1 Soil is usually made up of a variety of particles of different sizes. The photograph shows what happens when soil is mixed up with water and the particles are allowed to settle.

(a) The dot below represents a particle of the soil falling through water.

(i) Add labelled arrows to show the three forces acting on the particle as it falls through the water.

(2)

*(ii) Explain why a particle held stationary in water and then released accelerates downwards at first but then reaches a steady downwards speed.

(4)

(iii) Write an expression showing the relationship for these forces when the particle is falling at a steady speed.

(1)

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(b) A typical particle of sand in the sample has the following properties:

diameter 1.6×10^{-3} m

volume 2.1×10^{-9} m^3

density 2.7×10^3 kg $^{-3}$

weight 5.7×10^{-5} N

(i) Show that the upthrust acting on the particle is about 2×10^{-5} N.

density of water 1.0×10^3 kg m^{-3}

(2)

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(ii) Calculate the steady downwards speed this particle would achieve if allowed to fall through water.

viscosity of water 1.2×10^{-3} Pa s

(3)

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Speed .....

(c) The different types of particles in soil can be defined according to their diameters, as in the following table.

Soil particle	Particle diameter
clay	less than 0.002 mm
silt	0.002 mm 0.05 mm
sand	0.05 mm 2.00 mm
fine pebbles	2.00 mm 5.00 mm
medium pebbles	5.00 mm 20.00 mm
coarse pebbles	20.00 mm 75.00 mm

The photograph shows that when soil is allowed to settle in water, the pebbles tend to be found towards the bottom, followed by sand, silt and clay in succession.

Explain why this happens. Assume that all particles have the same density.

(3)

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(Total for Question 15 marks)

2 A kite is held by a string and flies because of lift produced by the flow of air.

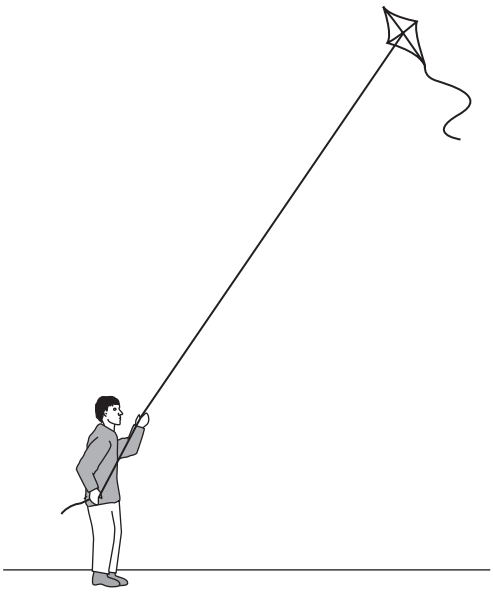


Figure 1

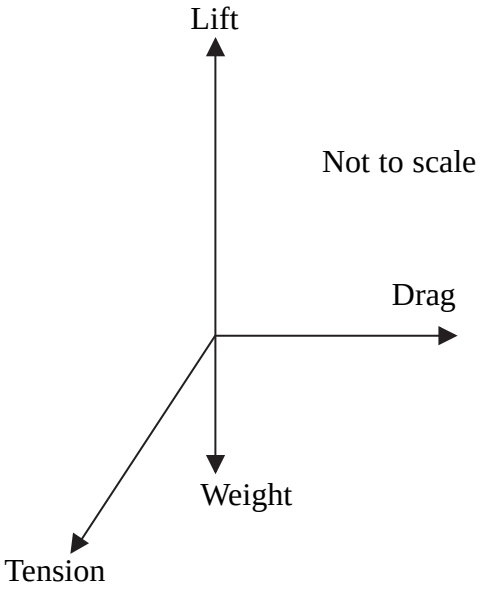


Figure 2

Figure 2 shows a free-body force diagram for the kite.

(a) Sketch a labelled vector diagram to show that the four forces are in equilibrium.

(1)

(b) The lift is 4.3 N, the drag is 6.0 N and the weight is 0.44 N.

Calculate the tension in the string. State its magnitude and direction from the horizontal.

(4)

Magnitude of tension =

Direction of tension from the horizontal =

(c) (i) The wind speed decreases so the girl flying this kite walks into the wind at a constant speed of 2.0 m s^{-1} to maintain the forces shown. Calculate the work done by the girl as she walks 25 m.

(2)

Work done =

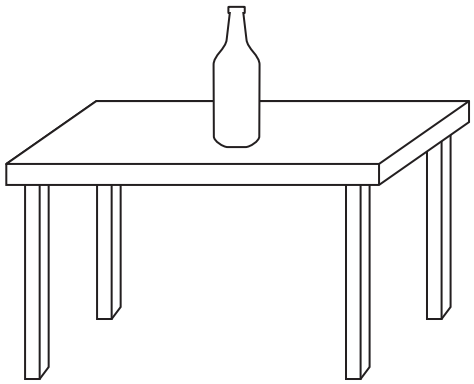
(ii) Calculate the rate at which work is done by the girl.

(2)

Rate at which work is done =

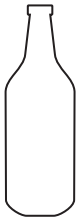
(Total for Question = 9 marks)

3 A student is asked to provide an explanation of why a bottle on a table remains stationary.



(a) Complete a free-body force diagram for the bottle.

(2)



(b) The student writes the following incorrect explanation.

The force of gravity pulls the bottle down.
The bottle pushes down on the table, so by Newton's first law,
the table pushes up with an equal and opposite force.
According to Newton's third law, if the forces are balanced,
nothing can move.

The student's explanation contains errors.

Rewrite the student's explanation correctly.

(3)

(Total for Question = 5 marks)

4 A man is walking at a constant horizontal velocity of 1.2 m s^{-1} in the rain. To the man the rain appears to be falling vertically at a velocity of 1.8 m s^{-1}.

Draw a labelled vector diagram, to scale, and use it to determine the actual velocity of the rain.

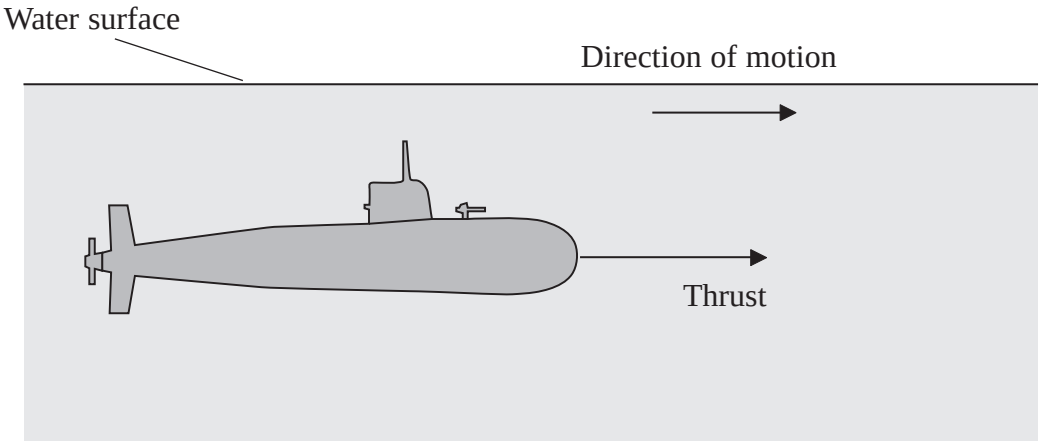
(5)

Magnitude of the actual velocity of the rain =

Angle of the rain to the vertical =

(Total for Question = 5 marks)

5 The diagram shows a submarine and one of the forces acting on it. The submarine moves at a constant depth and speed in the direction shown.



(a) Add labelled arrows to show the other **three** forces on the submarine.

(2)

(b) State **two** equations that show the relationship between the forces acting on the submarine.

(2)

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(c) The submarine has a volume of 7100 m^3.
Show that the weight of the submarine is about 7×10^7 N.

Density of sea water = 1030 kg m^{-3}

(2)

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(d) The submarine can control its depth by changing its weight. This is done by adjusting the amount of water held in ballast tanks.

As the submarine dives to greater depths the increased pressure of the surrounding water produces a compressive strain.

(i) Explain what is meant by compressive strain.

(1)

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(ii) This decreases the volume of the submarine. Explain the action that should be taken to maintain a constant depth as the volume of the submarine is decreased.

(2)

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(iii) The submarine is made from steel. Suggest why a material, such as fibreglass, which has a much smaller Young modulus than steel would be unsuitable at greater depths.

(2)

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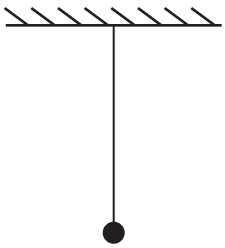
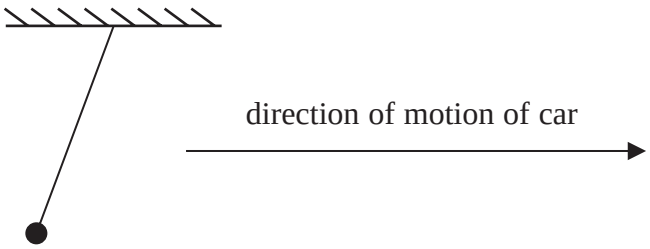
(Total for Question = 11 marks)

6 Many hand held devices such as smartphones and tablet computers contain accelerometers. These allow changes in orientation of the device to be tracked.

A student models a simple accelerometer by attaching a small mass on a string to the roof of a car.



When the car starts moving, the string is seen to change position as shown below.



(a) (i) Complete a free body force diagram for the mass when the car starts moving.

(2)

(ii) Draw a vector diagram, in the space below, to show how the resultant force on the mass is produced.

(2)

(iii) When the string is at 7° to the vertical, show that the acceleration of the car is about 1 m s^{-2}.

(2)

(b) Sketch the positions of the mass and string when the car is moving in the same direction and is:

(i) moving with constant velocity,

(ii) undergoing a much greater acceleration than in (a)(iii),

(iii) decelerating.

(3)

(i) moving with constant velocity,

(ii) undergoing a much greater acceleration than in (a)(iii),

(iii) decelerating.

(c) Explain why the string would **not** become horizontal, however great the acceleration.

(2)

(d) Suggest why many devices contain 3 accelerometers, arranged at right angles to each other.

(1)

(Total for Question = 12 marks)