34 m s^{-1} (*allow* ± 1 m s^{-1} *if scale diagram used*)	(A1)
3(c)(i)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	h = 6100/46 (= 133 m)	C1
	$\theta = \sin^{-1}(133/280)$ = 28°	A1
3(c)(ii)	force = 6100 / 280 **or** 46 sin 28°	C1
	= 22 N	A1

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Question	Answer	Marks
3(a)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
3(b)(i)	**1.** $T \sin 53° = 2.4$ $T = 3.0$ N	A1
	2. $F = T \cos 53°$ **or** $F^2 = T^2 - 2.4^2$ $F = 1.8$ N	A1
3(b)(ii)	$\sigma = T / A$ **or** $\sigma = F / A$	C1
	$A = \pi d^2 / 4$ **or** $A = \pi r^2$	C1
	$\sigma = 3.0 \times 4 / [\pi \times (0.50 \times 10^{-3})^2]$ $= 1.5 \times 10^7$ Pa	A1
3(c)(i)	$h = 75 - 75 \sin 53° = 15$ cm	A1
3(c)(ii)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	$(\Delta)E = 2.4 \times 15 \times 10^{-2}$ $= 0.36$ J	A1
3(c)(iii)	$E = ½mv^2$	B1
	$0.36 = ½ \times (2.4 / 9.81) \times v^2$	C1
	$v = 1.7$ m s^{-1}	A1

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Question	Answer	Marks
3(a)	for a body in (rotational) equilibrium	B1
	sum/total of clockwise moments about a point = sum/total of anticlockwise moments about the (same) point	B1
3(b)(i)	$(W \times 0.45)$ **or** (19×1.3) **or** $(W \times 1.85)$ **or** (22×2.6)	C1
	$(W \times 0.45) + (19 \times 1.3) + (W \times 1.85) = (22 \times 2.6)$ so $W = 14$ N	A1
3(b)(ii)	magnitude = 19 + 14 + 14 – 22 = 25 N	A1
	direction: vertically upwards	A1
3(c)(i)	the extension is zero when the force is zero	B1
	graph is a straight line and (so) Hooke's law obeyed	B1
3(c)(ii)	$k = F / x$ **or** k = gradient	C1
	e.g. $k = 60 / (1.00 - 0.25)$ $k = 80$ N m^{-1}	A1
3(c)(iii)	area shaded below graph line between $L = 0.25$ m and $L = 0.75$ m	B1

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Question	Answer	Marks
1(a)(i)	force × perpendicular distance (of line of action of force to the point)	B1
1(a)(ii)	units: $kg\,m\,s^{-2}\,m$ $= kg\,m^2\,s^{-2}$	A1
1(b)	$W = \rho Vg$ **or** $W = \rho ALg$	C1
	$A = 5.2 / (790 \times 2.4 \times 9.81)$ $(= 2.8 \times 10^{-4}\ (m^2))$	C1
	$= 2.8 \times 10^2\ mm^2$	A1
1(c)(i)	(component =) 5.2 sin 56° = 4.3 (N) **or** 5.2 cos 34° = 4.3 (N)	A1
1(c)(ii)	$(T \times 2.4)$ **or** (4.3×1.2) **or** (4.6×1.8)	C1
	$(T \times 2.4) + (4.3 \times 1.2) = (4.6 \times 1.8)$	C1
	$T = 1.3\ N$	A1

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Question	Answer	Marks
2(a)(i)	$(\Delta)p = \rho g(\Delta)h$ $520 = 1000 \times 9.81 \times h$	C1
	$h = 0.053\ m$	A1
2(a)(ii)	(upthrust =) $(\Delta)p \times A$ $= (\Delta)p \times \pi(d/2)^2$ **or** $(\Delta)p \times \pi r^2$	C1
	$= 520 \times \pi(0.031/2)^2 = 0.39\ (N)$	A1
2(a)(iii)	$T = 0.84 - 0.39$ $= 0.45\ N$	A1

Question	Answer	Marks
2(b)(i)	$a = (v - u)/t$ **or** $(\Delta)v/(\Delta)t$ **or** gradient	C1
	= e.g. $8.0 \times 10^{-2} / 2.0$ $= 4.0 \times 10^{-2}\ m\,s^{-2}$	A1
2(b)(ii)	distance = $(\frac{1}{2} \times 2.5 \times 0.10) + (\frac{1}{2} \times 1.5 \times 0.10)$ **or** $(\frac{1}{2} \times 4.0 \times 0.10)$ (= 0.20 (m))	C1
	depth = 0.32 – 0.20 = 0.12 m	A1
2(c)(i)	viscous (force)	B1
2(c)(ii)	viscous force increases (with speed/time/depth)	B1
	(so) acceleration decreases	B1