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**NAME:** ______________________

**STUDENT NO:** ______________________

**COURSE:** ______________________

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AUTUMN SEMESTER EXAMINATION 1995

APPLIED GEOLOGY, APPLIED CHEMISTRY, APPLIED PHYSICS

AND MATERIALS SCIENCE DEGREE

# PHYSICS 1 (F/T, P/T)

68101 and 68081

WEDNESDAY, 21 JUNE, 1995

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.

**JUNIOR 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 $= 6.37 \times 10^{6}\ m$

OVER/2

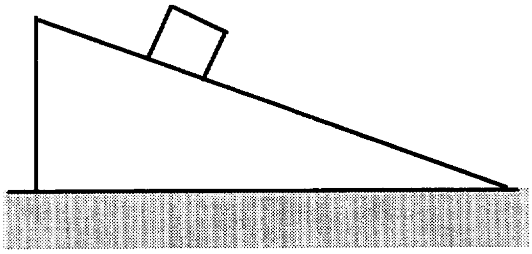
# SECTION A

## THIS IS A **COMPULSORY** QUESTION

QUESTION 1.

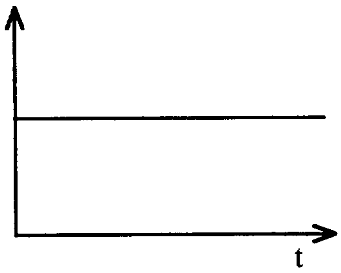
a. Put the answers to these multiple choice questions in your answer booklet. Show working where appropriate

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

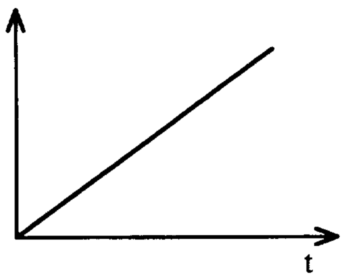


Which of the following graphs represents the variation of **velocity** with time?

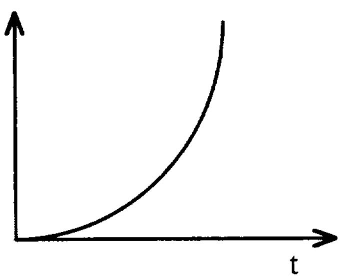
(A)



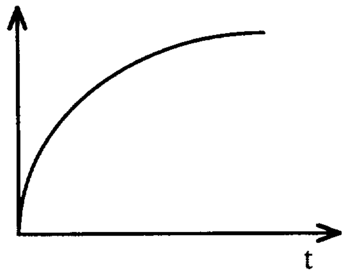

(B)




(C)




(D)



QUESTION 1 (contd.)

ii. On a boating picnic a child (whose mass is much less than the boat) dives off the back of a stationary boat. What happens to the boat?

A. it does not move

B. it moves in the same direction as the child

C. it moves in the opposite direction to the child but at the same speed

D. it moves in the opposite direction to the child but at a faster speed

E. it moves in the opposite direction to the child but at a slower speed.

iii. A 10 kg object rests on the floor of a lift. If the lift accelerates upwards at a constant rate of 2 $ms^{-2}$, what is the normal reaction between the floor and the object?

A. 10 N B. 20N C. 78 N

D. 98 N E. 118 N

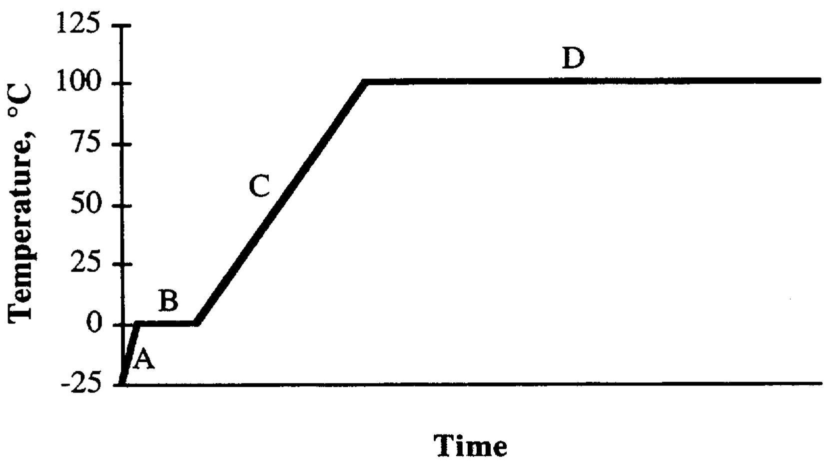
iv. A body is moving at 2.0 $ms^{-1}$ due North and changes its direction to move at 2.0 $ms^{-1}$ due East. Its change in velocity is :-

A. 2.8 $ms^{-1}$ North East B. 4.0 $ms^{-1}$ due East

C. 2.8 $ms^{-1}$ South East D. zero

E. 4.0 $ms^{-1}$ due North F. none of the above

v. A plastic jug is filled with ice at -25°C and heated at a constant rate over a bunsen. The temperature (T) versus time (t) graph is shown below




In which part of the graph is the specific heat capacity the greatest?

a. A b. B c. C d. D

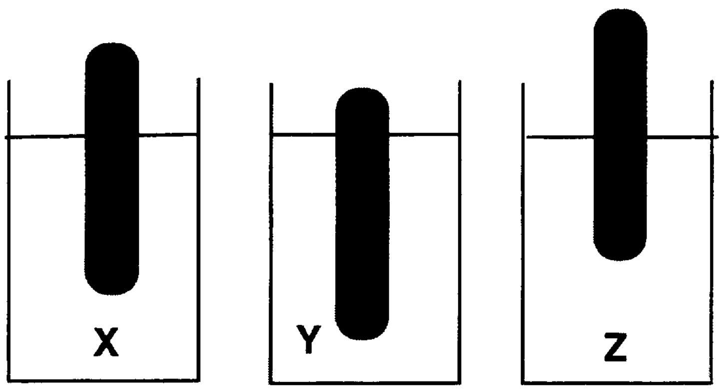
e. all parts are equal

QUESTION 1 (contd.)

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. 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

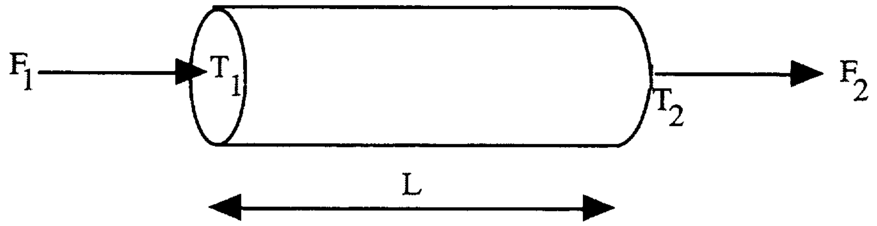
viii. The pressure surrounding a soap bubble is $P_o$. What is the pressure inside a soap bubble (surface tension $\gamma$) of diameter r?

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

10

QUESTION 1 (contd.)

b. Consider the following diagram of heat energy flowing through a cylinder




where F is the rate of heat flow per square metre in units of W $m^{-2}$, with $F_{loss}$ referring to the loss out the sides. (Subscripts 1 and 2 refer to the flow in and out respectively) The temperatures of the hot and cold ends of the cylinder are $T_1$ and $T_2$, and L is the length of the cylinder.

The equation developed to describe this heat flow in terms of the temperatures $T_1$ and $T_2$ is

$$F_1 - F_{loss} = K\frac{(T_1 - T_2)}{L}$$

where K is the coefficient of thermal conductivity of the cylinder. For a particular cylinder, $F_{loss}$ is a constant.

To test the validity of the above equation, data was collected using a cylinder of insulator of length 0.1m which is known to have a thermal conductivity between 0.3 and 0.4 $Wm^{-1}K^{-1}$. The data collected are tabulated below,

| | | | | | | |
|---|---|---|---|---|---|---|
| $F_1$ ($Wm^{-2}$) | 655 | 866 | 1100 | 1420 | 1704 | 1943 |
| $T_1$ (°C) | 120 | 165 | 235 | 360 | 460 | 558 |
| $T_2$ (°C) | 25 | 35 | 55 | 120 | 160 | 208 |

Uncertainty in $F_1 = \pm 25Wm^{-2}$  Uncertainty in $T_1$ and $T_2 = 0.1$°C

QUESTION 1 (contd.)

Answer the following questions,

i. Using the graph paper provided, draw a suitable graph based on the data given, to test if the above equation fits the observed data. Include any error bars if they are large enough to be seen on the graph.

5

ii. Estimate the slope and intercept of your graph and the uncertainty of these measurements. Give a clear indication of how you estimated these values.

3

iii. What is the thermal conductivity K determined from the graph (include uncertainties). Is the measured value for K in agreement with the expected value within the uncertainties of measurement?

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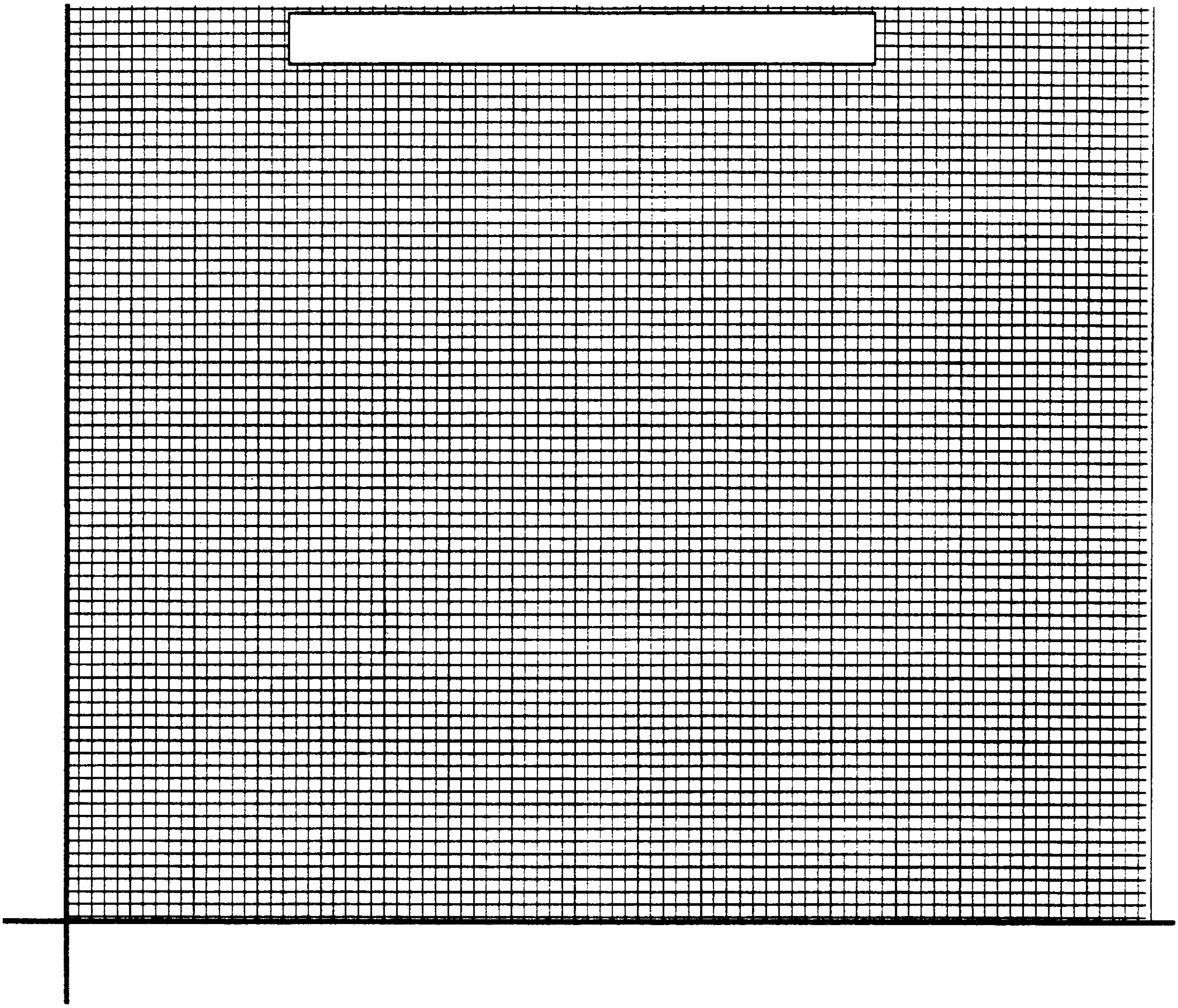
QUESTIION 1 (contd.)



# SECTION B

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

Question 2.

a. A body initially at rest rotates with a constant angular acceleration of 2 $rads^{-2}$ for 20 seconds.

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

ii. what is its angular velocity after 10 s?

4

b. We are told that the frequency, f, of the oscillation of a liquid drop depends on: the radius of the drop, r, the surface tension of the liquid $\gamma$, and the density of the liquid, $\rho$.

Use dimensional analysis to find the equation relating f to the other quantities (note the dimensions of surface tension are $[MT^{-2}]$ ).

6

c. A bicycle travels a distance of (10 ± 1) m in a time, t, of (135 ± 5) s. Writing the distance travelled, d as

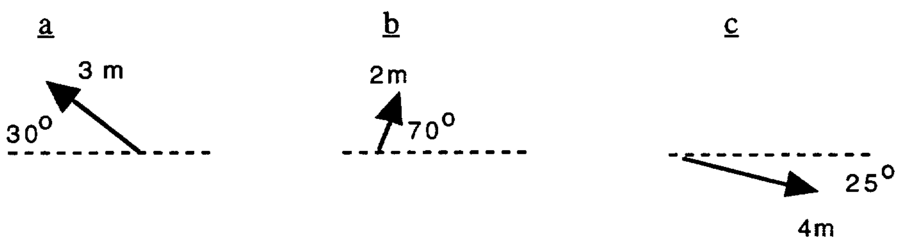
$$d = vt$$

calculate the average velocity of the bicycle, and the uncertainty in that velocity.

4

d. A body undergoes three displacements. Each displacement is represented by a vector, as shown below. Calculate the resultant displacement, R (magnitude and direction), where R is given by,

$$\underline{R} = \underline{a} + \underline{b} - 2\underline{c}$$

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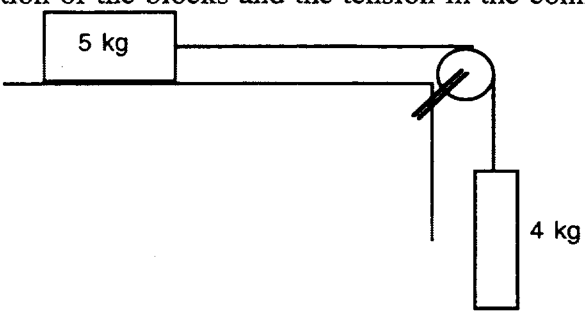
Question 3.

a i. When asked to give an example which illustrates Newton's third law a student replied
*When a book rests on a table, a gravitational force acts on the book in a downward direction and the 'equal and opposite force' required by Newtons third law is that of the normal force up on the book due to the table.*
Discuss in a few words whether or not you agree with the student.

ii. A 5 kg block is on a horizontal, frictionless surface. It is connected by a light string over a light frictionless pulley to a mass of 4 kg as shown. Find the acceleration of the blocks and the tension in the connecting cord.

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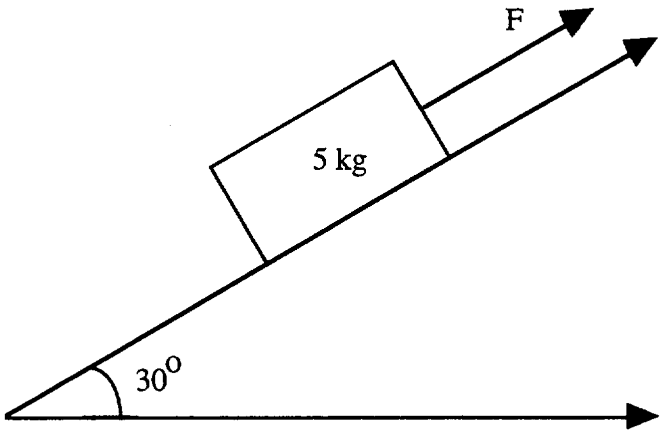
b. Consider the body below which is accelerating up an inclined plane.




If $\mu_k = 0.2$ and F = 40 N, what is the acceleration up the plane ?

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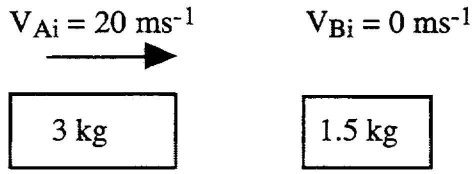
QUESTION 3 (contd.)

c.




Body A collides and sticks to body B. Calculate,

i. the initial momentum of the system

ii. the final momentum of the system

iii. the velocities of the bodies **after** collision.

4

d A force of 12 N is applied tangentially to the edge of a solid disc of radius 10 cm and mass 200 g. The disc is allowed to rotate about an axis through the centre of the disc. (Assume no frictional force.)

i. Sketch the set up

Calculate,

ii. the moment of inertia of the disc

ii. the torque exerted by the force on the disc

iii. the angular acceleration of the disc.

6

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**Question 4**

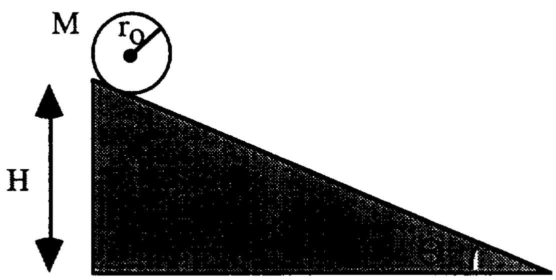
a. A simple pendulum bob of mass M is suspended by a string of length L. The bob is pulled to one side so that it is at a height L/4 above its freely hanging level. If the bob is now released from rest, calculate the speed of the bob at its lowest point.

**3**

b. A car is going up a hill with a 7 percent grade (a rise of 7 m for every 100 m along the road) at 60 km/h. There is a stop sign at the top of the hill. The driver is keen on saving both gasoline and his brakes and decides to "coast" to a stop. If friction losses are negligible, how far from the stop sign should the driver start coasting?
[NB: "coast" means to take one's foot off the accelerator. ]

**5**

c. Consider a solid sphere of mass M and radius $r_0$ that starts from rest at a vertical height H and rolls without slipping down an incline. Show that the speed of the solid sphere when it reaches the bottom of the incline is $\sqrt{\frac{10}{7}gH}$, where g is the acceleration due to gravity. Ignore losses due to retarding forces.




**6**

d. In the West Indies, Mark Waugh hits a cricket ball at a speed of 40 $ms^{-1}$ and at an angle of $20^o$ to the horizontal towards a sightscreen 80 m away. The ball hits the top of the sightscreen.

i. How long did it take the ball to reach the sightscreen?

ii. How high is the screen if the ball leaves the bat 0.4 m above the ground.

**6**

**20**

**Question 5**

a. A brass cylinder is initially at 20 °C. At what temperature will its volume be 0.300% larger than it is at 20.0 °C. $\alpha$ of brass =2.0 x $10^{-5}$ /°C.

**3**

b. In a cold climate, a carpenter builds an outer house wall with a layer of wood 2.0 cm thick on the outside and a layer of styrofoam insulation 3.0 cm thick as the inside wall surface. The exterior surface temperature is - 10°C and the temperature between the layers where the wood meets the styrofoam is 7°C.
The wood has k=0.080 W/m.K and the styrofoam has k= 0.010 W/m.K

i. What is the rate of heat flow per square metre through this wall?

ii. What is the surface temperature inside the house?

**4**

c. If 90 gram of molten lead at its melting point (327.3°C) is poured into a 300 gram casting made of iron and initially at 20°C, what is the final temperature of the system?

Specific heat capacity of iron --- 448 J/kg.°C
Specific heat capacity of lead --- 128 J/kg.°C
Heat of fusion of lead ---- 2.45 x $10^4$ J/kg
Melting point of iron --- 1535 °C

**5**

d. It has been found that a species of gas will eventually escape a planetary atmosphere entirely if its rms velocity exceeds one sixth of the planet's escape velocity.
If the temperature in the upper levels of atmosphere of Venus is 240 K, which gas is the largest constituent of the atmosphere of Venus (Hint: which gas will escape - Hydrogen or Carbon dioxide?)

molecular mass of $H_2$ ------- 3.32 x $10^{-27}$ kg
molecular mass of $CO_2$ ------- 7.3 x $10^{-26}$ kg

**4**

QUESTION 5 (contd.)

e. For the following question write down the necessary equations, but **do not solve** them.

A solar cooker consists of a curved reflecting mirror that focuses sunlight onto the object to be heated as shown in the diagram. The solar power per unit area reaching the earth at some location is 600 $W/m^2$. The diameter of the solar cooker is 0.6 m. Assume that 40 % of the incident energy is converted into heat energy, and the object contains 0.5 $m^3$ of water initially at 20 °C. Neglect the heat capacity of the container.

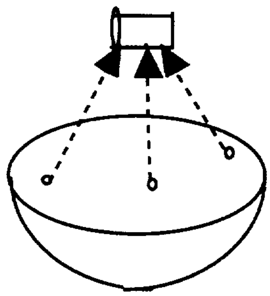
Write down an equation for :-

i. The energy reflected by the mirror

ii. The heat energy absorbed by the container

iii. The heat energy required to completely boil off the water

iv. The time taken to boil off the water



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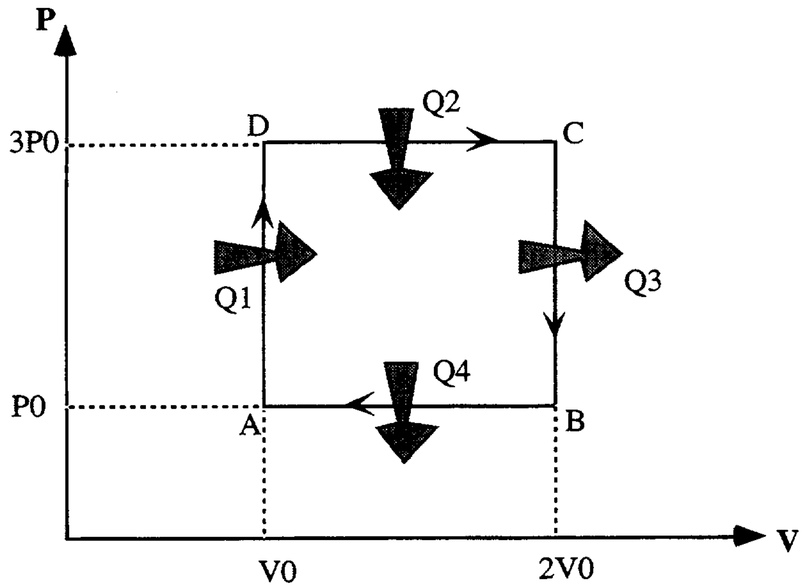
Question 6.

a. One way to cool a gas is to let it expand. Typically, a gas at 27°C and a pressure of 40 atmospheres might be expanded to atmospheric pressure and a volume of 13 times its original volume. Find the new temperature of the gas?

**3**

b. One mole of a monatomic ideal gas is taken through the reversible cycle shown in figure.




At point A, the pressure, volume and temperature are $P_0$, $V_0$, and $T_0$ , respectively. The conditions at other points are as shown in the following table.

| | A | B | C | D |
|---|---|---|---|---|
| pressure | $P_o$ | $3P_o$ | $3P_o$ | $P_o$ |
| volume | $V_o$ | $V_o$ | $2V_o$ | $2V_o$ |
| temperature | $T_o$ | ? | ? | $2T_o$ |

i. Calculate the temperatures at B and C.

ii. In terms of R and $T_0$ find the total heat entering the system per cycle

6

c. Draw a stress-strain curve for a ductile metal under tension. Indicate on the graph the ultimate strength and the fracture point.

2

QUESTION 6 (contd.)

d. A lift of mass 1200 kg is supported by a steel cable 30 mm in diameter and 90 m in length.

Determine

i. the stress in the cable when the lift is empty.

ii. the maximum amount the cable stretches.

iii. the maximum number of people (each of mass 70 kg), the stationary lift can hold if 10% of the ultimate strength is not exceeded.

For steel, Young's Modulus = $2.1 \times 10^{11}$ N $m^{-2}$

Ultimate Strength = $5.2 \times 10^{8}$ N $m^{-2}$

5

e. i. Explain briefly how a mercury barometer measures the atmospheric pressure.

ii. A mercury barometer reads 758.75 mm Hg. What is atmospheric pressure in Pascals? (density of mercury = 13600 kg $m^{-3}$)

4

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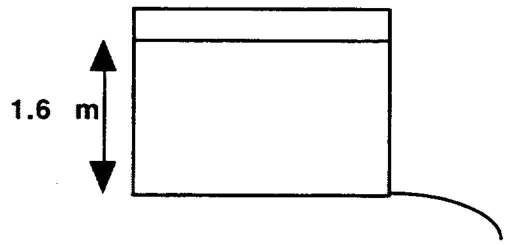
QUESTION 7.

a. If the density of ice is 920 kg $m^{-3}$ and the density of salt water is 1025 kg $m^{-3}$ what proportion of an iceberg floats <u>above</u> the water?

3

b. A hole, of radius 0.5 mm, develops near the bottom of a water tank (3.1 m in diameter). The hole is 1.6 m below the surface of the water. (density of water = 1000 kg $m^{-3}$) (See diagram)




i. What is the intial speed of the water out of the hole?

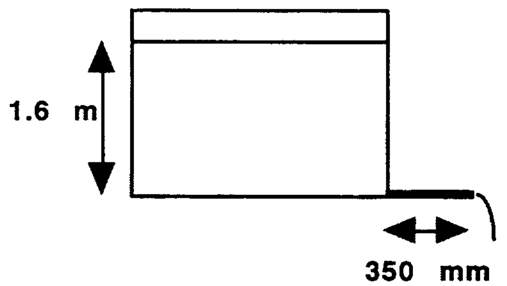
ii. What is the initial volume rate of flow out of the tank?

iii. Why does the volume rate of flow decrease as the tank empties?

iv. How long will it take the tank to empty if the average volume rate of flow out of the tank is half that calculated in part ii.

6

c. A tube, of length 350 mm and an internal radius of 0.5 mm, is connected to the hole in part b (see diagram).




i. What is the volume rate of flow through the tube if the viscosity of water is $1.21 \times 10^{-3}$ Pa.s, and the depth of water is 1.6 m.

ii. Compare with your answer in b ii. Why is it different?

4

d. The surface tension of mercury is 0.465 N $m^{-1}$ and its angle of contact with glass is $140^{o}$. A glass capillary tube of radius 3.2 mm is placed in a bowl of mercury.

i. What is the height of the mercury in the tube relative to that in the bowl?

QUESTION 7 (contd.)

ii. Show the situation in a diagram, clearly indicating the levels of the mercury inside and outside the capillary tube.
(density of mercury = 13600 kg $m^{-3}$)

4

e. Explain by words and diagrams what is meant by laminar and turbulent flow. Give examples.

3

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# Mechanics Equation Sheet

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

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

$a = \frac{v^2}{R}$ $\qquad \mathbf{\Gamma} = \mathbf{r} \times \mathbf{F}$ $\qquad \mathbf{\Gamma} = I\boldsymbol{\alpha}$

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

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

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

$P = \mathbf{F} \cdot \mathbf{v}$ $\qquad P = \Gamma\omega$ $\qquad W = \Gamma\theta$

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

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

# Dynamics Equation Sheet

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

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

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

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

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

Rotation about fixed axis:

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

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

# Thermal Equation Sheet

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

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

$R = R_0 (1 + A.T + B.T^2)$

$\Delta Q = mc\Delta T$

$\Delta Q = nC\Delta T$

$\Delta Q = mL$

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

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

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

$PV = nRT$

$PV = NkT$

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

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

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

$C_p - C_v = R$

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

$Q = W + \Delta U$

$\Delta U = nC_v\Delta T$

$W = P(V_f - V_i)$

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

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

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

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

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

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

# Properties of Matter/Fluids Equation Sheet

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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