SURFACE TENTION

Attempt any 5 qns.

2.5 hours.

Liquid	Surface tension γ(N/m)
Water at 0ºC	0.0756
Water at 20ºC	0.0728
Water at 100ºC	0.0589
Soapy water (typical)	0.037
Ethyl alcohol	0.0223
Glycerin	0.0631
Mercury	0.465
Olive oil	0.032
Tissue fluids (typical)	0.05
Blood, whole at 37ºC	0.058
Blood plasma at 37ºC	0.073
Gold at 1070ºC	1
Oxygen at −193ºC	0.0157
Helium at −269ºC	0.00012

Accrelation due to gravity $= 9.48\text{ms}^{-2}$

1. (a)(i).   Define coefficient of surface tention.   (1 mark)

(ii).   Use the molecular theory of matter to explain the existence of surface tension. (3 marks)

(b).   A clean glass capillary tube is of internal diameter 0.04cm is held vertically with its lower end below the surface of clean water in a beaker and with 10cm of the tube above the surface of water.

(i). Show that the height h to which the water rises in the tube is given by $h = \dfrac{2\gamma}{r\rho g}$ where γ is coefficient surface tension of water, r radius of the tube, ρ density of water and g acceleration of gravity.   (3 marks)

(ii) Given that coefficient of surface tension of water is $7.2 \times 10^{-2} \text{Nm}^{-1}$, calculate the height to which water will rise in the tube above   (2 marks)

(iii). Explain what will happen if the tube is then depressed until its length above the water surface is only 5cm. (3 marks)

(c). Describe an experiment to determine the surface tension of water using the capillary tube method (5 marks)

(d). A soap bubble whose radius is 12mm becomes attached to another of radius 20mm. Calculate the radius of the common interface (3 marks)

2. a) (i) Define surface energy. (1mark)

(ii) Derive an expression for height, h to which water can rise in a capillary tube.

(3 marks)

b) A U – tube with limbs of diameters 8.0mm and 3.0mm contains water of surface tension $7 \times 10^{-2}Nm^{-1}$, and angle of contact zero. Find the difference in the levels of the water in the two limbs. (Density of water $= 1000kgm^{-3}$) (4 marks)

(c) Derive the *dimensions* of coefficient of surface tension. (2 marks)

(b) Describe and explain briefly two phenomena caused by surface tension.

(6 marks)

(c) Show that the excess pressure inside an air bubble of radius r in a liquid of surface

tension γ is $\dfrac{2\gamma}{r}$ (4 marks)

3. a) State 2 factors which affect surface tension (2 marks)

b) The pressures inside and outside a soap, bubble of radius r are P_1 and P_2 respectively. Derive an expression for the difference $(P_1 – P_2)$ in terms of r and the surface tension, γ (3 marks)

(c) Mercury is poured into a glass U-tube with vertical limbs of diameters 2.0 mm and

12.0mm respectively. If the angle of contact between mercury and glass is

140° and the surface tension of mercury is $0.52Nm^{-1}$, calculate the difference in the levels of mercury.(Density of mercury $= 13600kgm^{-3}$) (5 marks)

(d) A droplet of mercury of radius 2.0 mm falls vertically and on hitting the ground is split into 2 droplets each of radius 0.50mm.

(i) Calculate the change in surface energy (4 marks)

(ii) Account for the change in (i) above (1 mark)

4. (a) (i) Calculate the work done against surface tension forces in blowing up a soap bubble of diameter 15 mm, if the surface tension of the soap solution is 0.03 Nm $^{-1}$
(3 marks)

(ii) A soap bubble of radius r_1 is attached to another bubble of radius r_2. If r_1 is less than r_2, show that the radius of the common interface is $\dfrac{r_1 r_2}{r_2 - r_1}$ (5 marks)

(b) i) Describe an experiment to determine the angle of contact. (3 marks)

(ii) Define angle of contact and state two factors that affect it. (04 marks)

(iii) Calculate the pressure inside a spherical air bubble of diameter 0.1cm blown at a depth of 20cm below the surface of a liquid of density $1.26 \times 10^3 Kgm^{-3}$ and surface tention $0.064Nm^{-1}$ given that height of mercury barometer is 0.76m and density of mercury $13.6 \times 10^3 Kgm^{-3}$.

(5 marks).

5. (a) i) Describe an experiment to show the effect of temperature on surface tension.
(3 marks)
(ii) Explain why small mercury droplets while large one flatten out. (03 marks)
(b) i) a liquid drop of 0.5cm breaks up into 27 tiny drops all of the same size. If the surface tention of the liquid is $0.07Nm^{-1}$, calculate the resulting change in energy.
(04 marks)
(ii) Calculate the gauge pressure inside a soap bubble 2.00×10^{-4} m in radius using the surface tension for soapy water as $0.037Nm^{-1}$. Convert this pressure to mm Hg. (2 marks)

(iii) Can capillary action be solely responsible for sap rising in trees? To answer this question, calculate the radius of a capillary tube that would raise sap 100 m to the top of a giant redwood, assuming that sap's density is 1050 kg/m^3, its contact angle is zero, and its surface tension is the same as that of water at 20.0° C. (4 marks)

(c)   The lower end of a capillary tube of internal diameter 0.8 mm is 20 cm below the surface of mercury whose coefficient of surface tension is 0.5 N m^{-1}.

Calculate

(i) The depression of the mercury   (3 marks)

(ii) The rise of the mercury if the pressure in the tube is 9.1×10^4 N m^{-2} (4 marks)

(Angle of contact of mercury with glass = 180^0, atmospheric pressure = 1.01×10^5 N m^{-2}, Density of mercury = 13600 kg m^{-3})

Bonus

6.   (a)**.** What is the pressure inside an alveolus having a radius of $2.50 \times 10{-}4$ m if the surface tension of the fluid-lined wall is the same as for soapy water? You may assume the pressure is the same as that created by a spherical bubble.

(b) The pressure inside an alveolus with a 2.00×10^{-4} m radius is 1.40×103 Pa , due to its fluid-lined walls. Assuming the alveolus acts like a spherical bubble, what is the surface tension of the fluid? (b) Identify the likely fluid.

(c) What is the gauge pressure in millimeters of mercury inside a soap bubble 0.100 m in diameter?

(d) A xylem tube is of radius $2.50 \times 10{-}5$ m . Verify that such a tube raises sap less than a meter by finding h for it, making the same assumptions that sap' s density is

1050 kg/m^3, its contact angle is zero, and its surface tension is the same as that of water at 20.0° C .

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(e) If the gauge pressure inside a rubber balloon with a 10.0-cm radius is 1.50 cm of water, what is the effective surface tension of the balloon?

(f) Calculate the gauge pressures inside 2.00-cm-radius bubbles of water, alcohol, and soapy water. Which liquid forms the most stable bubbles, neglecting any effects of evaporation?

(g) Suppose water is raised by capillary action to a height of 5.00 cm in a glass tube. (a) To what height will it be raised in a paraffin tube of the same radius? (b) In a silver tube of the same radius?

(h) Calculate the contact angle θ for olive oil if capillary action raises it to a height of 7.07 cm in a glass tube with a radius of 0.100 mm. Is this value consistent with that for most organic liquids?

(i) When two soap bubbles touch, the larger is inflated by the smaller until they form a single bubble. (a) What is the gauge pressure inside a soap bubble with a 1.50-cm radius? (b) Inside a 4.00-cm-radius soap bubble? (c) Inside the single bubble they form if no air is lost when they touch?

(j) Calculate the ratio of the heights to which water and mercury are raised by capillary action in the same glass tube.

(k) What is the ratio of heights to which ethyl alcohol and water are raised by capillary action in the same glass tube?