SPRING SEMESTER EXAMINATION 1996

APPLIED GEOLOGY, APPLIED CHEMISTRY, APPLIED PHYSICS

AND MATERIALS SCIENCE DEGREE

PHYSICS 1 (F/T, P/T)

68101 and 68081

MONDAY, 25 NOVEMBER, 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 $= 1.013 \times 10^{5}\ Pa$

Mass of earth $= 5.974 \times 10^{24}\ kg$

Radius of earth $= 6.37 \times 10^{6}\ m$

1 Curie $= 3.70 \times 10^{10}$ becquerel

OVER/2

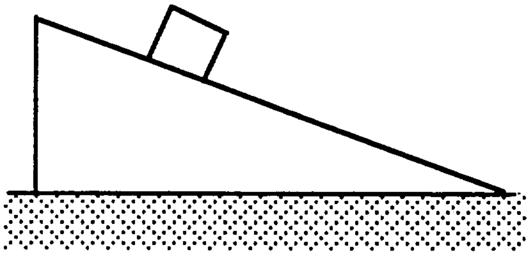
SECTION A

(THIS QUESTION IS COMPULSORY.)

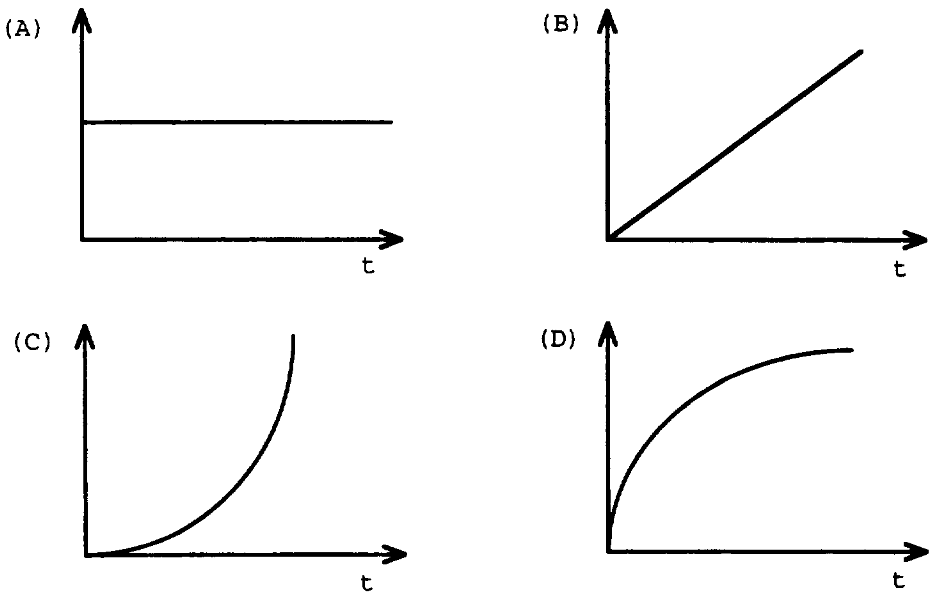
QUESTION 1.

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?



QUESTION 1 (contd.)

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)

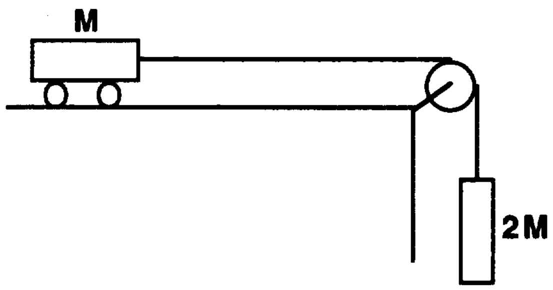
A. a constant downward force of gravity and a steadily decreasing upward force

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

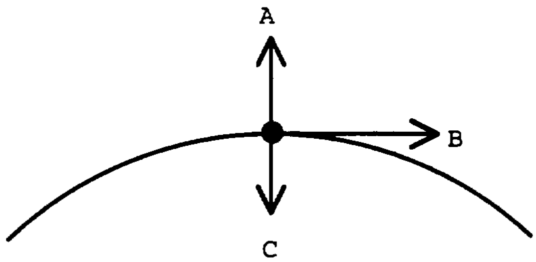
iii. The diagram shows a trolley of mass M on frictionless bearings being accelerated by a falling object of mass 2 M.



The acceleration of the trolley is

A. g/3 B. g/2 C. 2g/3 D. g E. 2g

iv. A body moves in an arc of a circle as shown below with constant speed. Which of the following statements is correct?



A. There is a force acting in the direction A.

B. There is a force acting in the direction B.

C. There is a force acting in the direction C.

D. There is no force acting since the body is moving with constant speed.

QUESTION 1 (contd.)

v. Cup A contains 100 grams of water. Cup B contains 200 grams of water.

Both are initially at room temperature (25 ^{o}C).

The water in Cup A is heated to 75 ^{o}C. The water in Cup B is heated to 50 ^{o}C.

The water in which cup has more heat been transferred to?

(Ignore the heat transferred to the cup itself)

- A. Cup A
- B Cup B
- C. Heat transfer the same for each cup
- D. Not enough information given.

vi. There are 4 identical rods. (All are made of the same metal and have the same shape). The sides of the rods are insulated so that no heat can flow in or out. The temperatures at each end of the rods are as follows:-

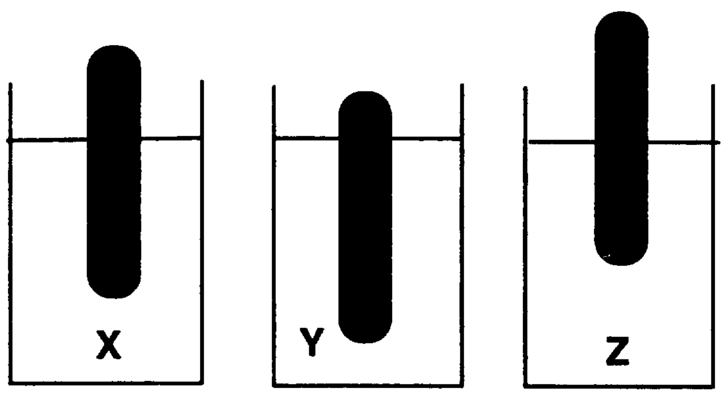
- A. 0 ^{o}C & 50 ^{o}C
- B. 50 ^{o}C & 90 ^{o}C
- C. -10 ^{o}C & 30 ^{o}C
- D. 30 ^{o}C & 60 ^{o}C

Along which rod does heat flow at the <u>slowest</u> rate?

Answer E if you think the heat flows at the same rate for each rod.

vii. The depth to which an object sinks in various liquids is shown in the diagram.

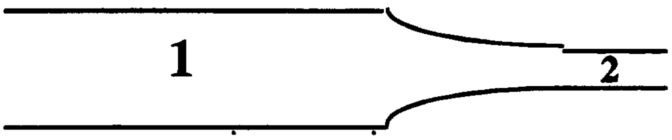
What can be said about the densities of X, Y and Z?



A.	$\rho_z < \rho_x < \rho_y$	B.	$\rho_z > \rho_x > \rho_y$	C.	$\rho_z = \rho_x = \rho_y$
D.	$\rho_x < \rho_y < \rho_z$	E.	$\rho_x > \rho_y > \rho_z$	F.	none of the above

QUESTION 1 (contd.) **Marks**

viii. 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.

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	8.2 ± 0.5
2.00 ± 0.01	15 ± 1
3.00 ± 0.01	23 ± 2
4.00 ± 0.01	32 ± 2

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

4

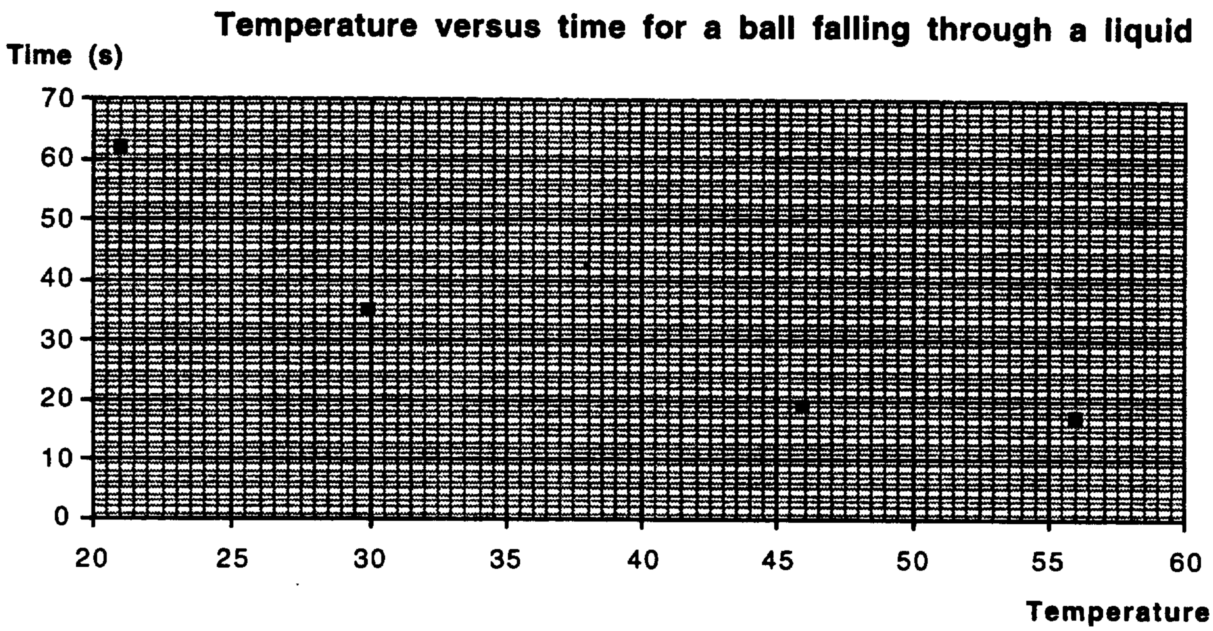
QUESTION 1 (contd.)

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 A ball of mass 3.0 kg is thrown vertically <u>**down**</u> from the top of a cliff with an initial speed of 18 ms^{-1}. How far has it fallen after 4 seconds? 3

b. A student is swinging a bucket of mass 6.4 kg in a horizontal circle of radius 4.2 m on the end of a rope. If the rope will break at a tension of 1100 N, calculate the maximum speed the bucket can have. 3

c. A wheel of diameter 2.5 m accelerates from rest with an angular acceleration of 0.5 $rad.s^{-2}$. After 6 s has elapsed, what is :-

i. the angular velocity of the wheel?
ii. the angle through which the wheel has rotated?
iii. the tangential velocity of a point at the edge of the wheel?
iv. the centripetal acceleration of a point at the edge of the wheel?

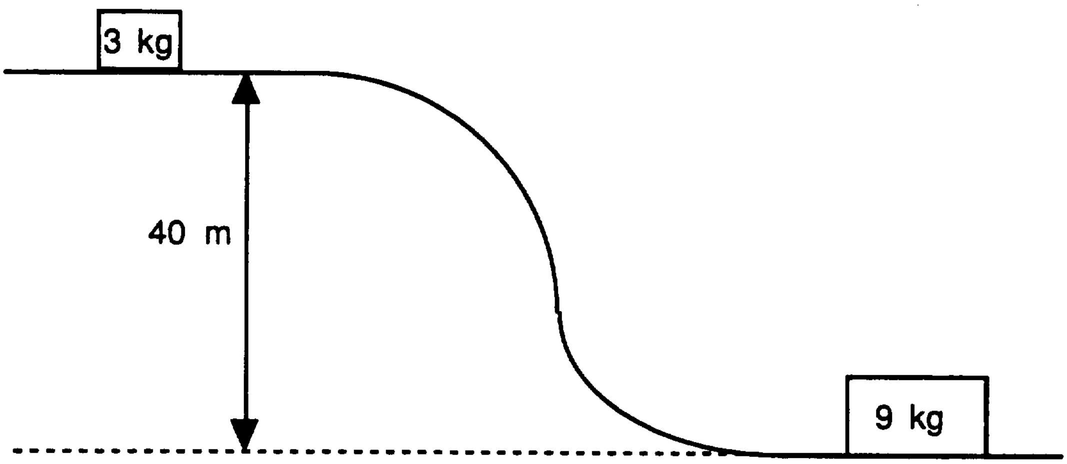
6

d. With the aid of examples, explain what is meant by elastic and inelastic collisions 2

QUESTION 2 (contd.) **Marks**

e. i. A body has mass of 3 kg, and its horizontal velocity at the top of a hill is 20 m/s. If vertical height of the hill is 40 m, calculate the kinetic energy and velocity of the body when it reaches the bottom of the hill. (Assume no friction is acting.)

ii. At the bottom of the hill, the 3 kg body now collides with and sticks to a 9 kg body originally at rest. How much kinetic energy is lost through this collision?



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QUESTION 3. **Marks**

a. A disoriented physics professor drives 4.92 km east, then 3.95 km south, then 1.80 km west. Find the magnitude and direction of the resultant displacement, using the method of components.

3

b. In a stall at the Royal Easter Show, you can win a stuffed toy if you toss a coin up into a small dish on a shelf. The dish is at a distance 2.1 metres horizontally from where you release the coin, but you aren't told the height of the shelf (above the release point). If you toss the coin with a velocity of 6.4 m/s at 60° above the horizontal, the coin lands in the dish. Calculate the height that the dish is above the point of release of the coin.

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c. A small block with mass m=0.110 kg rests on a horizontal frictionless tabletop. A string joins the mass m to another mass M=1.60 kg hanging from a smooth pulley at the edge of the table.

i. Calculate the acceleration of the mass m.

ii. Calculate the acceleration again, this time assuming a kinetic friction coefficient of 0.15. Show all your working.

5

d. A solid wooden door 1.10m wide and 2.10 m high is hinged along one side and has a total mass of 53.0 kg. Initially the door is open and at rest when it is hit at its centre by a lump of sticky mud of mass 0.520 kg travelling at 8.50 m/s. Calculate the final angular velocity of the door. Comment on the significance of the mud in the rotational motion.

5

e. State the conditions for equilibrium.

2

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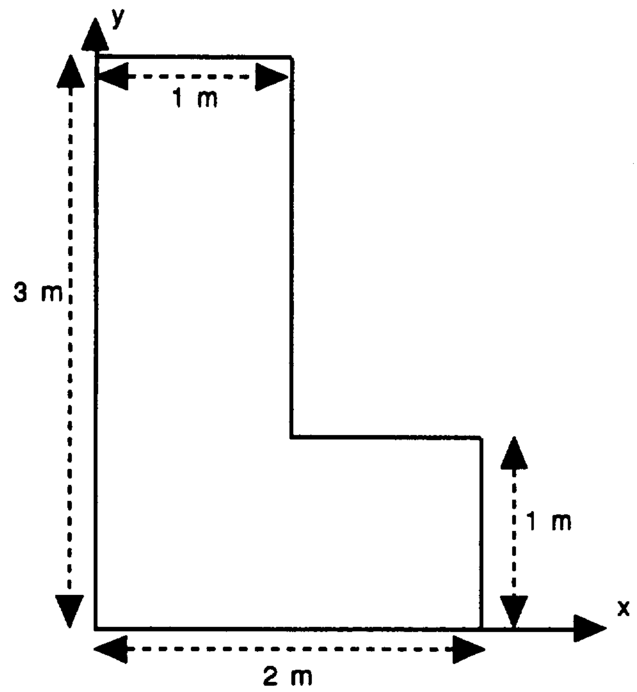
QUESTION 4. Marks

(The equation PE = $1/2\ kx^2$ may be helpful for this question.)

a. Consider the following L shaped steel plate.
What are the x and y coordinates of the centre of mass of the steel plate?



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b. The spring of a spring gun is compressed a distance of 3.2cm from its relaxed state, and a ball of mass 6.3g is put in the barrel. With what speed will the ball leave the barrel once the gun is fired? The spring constant k is 7.5 N/cm. Assume no friction and a horizontal gun barrel.

4

c. Suppose a flywheel is made in the form of a solid cylinder whose mass is 65kg and whose radius is 20cm. If the wheel is spun at 80,000 rev/min:-

i. what is its moment of inertia about its centre of mass?

ii. how much rotational kinetic energy does it store?

6

d. A hollow cylindrical shell with mass m=255kg and radius r=0.25m rolls without slipping with speed v_{cm}=0.3m/s on a flat horizontal surface.

i. What is its moment of inertia about the point of contact with the surface?

ii. What is its total kinetic energy?

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QUESTION 5. MARKS

a. A cube of solid material is heated so its temperature increases by 200 °C. Its volume is found to increase by 1.5%. Determine the coefficient of volume expansion of this material.

3

b. A wax which melts at 65 °C is heated from 20 °C and the amount of heat flowing into the wax is measured. The mass of the wax is 0.25 kg. It is found that 23 kJ of heat is required to melt 1/2 of the wax and that a further 2 kJ is required to melt the remainder of the wax.

i. Determine the heat of fusion of the wax.

ii. Determine the specific heat of the wax.

5

c. A cylindrical rod is made up of equal lengths of different materials placed end to end. One end of the rod is kept at 0 °C and the other at 100 °C. The temperature where the two materials are joined is 70 °C. The coefficient of thermal conductivity of the material with one end at 0 °C is 400 W/m.°C. Calculate

i. the rate of heat flow in each rod, and

ii. the coefficient of thermal conductivity of the other material.

5

d. A copper sphere is placed in the middle of a chamber in order to measure the emissivity of the sphere. When it is heated at the rate of 7.8 W the temperature of the sphere is found to be 100 °C. The surface area of the sphere is 0.030 m^2 and the temperature of the walls of the chamber is 25 °C. Determine the emissivity of the sphere.

4

e. Calculate the root mean squared speed of the molecules in air at 20 °C. Take the mean mass of the molecules in air to be 4.8×10^{-26} kg.

3

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QUESTION 6. MARKS

a. Answer two (2) of the following items:

- i. State in words the first law of thermodynamics.
- ii. Give one version of the second law of thermodynamics.
- iii. Define the Carnot cycle.
- iv. Define the thermal efficiency of a heat engine.

4

b. 2 mol of an ideal gas at a temperature of 20 ^{o}C are heated at constant pressure until the temperature reaches 120 ^{o}C. The molecules of the gas are diatomic.

- i. Calculate the amount of heat that flows into the gas.
- ii. Calculate the change in internal energy of the gas.
- iii. Calculate the work done by the gas.

6

c. i. Explain the difference between shear modulus and Young's modulus.

ii. A steel column 4 m long and 25 x 10^{-4} m^2 cross sectional area supports a mass of 3000 kg. As a result it is shortened by 2.25 x 10^{-4} m. What is Young's Modulus for steel?

iii. A cube of copper 60 mm on side is subjected to a shearing force of 150,000 N and as a result the top face of the cube is displaced 0.25 mm with respect to the bottom. What is the shear modulus of copper?

7

d. A glass tube of 0.41 mm radius is held vertically in a liquid of density 860 kg m^{-1} and surface tension 46x 10^{-3} N m^{-1}. The angle of contact is 35°. To what height will the liquid rise in the tube?

3

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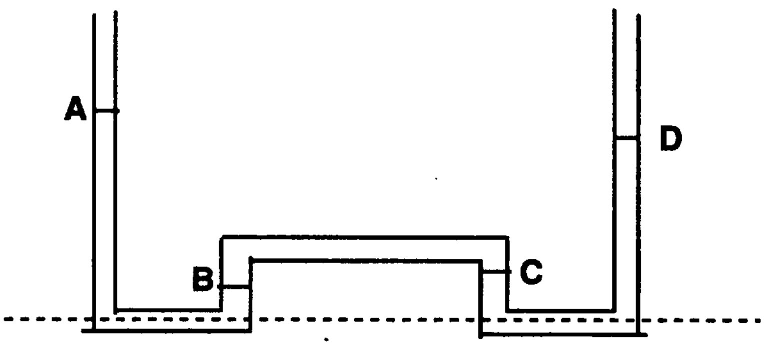
QUESTION 7 Marks

a. In the diagram below the tube is open to the atmosphere at both ends. (Atmospheric pressure = 101.3 kPa). Portion CD is filled with water (density 1000 kg m^{-3}) and BC is occupied by air. A, B, C and D are respectively 440 mm, 100 mm, 150 mm and 400 mm above the dotted line.

i. Find the pressure at C.

ii. Assuming that the pressure at C is the same as the pressure at B find the density of the liquid occupying AB.



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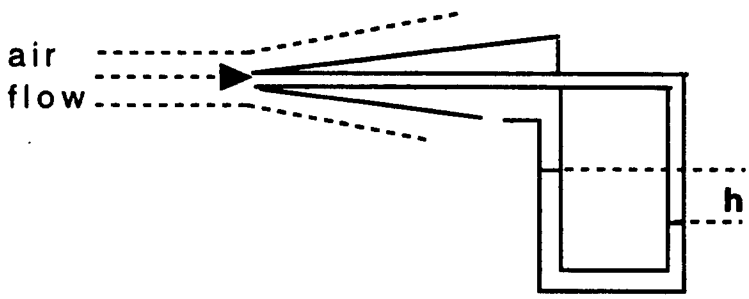
b. The following is a diagram of a measuring instrument used with fluids.



i. Explain how it works and what it measures.

ii. If the pressure difference indicated in the diagram is 167 mm of mercury (density 13,600 kg m^{-3}), what is the pressure difference in Pascals?

iii. If the density of air flowing past the instrument has a density of 0.9 kg m^{-3}, what is the speed of the air?

7

QUESTION 7 (contd.) **Marks**

c. i. What must be the pressure difference between the two ends of a 2.0-km section of pipe 0.50 m in diameter if it is to transport oil (η = 0.25 Pa-s) at a rate of 400 l/s?

ii. What is the flow velocity of the oil? 5

d. Explain what is meant by Reynolds Number and why it is important. 3

20

Mechanics Equation Sheet

$v = u + at$ $\quad$ $v^2 = u^2 + 2as$ $\quad$ $s = ut + \frac{1}{2}at^2$

$s = R\theta$ $\quad$ $v = R\omega$ $\quad$ $a = R\alpha$

$a = \frac{v^2}{R}$ $\quad$ $\underline{\Gamma} = \underline{r} \times \underline{F}$ $\quad$ $\underline{\Gamma} = I\underline{\alpha}$

$I = I_{cm} + Mh^2$ $\quad$ $I = Mk^2$ $\quad$ $x_{cm} = \frac{\int x\,dm}{M}$

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

$\omega = \omega_0 + \alpha t$ $\quad$ $\omega^2 = \omega_0^2 + 2\alpha\theta$ $\quad$ $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$P = \underline{F} \cdot \underline{v}$ $\quad$ $P = \Gamma\omega$ $\quad$ $W = \Gamma\theta$

$\underline{L} = m\underline{r} \times \underline{v}$ $\quad$ $\underline{I} = \underline{F}\Delta t$ $\quad$ $\Delta\underline{L} = \int \underline{\Gamma}\,dt$

$F = \frac{GMm}{r^2}$ $\quad$ $U = -\frac{GMm}{r}$

Dynamics Equation Sheet

$a_n = \frac{v^2}{\rho}$ $\quad$ $a_t = \frac{dv}{dt}$

$a_n = \rho\omega^2$ $\quad$ $a_t = \rho\alpha$

$W = \Delta K + \Delta U_g + \Delta U_e$ $\quad$ $U_g = mgy$ $\quad$ $U_e = \frac{1}{2}kx^2$

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

$\Delta l = l_0 \alpha \Delta T$ $\qquad$ $\Delta V = V_0 \beta \Delta T$

$\Delta Q = mc\Delta T$ $\qquad$ $\Delta Q = nC\Delta T$ $\qquad$ $\Delta Q = mL$

$\frac{dQ}{dt} = -kA\frac{dT}{dx}$ $\qquad$ $\frac{dQ}{dt} = -e\sigma A\left(T^4 - T_0^4\right)$ $\qquad$ $\frac{dQ}{dt} = \frac{\Delta T}{R}$

$PV = nRT$ $\qquad$ $PV = NkT$ $\qquad$ $PV^\gamma = \text{constant}$

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

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

$Q = W + \Delta U$ $\qquad$ $\Delta U = nC_v\Delta T$ $\qquad$ $W = P(V_f - V_i)$

$W = \frac{P_iV_i - P_fV_f}{\gamma - 1}$ $\qquad$ $W = nRT \ln\left(\frac{V_f}{V_i}\right)$ $\qquad$ $\Delta S = \int \frac{dQ}{T}$

$\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$ $\qquad$ $e = \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$ $\qquad$ C.O.P. = $\frac{Q}{W} = \frac{T_2}{T_1 - T_2}$

Properties of Matter/Fluids Equation Sheet

$$Y = \frac{F/A}{\Delta l/l_0} \qquad B = \frac{\Delta p}{\Delta V/V_0} \qquad n = \frac{F/A}{d/y} \qquad \sigma = \frac{\Delta b/b_0}{\Delta l/l_0}$$

$$P = P_0 + \rho g h \qquad P + \tfrac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

$$\gamma = \frac{F}{l} = \frac{W}{\Delta A} \qquad h = \frac{2\gamma\cos\theta}{\rho g R} \qquad \Delta P = \frac{2\gamma}{R} \text{ or } \frac{4\gamma}{R}$$

$$Q = Av = \text{constant} \qquad Q = \frac{\pi R^4 \Delta P}{8\eta l} \qquad v_1^2 = \frac{2(P_1 - P_2)}{\left[\rho\left\{\left(\frac{A_1}{A_2}\right)^2 - 1\right\}\right]}$$

$$\eta = \frac{F/A}{\Delta v/\Delta y} \qquad F = 6\pi\eta R v$$

$$N_R = \frac{\rho v D}{\eta} \qquad v_t = \frac{2r^2 g(\rho_s - \rho_f)}{9\eta}$$