REVIEW QUESTIONS

The following questions come from recent examination papers and, as such, are good examples of the type of question that will appear on your examination appear. The marks allocated also indicate, in minutes, the amount of time available under exam conditions to do the questions.

---

1 A 40 kg block of aluminium is hung from the end of a vertical 0.50 m long steel wire with a cross-sectional area of $5.0 \times 10^{-5} m^2$

(i) Find the stress and strain in the wire.

(ii) What is the increase in the length of the steel wire?

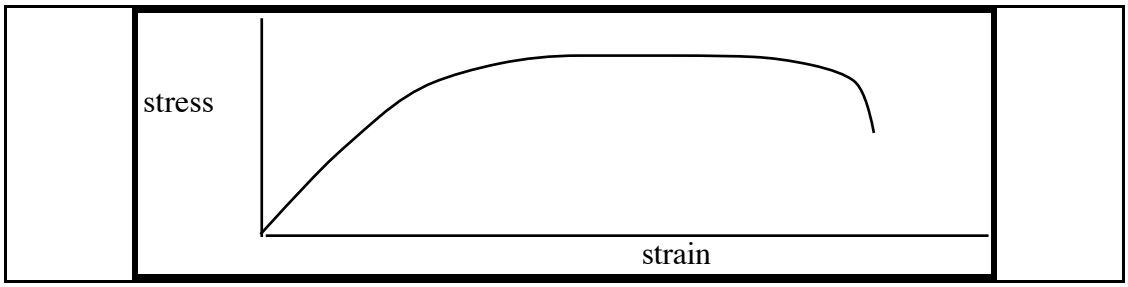
Young's modulus of aluminium	:	7.0×10^{10} Pa
Young's modulus of steel	:	2.0×10^{11} Pa
Tensile strength of steel	:	3.0×10^{8} Pa

[6 marks]

2 (a) Explain the meaning of the terms t*ensile stress* and *tensile strain*.

[4 marks]

(b)



The graph shows the relationship between tensile stress and tensile strain for a specimen of metal. Copy the graph and label it with the following regions or points.

(i) Region of plastic flow

(ii) Fracture point

(iii) Elastic limit.

Comment on the significance of each of these.

{6 marks]

3 (a) Elastic moduli, elastic limits and strengths of material all are quoted with the same units, pascals. Explain the differences between these three physical quantities.

(b) What is the maximum weight that can be supported by a brick 50 mm thick, 80 mm wide and 200 mm long?

Young's modulus for brick	:	2.0×10^{10} Pa
Compressive strength for brick	:	4.0×10^{7} Pa

[10 marks]

4 For a leg bone of length 0.50 m and diameter 30 mm estimate

(i) the maximum stretching force it can bear,

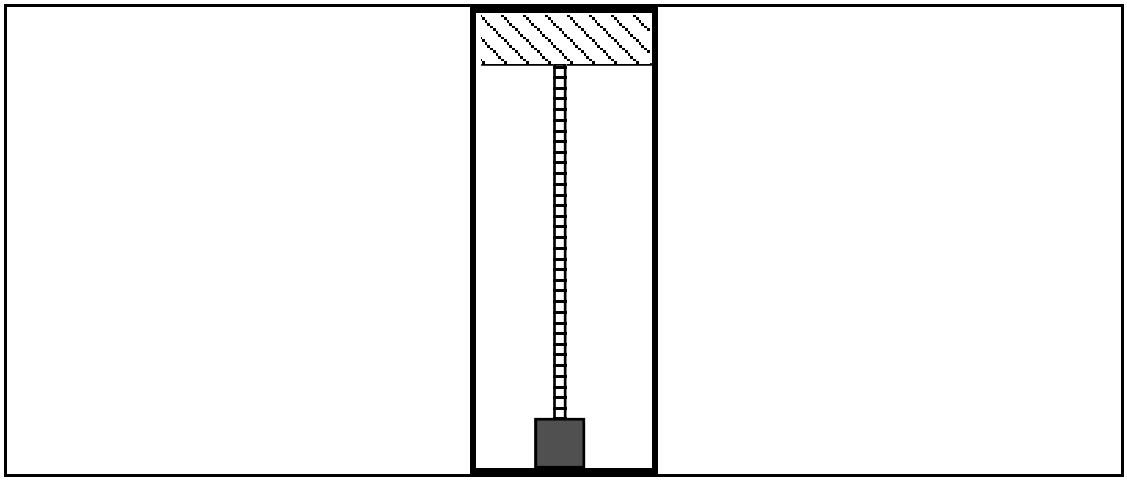
(ii) the maximum change in length before fracture occurs.

Tensile strength of bone	:	1.7×10^{8} Pa
Young's modulus of bone	:	9.4×10^{9} Pa

[8 marks]

5 A mass of 10 kg is hung from the end of a thin strip of steel which is 0.20 m long, 10.0 mm wide and 1.00 mm thick.

As a consequence the strip stretches by 0.01 mm.



(i) Name the elastic modulus appropriate to this situation.

(ii) Calculate its value.

[8 marks]

6 What are the stress, the strain and hence the approximate Young's modulus for a fibre of the protein elastin which has a cross-sectional area 1.0×10^{-10} m^2 and which is stretched to twice its original length by a force of 5.0×10^{-5} N?

[4 marks]

7 Calculate the volume of 1.025×10^3 kg of sea-water at a depth near 5 km where the pressure is 5.0×10^7 Pa. Hence calculate the density of sea-water at this depth.

Bulk modulus of sea-water : 2.2×10^9 Pa

Density of surface sea-water : 1.025×10^3 $kg.m^{-3}$

[5 marks]

8

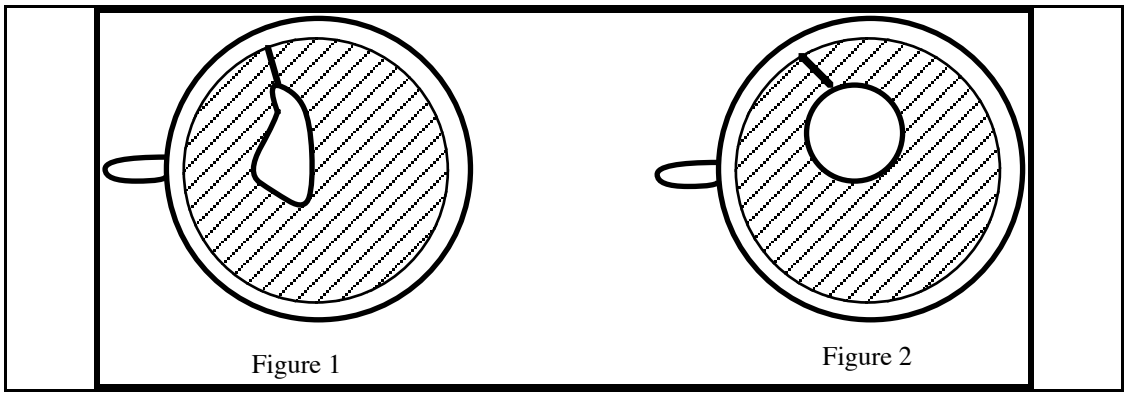


Figure 1 shows a wire loop that has a soap film across it which is supporting a loop of thread. When the film inside the loop of thread is punctured, the loop takes up a circular shape as in figure 2.

Explain this phenomenon.

[5 marks]

9 (a) Sketch the shape of the liquid surface for the following two situations.

(i) A liquid wets a partly immersed object,

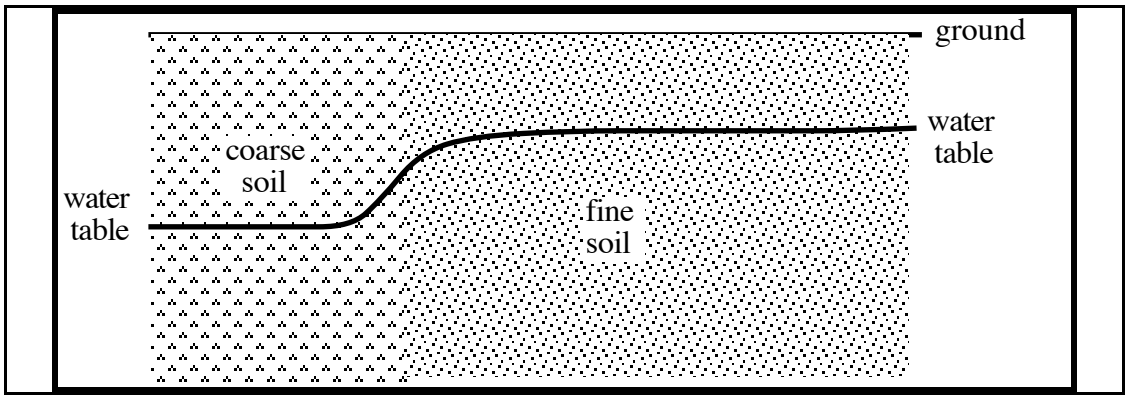
(ii) A liquid does not wet a partly immersed object.

(b) Sap of density 1×10^3 $kg.m^{-3}$ and surface tension 1×10^{-1} $N.m^{-1}$ rises in a capillary of radius 1×10^{-5} m in a tree. Assume that the sap wets the surface of the capillary.

To what height can the sap rise due to capillary-action alone?

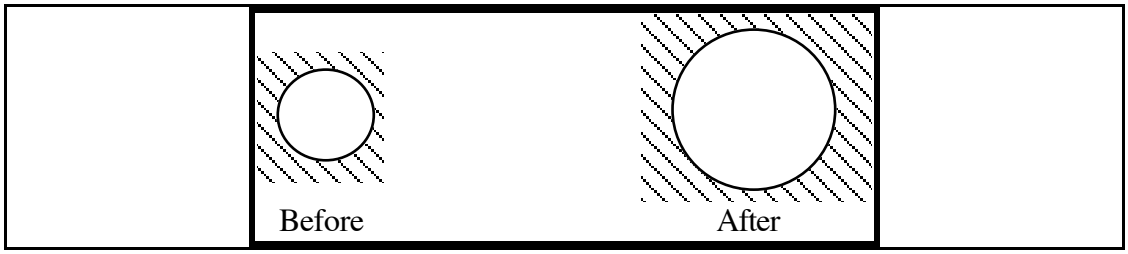
[8 marks]

10 A section of coarse-grained soil is adjacent to a finer-grained soil of the same material. Explain why the water table (the underground level of the water) is higher in the finer-grained soil.



[6 marks]

11



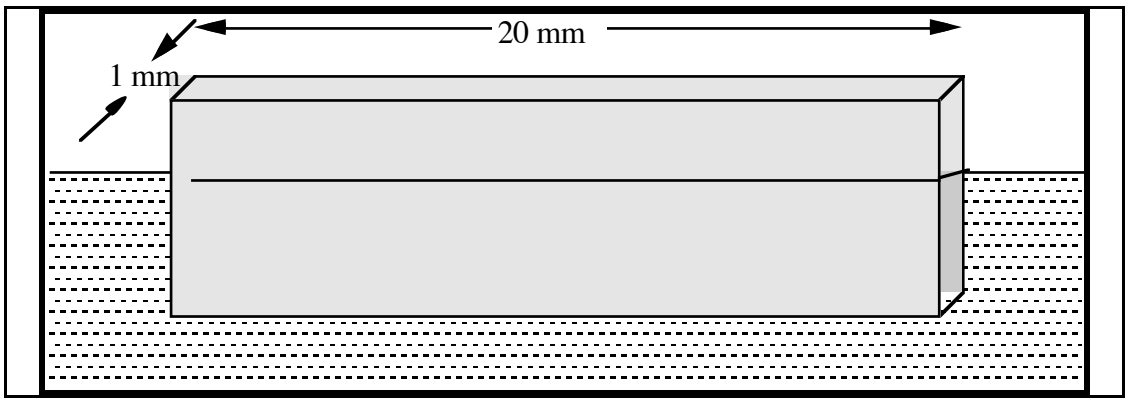
When an air bubble inside water expands, the work required is greater than that needed just to expand the gas inside the bubble.

(i) Describe the origin of this extra work.

(ii) Calculate its magnitude for a bubble which expands from a radius of 0.5 mm to a radius of 1.0 mm

[8 marks]

12



As shown in the diagram above, a glass slide 1 mm thick and 20 mm wide is partially immersed in water.

Surface tension of water : 0.07 $N.m^{-1}$.

(i) Calculate the force due to surface tension acting on the slide.

(ii) In what direction is this force acting?

(iii) How does this force change if detergent is added to the water?

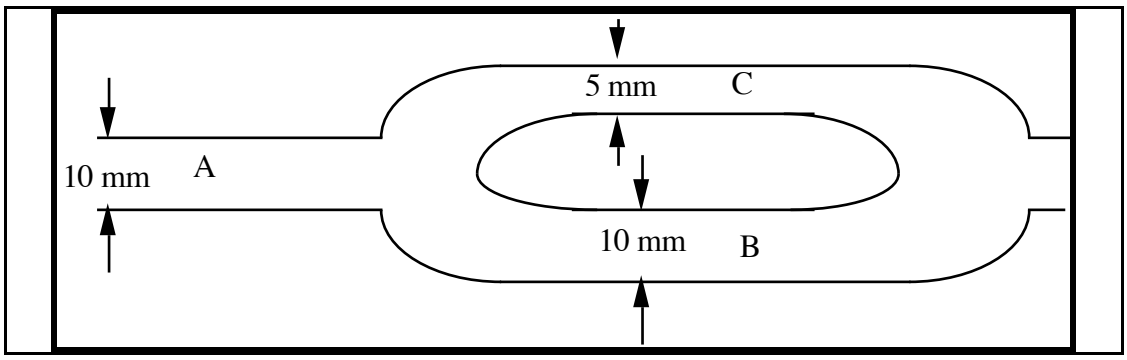
[8 marks]

13 (a) Explain what is meant by the term *streamline* in describing fluid flow.

(b) A blood vessel of radius *r* splits into five vessels, each with radius $\frac{r}{4}$. If the average velocity of blood flow in the large vessel is *v*, find the average velocity in each of the small vessels.

[8 marks]

14 A water pipeline with a branched section is constructed as shown in the diagram. The two branches have the same length.



(i) For what velocity does the flow at A become turbulent?

The velocity at point A is 0.01 $m.s^{-1}$.

(ii) What is the ratio of the volume rate of flow at B to that at C?

(iii) Calculate the flow velocity at C.

[12 marks]

15 A scale model of a bacterial flagellum is to be made using a cylinder 5.0 mm in diameter. The velocity of the cylinder is to be 20 $mm.s^{-1}$.

The Reynolds number for the flagellum is 10^{-3}.

The model should have the same Reynolds number as the real system if conclusions drawn from the model are to be correct for the living organism.

What must be the kinetic viscosity ($=\frac{\eta}{\rho}$ where η is the viscosity and ρ the density) of the fluid to be used for the model experiment?

Using the data below, suggest a suitable fluid for the experiment.

Fluid	Kinematic Viscosity/$m^2.s^{-1}$
Ether	10^{-7}
Water	10^{-6}
Glycerol	10^{-4}
Sucrose	10^{-1}

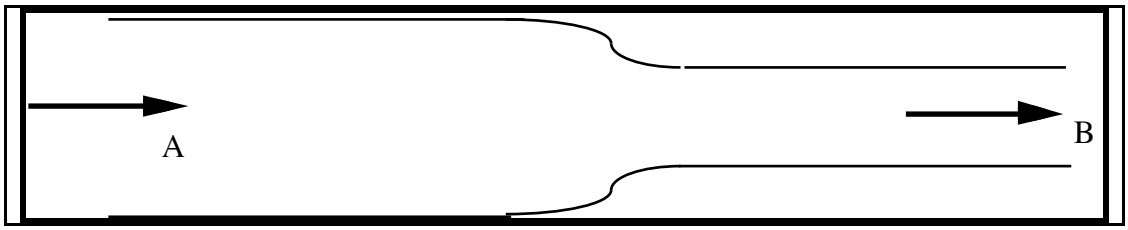
[9 marks]

16 (a) Use an energy argument to explain Bernoulli's principle, that is why, for constricted streamline flow, the fluid pressure decreases as the flow velocity increases.

(b) How does the presence of turbulence affect the applicability of Bernoulli's theorem?

[10 marks]

17



As illustrated above, water flows through a section of a tube with circular cross-section. The radius of the tube at *A is* 10.0 mm and that at *B* is 5.0 mm. The water velocity at point *A* is 1.0 $\times 10^{-2}$ m.s^{-1}.

(i) Copy the diagram above and sketch the pattern of streamlines in the tube.

(ii) Calculate the velocity of water at point *B*.

(iii) If the flow rate is gradually increased where will turbulence be first observed?

(iv) Estimate the velocity of water at *B* when this happens. Explain how you made this estimate.

Viscosity of water : 1×10^{-3} kg.m^{-2}. s^{-1}

[10 marks]

18 A non-viscous fluid is flowing smoothly in a horizontal pipe. At point *A* the cross section is 3.0 m^2 and at point *B* it is 1.5 m^2.

(i) At which point is the pressure higher?

(ii) State very briefly the physical principles behind your answer.

[6 marks]

19 The normal rate of flow of the blood through the circulatory system is about 8.3 $\times 10^{-5}$ m^3.s^{-1}. All the blood passes through the aorta which has a radius of about 9 mm.

(i) Estimate the mean velocity of blood flowing in the aorta.

(ii) Show, by calculation, that the flow would probably be non-turbulent.

Viscosity of blood : 4×10^{-3} Pa.s

Density of blood : 1×10^{3} kg.m^{-3}

[8 marks]

20 Describe an experiment that shows a qualitative relationship in fluid flow between shear stress and velocity gradient.

In your description indicate how both these quantities could be measured.

[6 marks]

21 An echiuroid worm feeds by passing a current of water through a porous membrane 10 μm thick containing cylindrical holes each of area 1×10^{-12} m^2. The area of the membrane is 2×10^{-3} m^2 and half this area is holes.

If 1.2×10^{-3} m^3 of water flow through the net in an hour, calculate the pressure difference that exists across the net.

Viscosity of water : 1×10^{-3} Pa.s

Poiseuille's equation : $Q = \frac{\Delta p}{l} \frac{r^4}{\eta} \cdot \frac{\pi}{8}$

where Q is the volume rate of flow of fluid of viscosity, η, through a pipe, or radius r and length l, as a result of a pressure difference Δp.

[10 marks]

2 2 Q, the rate of flow of fluid through a pipe of radius r and length l, subject to a pressure difference p is given by Poisuille's equation :

$$Q = \frac{\pi r^4 \Delta p}{8 l \eta}$$

where η is the viscosity of the fluid.

Blood flows from the foreleg of an animal through a hypodermic needle inserted into an artery. The needle is of length 80 mm and internal radius 0.30 mm. The drop in blood pressure across the artery is 1.2×10^4 Pa.

Calculate the time required to obtain a sample of 50 mL (millilitres).

Viscosity of blood : 4×10^{-3} Pa.s

[6 marks]

2 3 Poiseuille's equation states that for streamline flow the quantity of fluid passing through a pipe in a fixed time is proportional to the product of the pressure difference and the fourth power of the radius.

(a) Water in a pipe is flowing without turbulence under a certain pressure difference. If the radius of the pipe is reduced by 20%, what percentage increase in pressure difference is required to maintain the same flow rate?

(b) In agricultural irrigation, typical values of flow velocity and pipe width are 1.0 m.s-1 and 100 mm, respectively. Is a calculation such as in part (a) applicable? Explain.

[8 marks]

2 4 Poiseuille's equation for the rate of flow of a viscous fluid, is

$$Q = \frac{\pi r^4 \Delta p}{8 l \eta}$$

In the body, there are of the order of 10^{10} capillaries. The average length of the capillaries is about 2×10^{-3} m and the average radius about 4×10^{-6} m. These capillaries act in parallel to convey blood through the body at a rate of 8×10^{-5} $m^3.s^{-1}$.

Calculate the total pressure drop along a capillary.

Viscosity of blood : 4×10^{-3} Pa.s

[5 marks]

2 5 The rate of fluid flow through a pipe depends on four physical variables. Name each of these variables and state whether an increase in its magnitude would increase the flow rate.

[8 marks]

2 6 Explain, in each case with an example, the following terms:

non-newtonian flow

dilatancy

thixotropy

stress relaxation

[8 marks]

27 Explain, with examples, *three* of the following terms

pseudo-plastic

dilatant

viscoelastic

thixotropic

creep.

[9 marks]

28 (a) Compare the ways in which solid, liquids and viscoelastic materials respond to an applied stress.

(b) Blood is a thixotropic material. How does this affect the design of an artificial heart or blood pump?

[8 marks]

29 (a) Explain briefly, preferably with the aid of a diagram, the meanings of the term *shear stress* and *shear strain*.

[4 marks]

(b) State the relationship between *shear stress* and *shear strain* for an elastic solid.

[1 marks]

(c) Use these concepts to describe the difference in behaviour, under shear, of an elastic solid and a viscous liquid.

[4 marks]

(d) Define, preferably with the aid of a diagram, coefficient of (dynamic) *viscosity* (η).

[4 marks]

(e) Using words and/or diagrams, distinguish amongst a *newtonian* liquid, a *dilatant* liquid and a *pseudoplastic* liquid.

[6marks]

(f) State what is meant by a thixotropic substance.

[3 marks]

30 Liquid is placed in a burette and allowed to drain from it under conditions of laminar flow. Explain how you would use a graph showing the rate of flow as a function of height of liquid in the burette to determine whether the liquid is newtonian or non-newtonian.

If the liquid were a solution of starch in water sketch the expected shape of the curve.

[8 marks]

31 Ordinary house paint is a non-newtonian liquid, i.e. its viscosity depends on shear rate. What observational evidence can you produce for this statement?

[8 marks]

32 (a) Write down the two experimental laws of sliding friction.

(b) Explain the difference between the apparent area of contact between two surfaces and the real area of contact.

(c) How does the real area of contact change with increasing load?

[8 marks]

33 Discuss the type of lubrication used in man-made machinery and in the synovial joints in animals.

[8 marks]

34 The coefficient of friction between the wheels of a car and the road is 0.8. If the rear (driving) wheels of the car support 40% of its weight estimate the car's maximum acceleration.

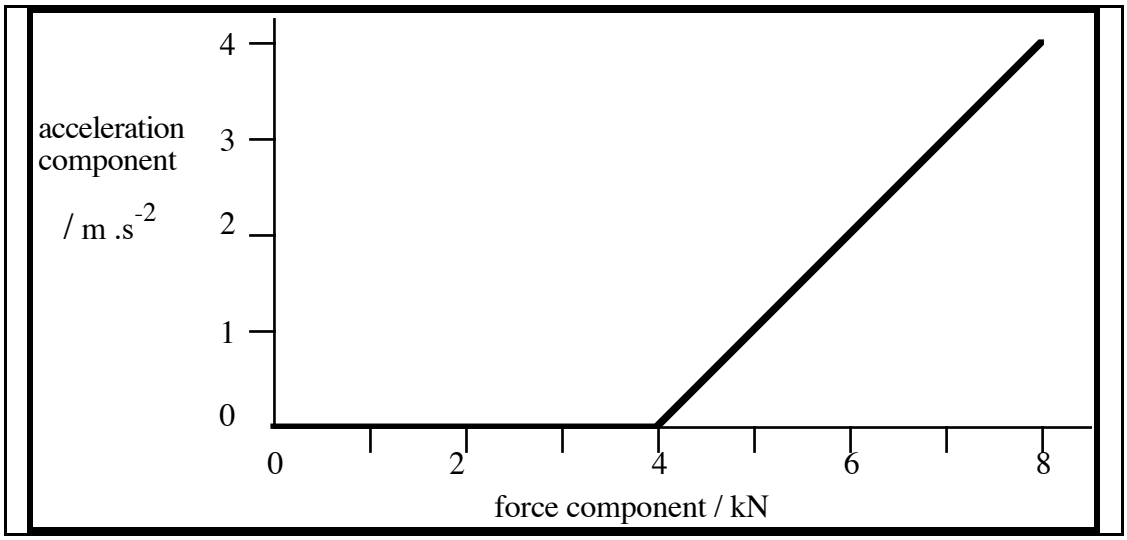
[6 marks]

35 (a) Use a microscopic model of the frictional process to explain why the frictional force exerted when a body slides over a surface is dependent on the weight of the body but approximately independent of the area of contact.

(b) Why does the presence of a lubricant such as oil or water decrease the frictional force?

[10 marks]

36



A laden sledge of mass 1000 kg is towed across smooth level ground by a tractor. The graph shows the acceleration (a) of the sledge as a function of the force exerted on it by the tractor.

(i) Explain the shape of this graph in terms of the laws of sliding friction.

(ii) Estimate the coefficient of sliding friction between sledge and ground.

[8 marks]

37 A beer barrel is dragged without rolling at constant speed across a horizontal floor. How does the force required to propel the barrel depend on

(i) the weight of the barrel,

(ii) the area of contact with the floor.

If the barrel is rolled across the floor at constant speed how does the propulsive force required compare with the former case?

[8 marks]

38 The following table gives the bulk moduli and the densities of four metals : iron, magnesium, tin and tungsten.

	Bulk modulus/(10^{10} Pa)	Density/(10^{3} kg.m^{-3})
iron	17.0	7.9
magnesium	3.6	1.7
tin	7.3	19.6
tungsten	19.3	31.1

(i) Which of the other three metals has a specific acoustic impedance closest to that of iron?

(ii) Calculate the speed of sound in that metal and compare with the speed of sound in iron?

[6 marks]

39 (a) Describe the physics underlying the medical technique of echoscopy.

(b) In a brain scan echoes from the right side of the skull, the midline of the brain and the left side of the skull are obtainable after times of 12 □s, 128 □s and 250 □s respectively. The sound velocity in the brain is 1540□m.s^{-1}.

(i) How far is the midline of the brain displaced?

(ii) Which hemisphere of the brain is enlarged? Justify your answer.

[8 marks]