1. A block of wood is floating in calm water.

The density of the wood is 700 kg m^{-3}. The density of water is 1000 kg m^{-3}.

What percentage of the volume of the block is **above** the waterline?

A 30
B 50
C 70
D 89

Your answer ☐ **[1]**

2. An object is completely immersed in water.

Upthrust acts on the object.

Which calculation will correctly give the magnitude of the upthrust?

A density of the object × *g*
B density of the water × *g*
C mass of water displaced × *g*
D volume of object × *g*

Your answer ☐ **[1]**

3. A spring has a force constant of 4900 N m^{-1}.

A force is applied to the spring, causing it to compress by 0.50 m.

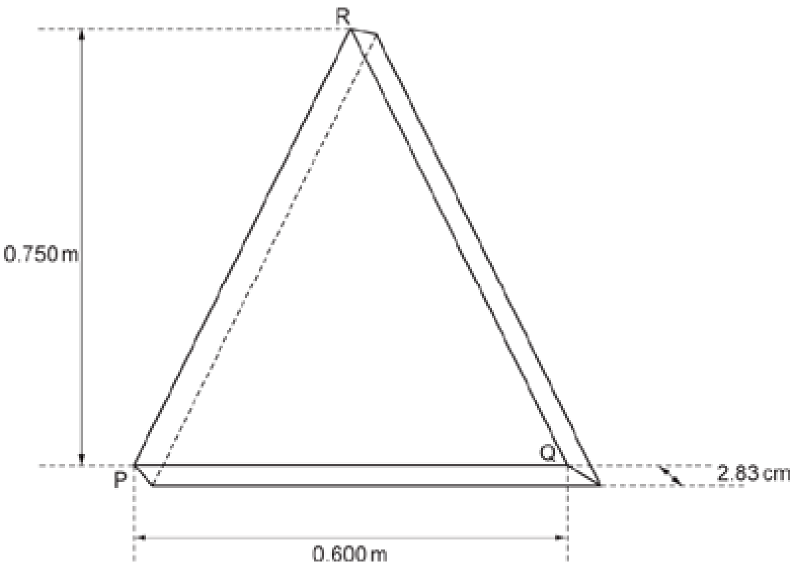
What is the change in the elastic potential energy stored in the spring?

A decreases by 610 J
B decreases by 1200 J
C increases by 610 J
D increases by 1200 J

Your answer ☐ **[1]**

4. A solid uniform wooden isosceles prism has a mass of 3.98 kg. The corners of one of the triangular faces are P, Q and R.

Fig. 4.1 (not to scale)



A student determines the thickness of the prism to be 2.83 cm.

i. Explain how to determine the thickness of the prism accurately in the laboratory.

____

____

______________________________ **[2]**

ii. Calculate the density ρ of the wood.

ρ = ... kg m^{-3} **[2]**

5. A pulsar is a rapidly rotating neutron star that emits radio waves.

A typical neutron star can be modelled as a sphere with mass ≈ 2×10^{30} kg and radius ≈ 10 km.

Show that the average density of a neutron star is similar to the average density of an atomic nucleus.

- radius of a nucleon ≈ 1 fm

[3]

6(a).

A sealed container contains *n* moles of an ideal gas. The gas has pressure *p*, absolute temperature *T* and occupies volume *V*.

The mass of one mole of the gas is *M*.

Use an ideal gas equation to show that the density *ρ* of the gas is given by the expression $\rho = \frac{pM}{RT}$.

[3]

(b). An airship has a cabin suspended underneath a gasbag inflated with helium.

The airship is floating above the ground and is stationary.

The volume of the gasbag is 12 000 m^3.
The temperature of the helium and the surrounding air is 20°C.
Atmospheric pressure is 1.0×10^5 Pa.
The molar mass of air is 0.029 kg mol^{-1}.
The volume of the cabin is negligible compared to the volume of the gasbag.

i. Show that the density of air under the conditions described is about 1.2 kg m^{-3}.

[1]

ii. Calculate the weight of air displaced by the airship.

weight of air .... N **[2]**

iii. Explain why the weight of air displaced by the airship has the same magnitude as the weight of the airship and its contents.

[2]

---

iv. The pressure of the helium in the gasbag is maintained at a value only slightly greater than atmospheric pressure.
Suggest why a larger pressure is not used.

[2]

(c). The airship engine drives a fan which moves 7.8 kg of air per second at a relative speed of 45 m s^{-1}, so the airship starts to move.
All other conditions given in **(b)** remain the same.

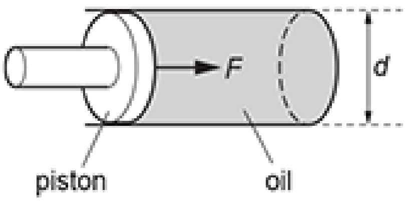
Calculate the thrust that the engine produces.

thrust ....N **[2]**

(d). The airship has a higher maximum speed at high altitudes, but also produces less thrust from the engine. Explain these observations.

[2]

7. The diagram shows a closed cylinder with internal diameter *d*.



The cylinder is filled with oil. A piston applies a force *F* to the oil.
Which is the correct expression for the pressure in the oil?

A $\frac{2F}{\pi d^2}$

B $\frac{\pi d^2}{2F}$

C $\frac{4F}{\pi d^2}$

D $\frac{\pi d^2}{4F}$

Your answer

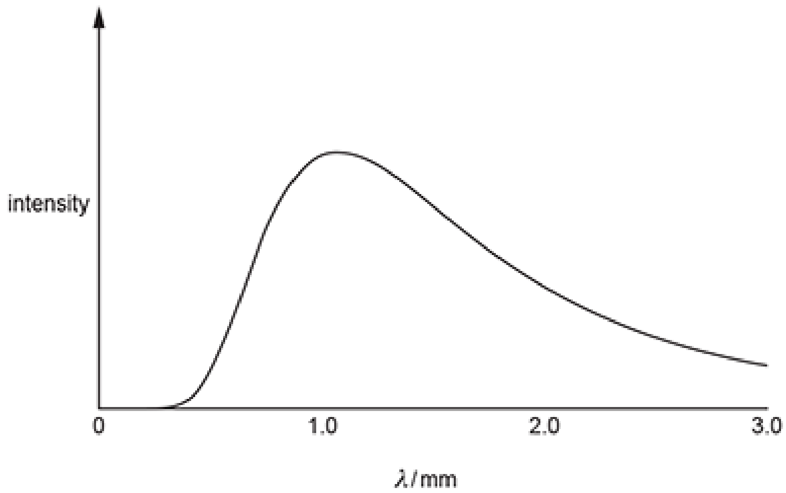
[1]

8. Astronomers can detect microwave background radiation coming from space in every direction.

The temperature of this microwave radiation is 2.7 K and its **total** intensity is about 3×10^{-6} W m^{-2}.

The figure below shows how the intensity of the microwave background radiation varies with its wavelength λ.

The **peak** intensity is at a wavelength of 1.1 mm.



This spectrum of microwave background radiation changes with temperature according to Wien's displacement law.

i. Suggest and explain how the spectrum might have looked in the distant past. You may draw on the figure to support your answer.

[2]

ii. Calculate the energy of a photon which has a wavelength of 1.1 mm.

energy = ... J **[2]**

iii. Estimate the number of photons of microwave background radiation incident per second on the back of your hand.

Assume that all emitted photons have the energy calculated in **(ii)**, and that the back of your hand has a surface area of 150 cm^2.

number of photons per second = ...s^{-1} **[2]**

iv. A scientist suggests that the microwave background radiation could be used as an energy source.

The scientist proposes using large tanks of water to absorb the microwave radiation.

Estimate the maximum rise in temperature that could be produced per second for a large cylindrical tank of depth 5.0 m. Assume that all microwave radiation incident on the top of the tank is absorbed.

density of water = 1000 kg m^{-3}
specific heat capacity of water = 4200 J kg^{-1} K^{-1}

maximum rise in temperature per second = ...°C s^{-1} **[3]**

9. The table shows some data on the planet Venus.

Mass / kg	4.87×10^{24}
Radius / km	6050
Density of atmosphere at surface / kg m^{-3}	65
Period of rotation about its axis / hours	5830

Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3.

i. Calculate the centripetal acceleration *a* of probe **B** at the equator due to the rotation of Venus about its axis.

a = ... ms^{-2} **[3]**

ii. The atmosphere exerts the same upthrust on each probe.

Using your answer to **(a)**, calculate the upthrust acting on each probe.

upthrust = ... N **[3]**

iii. Explain which probe will experience the greater normal contact force from the surface of Venus.

[3]

10(a).

A nebula is a giant cloud of gas and dust in space. A nebula **X** is modelled as a sphere of gas and dust particles of diameter 6.4 pc.
The nebula has 1.0×10^{12} gas and dust particles per m^3 and a temperature of 250 K. The nebula behaves like an ideal gas.

i. Show that the volume of the nebula is 4.1×10^{51} m^3.

1 pc = 3.1×10^{16} m

[2]

ii. Calculate the **total** kinetic energy E_k of the gas and dust particles in the nebula.

E_k= .... J **[3]**

(b). The nebula that formed the Sun is estimated to have a diameter of 3.0 pc and had a similar composition to nebula **X** in **(b)**.

The mass of the nebula **X** is **much greater** than the mass of the Sun.

i. Calculate the ratio $\frac{\text{mass of nebula } \mathbf{X}}{\text{mass of the Sun}}$

ratio = ... **[2]**

ii. After a long time, nebula **X** will form a stable star.

Describe the eventual evolution of this star.

[4]

11(a). A tent is secured by 3 ropes along each of its long sides, as shown in **Fig. 18. 1**.

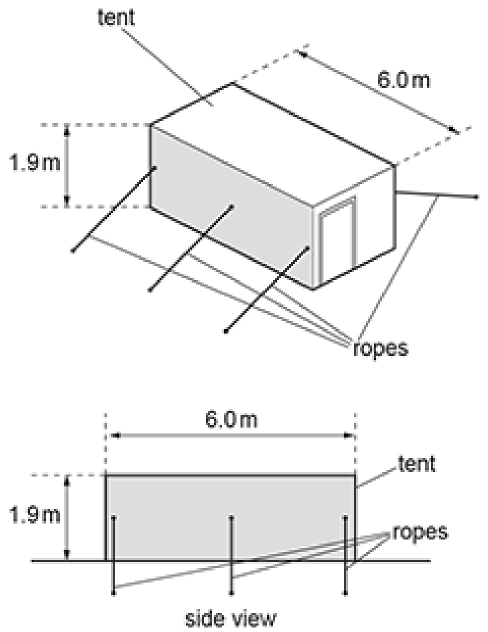


Fig. 18.1

Wind of speed 12 ms^{-1} blows at right angles to the **shaded** side of the tent for 3.0 s. The density of air is 1.2 kg m^{-3}.

i. Show that the mass of air which hits the tent in this time is about 490 kg.

[3]

ii. All of the air incident on the shaded side of the tent is deflected at 90° to the original direction as shown in **Fig. 18. 2**.

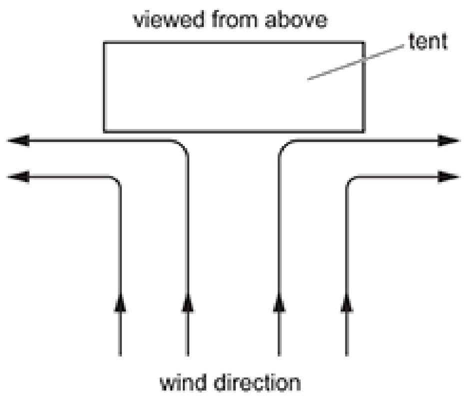


Fig. 18.2

Use the information given in **(a)(i)** to calculate the magnitude of the force *F* exerted by the wind on the shaded side of the tent.

F = ... N **[2]**

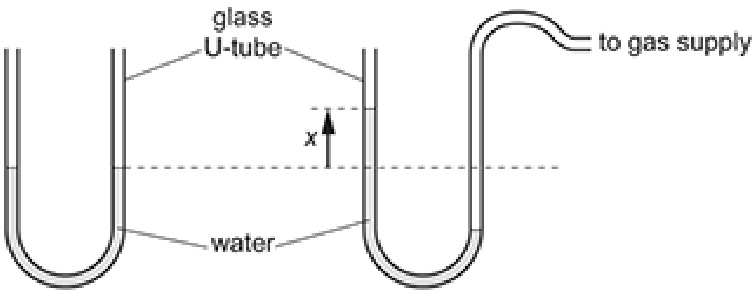
(b). *When the wind speed exceeds 20 ms^{-1} the ropes securing the tent break.

Describe, and explain in terms of forces, how the ropes and the shape of the tent could be modified to withstand wind speed exceeding 40 ms^{-1}.

[6]

12.

The diagram shows a glass U-tube partially filled with a mass of water.



One end of the U-tube is connected to a gas supply of **constant** pressure and the other end is open to the atmosphere. The displacement of the water from its equilibrium position is *x*.
The density ρ of water is 1000 kg m^{-3}.

i. The pressure from the gas supply raises the water in the U-tube.
   The vertical distance between the two levels of water in the two vertical sections of the U-tube is 10.0 cm (x = 5.0 cm).

   Δp is the difference between the gas pressure and atmospheric pressure.
   Calculate Δp.

Δp = ... Pa **[2]**

ii. When the gas supply is disconnected, the water levels in the U-tube oscillates with simple harmonic motion. The acceleration *a* of the water level in the left-hand side of the U-tube is given by the equation

$$a = -\frac{2\rho g A}{m}x$$

where *m* is the mass of the water in the U-tube, *A* is the internal cross-sectional area of the U-tube, *ρ* is the density of water, *g* is the acceleration of free fall and *x* is the displacement of the water level in the left-hand side of the U-tube.

For this U-tube, $A = 1.0 \times 10^{-4}$ m^2 and $m = 0.052$ kg.

Show that the period *T* of the oscillations is about 1 second.

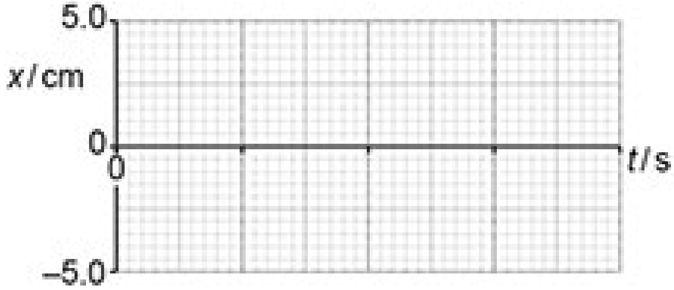
1

[3]

The oscillations of the water level are slightly **damped**.
At time $t = 0$, $x = 5.0$ cm.

2

Sketch a suitable graph of displacement *x* against time *t* for the oscillating water level. Add suitable values to the time *t* axis.



[3]

The U-tube is now connected to another gas supply where the pressure oscillates at a frequency of about 1 Hz.

3

Explain the effect this will have on the water in the U-tube.

[2]

13(a). A student investigates the motion of a steel ball in oil in a laboratory.

The radius *r* of the ball is 8.1 mm.

The student uses a measuring cylinder and a digital balance to determine the density of the oil.
The student records the following measurements:

- mass of empty measuring cylinder = 96 g
- volume of oil added to measuring cylinder = 87 cm^3
- total mass of measuring cylinder and oil = 169 g

Show that the density of the oil is about 840 kg m^{-3}.

[2]

(b). The steel ball is submerged in the oil.

Show that the upthrust acting on the steel ball is 1.8×10^{-2} N.

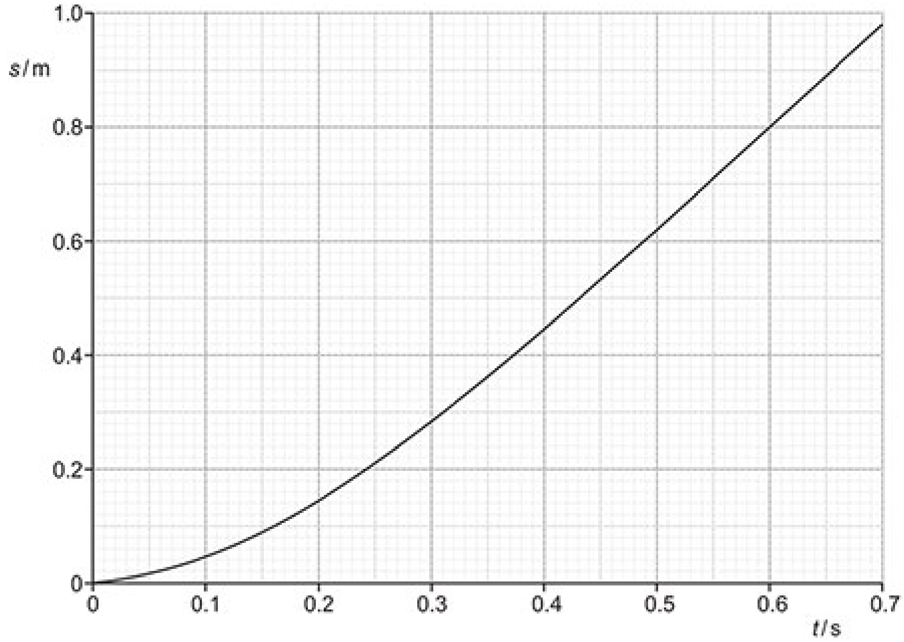
[2]

(c). The student fills a long tube with the oil.

The student drops the steel ball from rest at the surface of the oil at time $t = 0$.

The displacement *s* of the ball is measured from the surface of the oil.

The graph shows the displacement *s* against time *t* for the steel ball from the instant it enters the oil.



i. The terminal velocity *v* of the steel ball is 1.8 m s^{-1}.

Describe and explain how this can be determined from the graph.

____

____

____

____ **[3]**

ii. Use the graph to calculate the velocity *u* of the steel ball at time *t* = 0.20 s.

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

(d). The mass of the steel ball is 17 g.

The drag *F* acting on the steel ball falling through the oil is given by the equation $F = 6\pi\eta rv$

where η is a constant for the oil, *r* is the radius of the steel ball and *v* is the speed of the steel ball through the oil.

At *v* = 1.8 ms^{-1}, the force *F* is equal to the **difference** between the weight of the steel ball and the upthrust acting on the steel ball.

Calculate η.

Include an appropriate unit.

η = ... unit .... **[3]**

END OF QUESTION PAPER