UTS

University of Technology, Sydney

Cover Page - Type A:

AUTUMN SEMESTER EXAMINATION 1996

APPLIED GEOLOGY, APPLIED CHEMISTRY, APPLIED PHYSICS

AND MATERIALS SCIENCE DEGREE

PHYSICS 1 (F/T, P/T)

68101 and 68081

WEDNESDAY, 26 JUNE, 1996

START 9.30 AM - FINISH 12.40 PM

TIME ALLOWED: 3 HOURS + 10 MINUTES

This paper is designed to be completed in 3 hours. An extra 10 minutes has been added to the time allowed and it is recommended that you use this 10 minutes to read the paper before commencing to answer the questions.

ANSWER **QUESTION 1 AND ANY 5 OTHER QUESTIONS**

CALCULATORS MAY BE USED.

ANSWER **EACH** QUESTION IN A **SEPARATE** BOOKLET.

CLEARLY MARK THE QUESTION NUMBER ON THE FRONT OF EACH BOOKLET.

FIRST YEAR PHYSICS DATA SHEET

$g = 9.80\ ms^{-2}$

$\sigma = 5.670 \times 10^{-8}\ Wm^{-2}\ K^{-4}$

$R = 8.314\ J\ mole^{-1}\ K^{-1}$

$N_o = 6.022 \times 10^{23}$ molecules $mole^{-1}$

$k = 1.381 \times 10^{-23}\ JK^{-1}$ $molecule^{-1}$

$c = 2.998 \times 10^{8}\ ms^{-1}$

$h = 6.626 \times 10^{-34}\ Js$

$\varepsilon_o = 8.854 \times 10^{-12}\ Fm^{-1}$

$\mu_o = 4\pi \times 10^{-7}\ Hm^{-1}$

$e = 1.602 \times 10^{-19}\ C$

$m_e = 9.110 \times 10^{-31}\ kg = 0.00055\ u$

$m_p = 1.673 \times 10^{-27}\ kg = 1.00728\ u$

$m_n = 1.675 \times 10^{-27}\ kg = 1.00866\ u$

$G = 6.673 \times 10^{-11}\ m^2N\ kg^{-2}$

$1u = 1.661 \times 10^{-27}\ kg$

Rydberg's Constant = $1.097 \times 10^{7}\ m^{-1}$

Temperature of Ice Point = 273.15 K

1 atmosphere = 1.013×10^{5} Pa

Mass of earth = 5.974×10^{24} kg

Radius of earth = 6.37×10^{6} m

1 Curie = 3.70×10^{10} becquerel

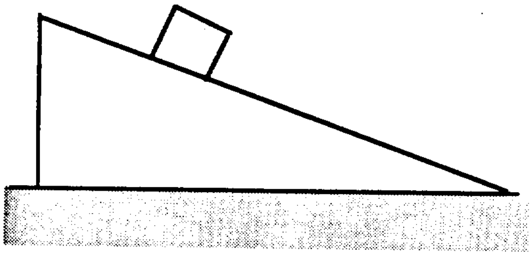
OVER/2

SECTION A
(THIS QUESTION IS COMPULSORY.)

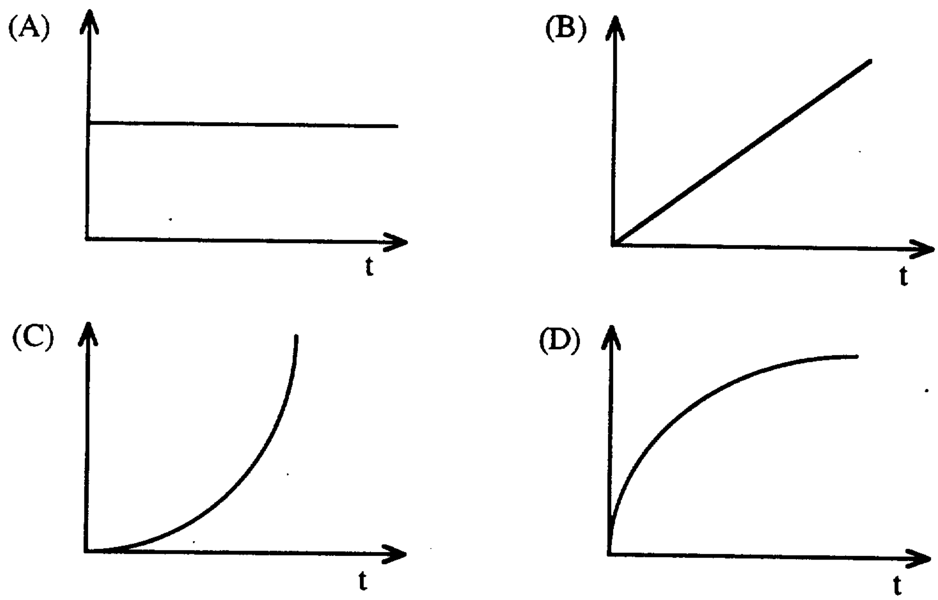
QUESTION 1.

a. Put the answers to the multiple choice question in your examination booklet. Show working where appropriate.

i. A block is sliding down a frictionless incline, as shown in the diagram below.



Which of the following graphs represents the variation of **distance** with time?



ii. A boy throws a steel ball straight up into the air. **Disregarding any effects of air resistance**, the force(s) acting on the ball while it is in the air is (are)

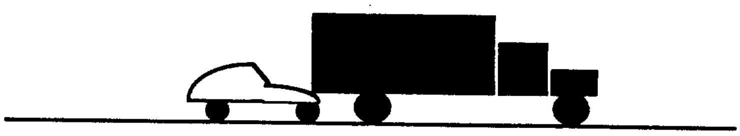
A. a constant downward force of gravity and a steadily decreasing upward force

B. a steadily decreasing upward force until it reaches its highest point, after that there is a steadily increasing downward force.

C. a constant downward force of gravity along with an upward force that steadily decreases until the highest point, after that there is only the constant force of gravity

D. a constant downward force of gravity

iii. The diagram shows a large truck which has broken down and is being pushed to the garage by a small car.



At first the car pushing the truck **speeds up** to get to cruising speed. What is happening?

A. The force of the car pushing against the truck is equal to that of the truck pushing back against the car

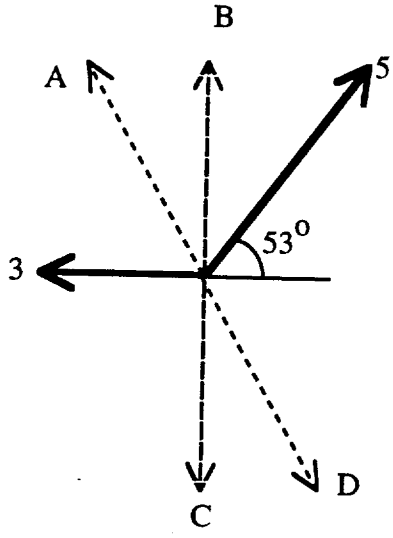
B. The force of the car pushing against the truck is greater than that of the truck pushing back against the car

C. The force of the car pushing against the truck is less than that of the truck pushing back against the car

D. the car's engine is running so it applies a force as it pushes against the truck, but as the truck's engine is not running it can't push back against the car. The truck is moving because it is in the way of the car.

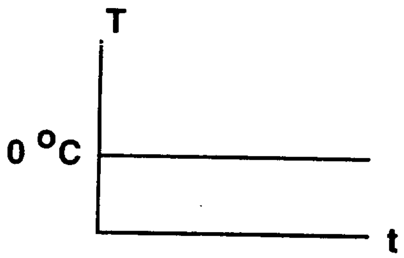
E. neither the car nor the truck exert a force on each other, the truck is pushed because it is in the way of the car.

iv. Two forces of magnitude 3 and 5 units act on a body as shown. For the body to be in **equilibrium** a third force of magnitude 4 units must act. In which direction will the third force will be: A, B, C or D.?

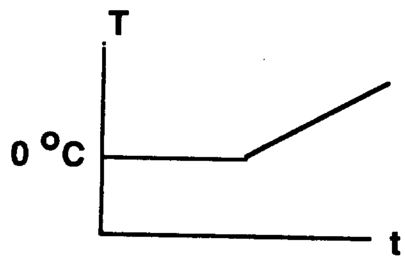


v. A cup contains a mixture of ice and water. Heat is transferred to the mixture. Which of the following graphs of temperature (T) against time (t) would be obtained if before the end of the time interval all the ice has melted.

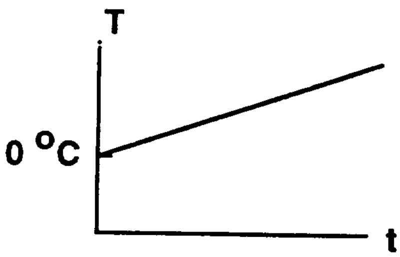
A.



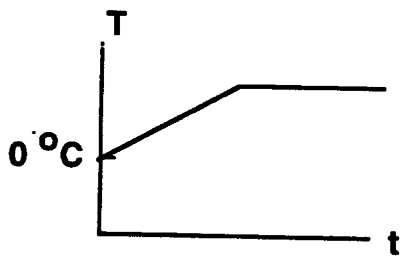
B.



C



D.



E. None of the above

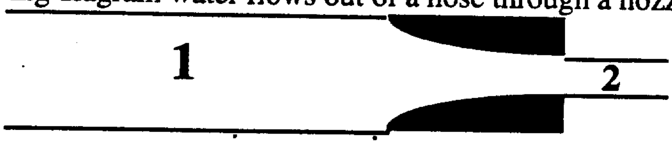
QUESTION 1 (contd.)

Marks

vi. A gas is believed to made up of molecules scattered throughout empty space. The reason that a gas such as air, in a air bed, can support the weight of a person is that the air molecules

- A. are packed tightly together when the bed is pumped up and have no empty spaces between.
- B. are highly elastic and resist being compressed.
- C. are in constant motion, and their striking of the walls of the bed keeps the bed inflated.
- D. can be compressed to form an elastic fluid which flows around inside the bed.

vii. In the following diagram water flows out of a hose through a nozzle.



If v is the velocity of the fluid, and P is the pressure of the fluid, what is the relationship between the velocities and pressures at 1 and 2?

A.	$v_2 > v_1$,	$P_2 > P_1$	B.	$v_2 > v_1$,	$P_2 < P_1$
C.	$v_2 < v_1$,	$P_2 > P_1$	D.	$v_2 < v_1$,	$P_2 < P_1$
E.	none of the above.				

viii. The pressure surrounding a soap bubble is Po. What is the pressure inside the soap bubble (surface tension γ) of diameter r?

A	Po	B.	Po + $2\gamma/r$	C.	Po - $2\gamma/r$
D.	Po + $4\gamma/r$	E.	Po - $4\gamma/r$		

10

b. i. In an experiment to compare the effectivness of rocket fuels, rockets were fired along a horizontal frictionless track and their velocity measured as a function of time. Results for a particular rocket were:-

Time (seconds)	Velocity (metres/second)
1.00 ± 0.01	16 ± 1
2.00 ± 0.01	30 ± 1
3.00 ± 0.01	46 ± 2
4.00 ± 0.01	61 ± 2

From these figures determine graphically (using the graph paper supplied) the acceleration of the rocket (assumed constant).

4

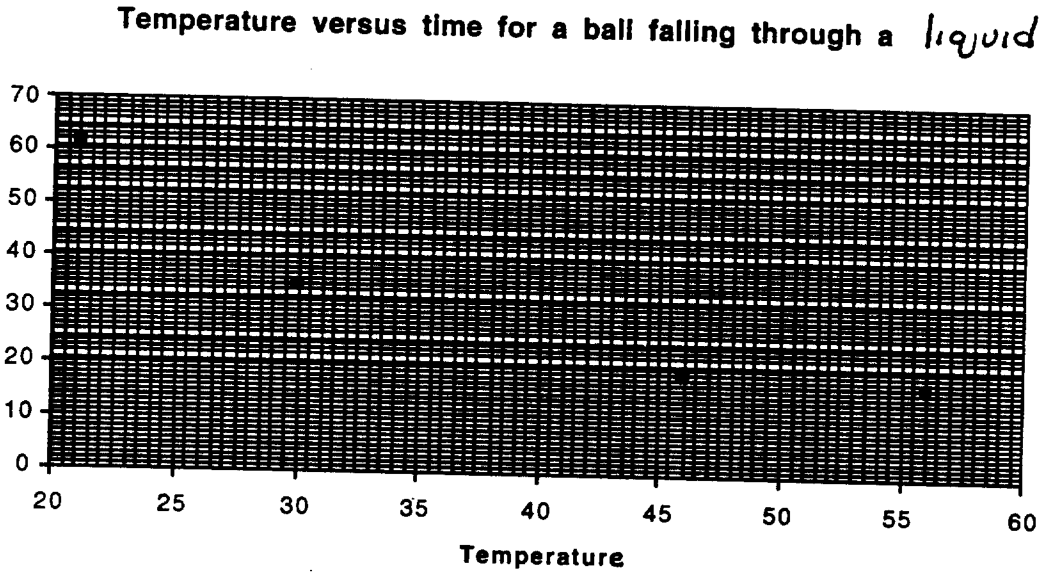
QUESTION 1 (contd.)

Marks

ii. An experiment is performed in which the time for a small metal sphere to fall a fixed distance through a liquid is recorded as the temperature of the liquid increases. The data gathered are shown in the table below and are plotted on the graph in Figure 1.

Temperature (°C)	Time (s)
21	62
30	35
42	22
46	19
52	18

Figure 1



List 4 mistakes in Figure 1.

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iii. A student is given a 5 m tape measure and handheld stopwatch. The student is asked to use this equipment to measure the time it takes for a coin to fall through a distance of 4 m. The student repeats the measurement ten times and obtains values between 0.6 s and 1.2 s.

State four possible causes for the variability in the measured values. Which cause do you think is the most important and give your reason(s) for the choice.

3

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SECTION B

(ATTEMPT ANY **FIVE** QUESTIONS IN THIS SECTION.)

QUESTION 2. Marks

a. We are told that the speed of ocean waves, v, depends on :the wavelength of the wave, λ, and the acceleration due to gravity, g.

Use dimensional analysis to find the equation relating v to the other quantities. 4

b. Consider the following vectors

A	$A_x = 3$	$A_y = 4$
B	$B_x = -2$	$B_y = 3$

On a clearly labelled set of x-y axes sketch the following vectors

i. **A**

ii. **B**

iii. **A** + **B**

iv. **A** - 2**B**

5

c. A body initially at rest rotates with a constant angular acceleration of 2.1 rad s^{-2} for 7 seconds.

i. what is the angular velocity after 7 seconds?

ii. sketch an angular velocity versus time graph for the time t = 0 to t = 7s

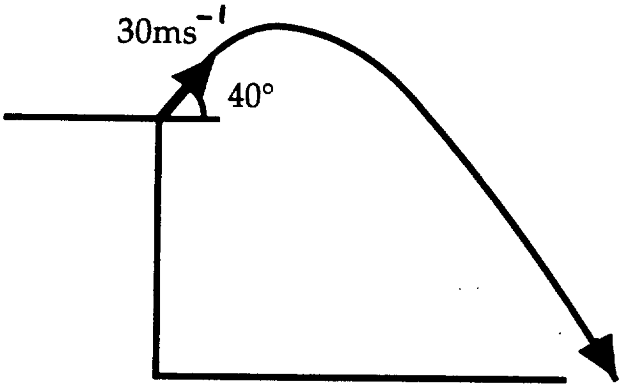
iii. through what angle does it rotate in this time?

iv. sketch an angle versus time graph for the time t = 0 to t = 7s

5

QUESTION 2 (contd.) Marks

d. An object is thrown from a building at a height of 150 m above the ground. The initial velocity of the object is 30 ms^{-1} at an angle of 40° to the horizontal, as shown below.



Calculate:

i. the maximum height above the ground reached by the object.

ii. the time for the object to reach the ground.

iii. the horizontal distance travelled by the object.

6

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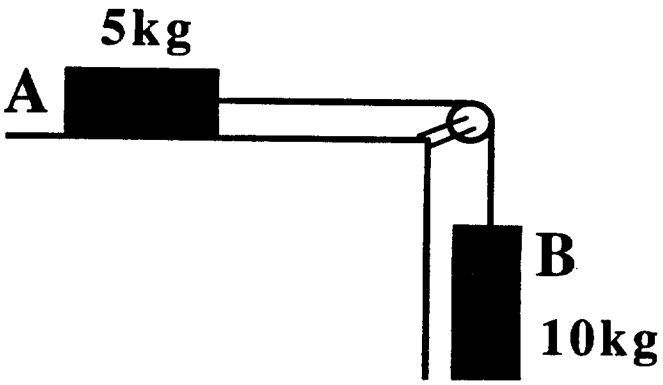
QUESTION 3. Marks

a. What is Newton's Third Law? Illustrate your explanation with an example. 3

b. Consider the diagram below



Given that the coefficient of kinetic friction between body A and the surface is 0.21,

i. Draw a free body diagram for each of the bodies A & B.

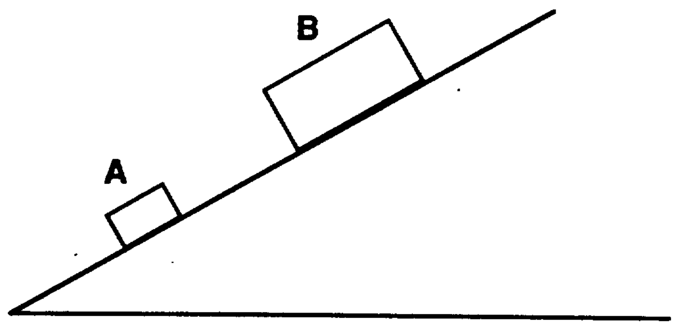
ii. Calculate the acceleration of body A.

iii. Calculate the tension in the string.

iv. If the friction force between body A and the surface decreases to zero, would the tension in the string increase, decrease or stay the same? (Explain your answer)

7

d. Object A and object B are free to move up a smooth plane, inclined at 30^{o} to the horizontal (see diagram). Object A of mass 0.10 kg is travelling at 8 ms^{-1} when it strikes and sticks to object B of mass 1.2 kg. At the time of impact, object B was stationary.



Calculate

i. the total kinetic energy of the system before the collision.

ii. the final velocities of the bodies immediately after the collision.

iii. how far up the plane the two objects will move

6

d. A force of 20 N is applied tangentially to the edge of a uniform solid disc of radius 150 mm and mass 200 g. The disc is allowed to rotate about an axis perpendicular to and through the centre of the disc. calculate,

i. the moment of inertia of the disc about the axis

ii. the torque acting on the disc about the axis

iii. the angular acceleration of the disc, assuming no frictional forces act.

4

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QUESTION 4

Marks

a. State the work-energy theorem and use it to show that a body having fallen freely a distance d after being dropped from rest near the surface of the earth has a speed, v, given by $v = \sqrt{2gd}$.

4

b. i. A tennis ball dropped vertically without rotation onto solid ground from a height of 1.00 m bounces, without rotation back up to a height of 0.82 m. At what speed must it be thrown downward to return to its original height of 1.00 m? You should assume that the proportion of the energy lost in the action of bouncing does not depend on the speed of the ball.

ii. At what height above the ground and on the return path does the speed of the ball equal the speed at which it was thrown down?

6

c. A hoop of mass 1.00 kg and radius of gyration 0.5 m is rotated from rest about its centre with an angular acceleration of 2.00 rad.s^{-2} for a time interval of 10 s. Determine;

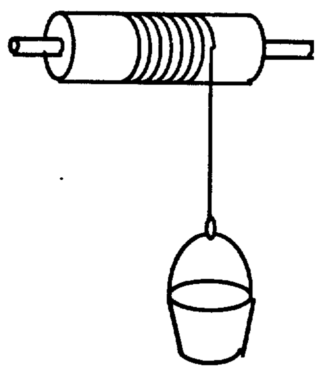
i. The final angular speed.

ii. The number of revolutions the hoop has done.

iii. The work done on the hoop

6

d. A bucket with mass 0.5 kg attached to a pulley system as shown below is dropped without the rope slipping. The pulley is a solid cylindrical drum, and the rope has negligible mass.



The bucket is dropped (from rest) and its speed after falling a distance of 10.0 m is 4.00 m.s^{-1}. What is the mass of the drum?

4

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QUESTION 5.

Marks

a. An aluminium ring, having an inner diameter of 25 mm, is to be slipped over a steel rod whose diameter is 25.15 mm. Both ring and the rod are initially at 20 ^{o} C. What can be done so that the aluminium ring just slips over the rod? Discuss briefly and show all your calculations.

Linear thermal expansion coefficient of Aluminium $\alpha = 7.2 x 10^{-6} K^{-1}$

of Steel $\alpha = 1.1 \times 10^{-5} K^{-1}$

5

b. A portable cooler consists of a sheet-steel liner of mass 0.75 kg insulated on the outside. The cooler holds 1.5 kg of water at 17.5 ^{o}C. A block of ice of mass 0.12 kg and at -5 ^{o}C is dropped into the water. Calculate the equilibrium temperature (neglecting external heat exchanges).

Specific heat, water = 4190 J/kg/K

Specific heat, ice = 2110 J/kg/K

Heat of fusion, water = $3.34 x 10^5$ J/kg

Specific heat, steel = 450 J/kg/K

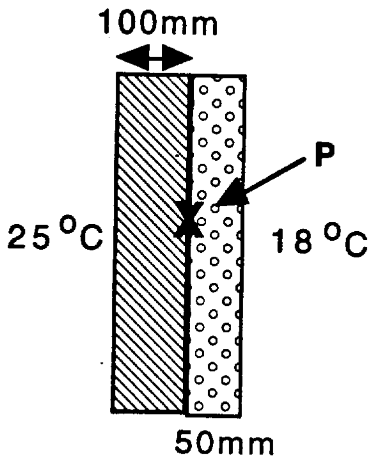
5

c. A double brick wall in a house is composed of 2 types of bricks one 100 mm thick and the other 50 mm thick as shown in the diagram. Outside the house, the brick surface is at temperature 25 ^{o}C and inside the house, the brick surface temperature is at 18 ^{o}C. Calculate:

i. heat flow rate through 1 m^2 of wall surface

ii. the temperature where the two bricks meet inside the wall (point P in the diagram).

For both types of bricks k_{brick} = 1.33 W/m/K



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QUESTION 5 (contd.)

Marks

d. The 2.5 litre oxygen gas bottle in a small oxy-acetylene welding set is at 20 ^oC. A pressure gauge attached to the bottle indicates 865 kPa.

Calculate:

i. the number of molecules in the container

ii. the root mean square velocity of the molecules

iii. the internal energy contained within the cylinder

iv the molar specific heat at constant volume Cv

v the molar specific heat at constant pressure Cp

vi the ratio of specific heats γ

Data: molecular weight (M) of $O_2 = 2x16 = 32$ g/mol

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QUESTION 6.

Marks

a. A mass of 1 kg of air at 100 kPa and 20 °C is compressed isothermally to a pressure of 400 kPa. 100 kJ of heat are then added at a constant pressure. Sketch these processes on a p-V diagram and calculate the:

i. Work performed during compression

ii. Temperature after heat is added

$c_{p\ air} = 1005$ J/kg/K

molecular weight of air = 28.92 g/mol

5

b. A heat engine operates with a high temperature reservoir of 1000 K and a low temperature reservoir of 300 K. Which is the more effective way of improving the performance of the engine (and give reasons why)?

i. Increasing the source temperature to 1100 K

ii. Decreasing the sink temperature to 200 K

4

c. Could the efficiency of the heat engine in part b be 100%? Explain your answer.

2

d. Explain briefly what is meant by surface tension.

2

e. i. If the atmospheric pressure is 1.013×10^5 Pa, what is the pressure 15 m below the surface of a fresh water lake? (density of water = 1000 kg m^{-3})

ii. An air bubble rises from a depth of 15 m (pressure as in part i.) where the temperature is 5 °C to near the surface (pressure is atmospheric pressure) where the water temperature is 19 °C. The volume of the air bubble near the surface is V_1 and its volume at a depth of 15 m is V_2. What is the ratio V_1/V_2?

iii. What is the pressure inside an air bubble of radius 0.061 mm, 15 m below the surface of the fresh water lake in part i.?
(surface tension of water = 7.2×10^{-2} Nm^{-1})

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QUESTION 7.

Marks

a. Explain by means of a clearly labelled diagram, the proportional limit, the elastic limit and the fracture point of a substance.

3

b. A rod made of iron (coefficient of linear expansion = $1.1 \times 10^{-5}\ K^{-1}$, Young's Modulus = $2.1 \times 10^{11}\ Nm^{-2}$), is 0.75 m long and has a radius of 8.5 mm.

i. The iron rod expands 0.13 mm when heated. What was the change of temperature of the rod?

ii. If the movement of the rod is restricted, tension will build up in the rod. If the rod would have normally expanded 0.13 mm (as in part i.), what tension will build up in the rod?

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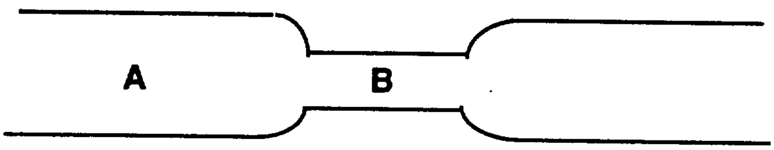
c. Water of density 1000 kg m^{-3} flows along a pipe as shown in the diagram



The pressure difference between A and B is 800 Pa, and the velocity at A is 0.35 ms^{-1}. Treating water as an ideal fluid, calculate

i. the velocity at B

ii. the cross sectional area at A given that the cross sectional area at B is $1.25 \times 10^{-3}\ m^2$.

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d. What is Reynold's Number. Explain any symbols used. Give one example of its use.

3

e. What is the terminal velocity in air (density = 1.3 kg m^{-3}, viscosity = 2.1×10^{-5} Pa s) of a raindrop (density 1000 kg m^{-3}) of radius 0.21 mm?

4

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Mechanics Equation Sheet

$v = u + at$	$v^2 = u^2 + 2as$	$s = ut + \frac{1}{2}at^2$
$s = R\theta$	$v = R\omega$	$a = R\alpha$
$a = \frac{v^2}{R}$	$\underline{\Gamma} = \underline{r} \times \underline{F}$	$\underline{\Gamma} = I\underline{\alpha}$
$I = I_{cm} + Mh^2$	$I = Mk^2$	$x_{cm} = \frac{\int x\,dm}{M}$

Thin Rod	Hoop	Solid Cylinder/Disk	Sphere	Hollow Cylinder
$I = \frac{Ml^2}{12}$	$I = MR^2$	$I = \frac{1}{2}MR^2$	$I = \frac{2}{5}MR^2$	$I = \frac{1}{2}M(a^2 + b^2)$

$\omega = \omega_0 + \alpha t$	$\omega^2 = \omega_0^2 + 2\alpha\theta$	$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
$P = \underline{F} \cdot \underline{v}$	$P = \Gamma\omega$	$W = \Gamma\theta$
$\underline{L} = m\underline{r} \times \underline{v}$	$\underline{J} = \underline{F}\,\Delta t$	$\Delta\underline{L} = \int \underline{\Gamma}\,dt$
$F = \frac{GMm}{r^2}$	$U = -\frac{GMm}{r}$	

Dynamics Equation Sheet

$a_n = \frac{v^2}{\rho}$	$a_t = \frac{dv}{dt}$	
$a_n = \rho\omega^2$	$a_t = \rho\alpha$	
$W = \Delta K + \Delta U_g + \Delta U_e$	$U_g = mgy$	$U_e = \frac{1}{2}kx^2$

Centroidal radius of gyration of rectangle a x b: $k = \sqrt{\frac{(a^2 + b^2)}{12}}$

$K = \frac{1}{2}I_{cm}\omega^2 + \frac{1}{2}Mv_{cm}^2$ $\quad L_{cm} = I_{cm}\omega$ $\quad \sum \Gamma_{cm} = I_{cm}\alpha$

Rotation about fixed axis:

$K = \frac{1}{2}I_0\omega^2$ $\quad L_0 = I_0\omega$ $\quad \sum \Gamma_0 = I_0\alpha$

Rolling without slipping: $\quad \sum \Gamma_C = I_C\alpha$

Thermal Equation Sheet

$\Delta l = l_0 \alpha \Delta T$

$\Delta V = V_0 \beta \Delta T$

$\Delta Q = mc\Delta T$

$\Delta Q = nC\Delta T$

$\Delta Q = mL$

$\frac{dQ}{dt} = -kA\frac{dT}{dx}$

$\frac{dQ}{dt} = -e\sigma A(T^4 - T_0^4)$

$\frac{dQ}{dt} = \frac{\Delta T}{R}$

$PV = nRT$

$PV = NkT$

$PV^\gamma = \text{constant}$

$PV = \frac{Nm\overline{v^2}}{3}$

$\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$

$C_p - C_v = R$

$C_v = \frac{3}{2}R$ (mono-), $\frac{5}{2}R$ (di-), $\frac{6}{2}R$(poly-)

$Q = W + \Delta U$

$\Delta U = nC_v\Delta T$

$W = P(V_f - V_i)$

$W = \frac{P_iV_i - P_fV_f}{\gamma - 1}$

$W = nRT \ln\left(\frac{V_f}{V_i}\right)$

$\Delta S = \int \frac{dQ}{T}$

$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$e = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$

$\text{C.O.P.} = \frac{Q}{W} = \frac{T_2}{T_1 - T_2}$

Properties of Matter/Fluids Equation Sheet

$$Y = \frac{F/A}{\Delta l/l_0}$$

$$B = \frac{\Delta p}{\Delta V/V_0}$$

$$n = \frac{F/A}{d/y}$$

$$\sigma = \frac{\Delta b/b_0}{\Delta l/l_0}$$

$$P = P_0 + \rho g h$$

$$P + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

$$\gamma = \frac{F}{l} = \frac{W}{\Delta A}$$

$$h = \frac{2\gamma\cos\theta}{\rho g R}$$

$$\Delta P = \frac{2\gamma}{R} \text{ or } \frac{4\gamma}{R}$$

$$Q = Av = \text{constant}$$

$$Q = \frac{\pi R^4 \Delta P}{8\eta l}$$

$$v_1^2 = \frac{2(P_1 - P_2)}{\left[\rho\left\{\left(\frac{A_1}{A_2}\right)^2 - 1\right\}\right]}$$

$$\eta = \frac{F/A}{\Delta v/\Delta y}$$

$$F = 6\pi\eta R v$$

$$N_R = \frac{\rho v D}{\eta}$$

$$v_t = \frac{2r^2 g(\rho_s - \rho_f)}{9\eta}$$