Cover Type A

University of Technology, Sydney

THIS PAPER MAY BE REMOVED FROM THE EXAM CENTRE.

AUTUMN SEMESTER EXAMINATION 1999

FACULTY OF SCIENCE

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

68101 and 68081

FRIDAY, 18 JUNE, 1999

START 2:00 PM - FINISH 5:10 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

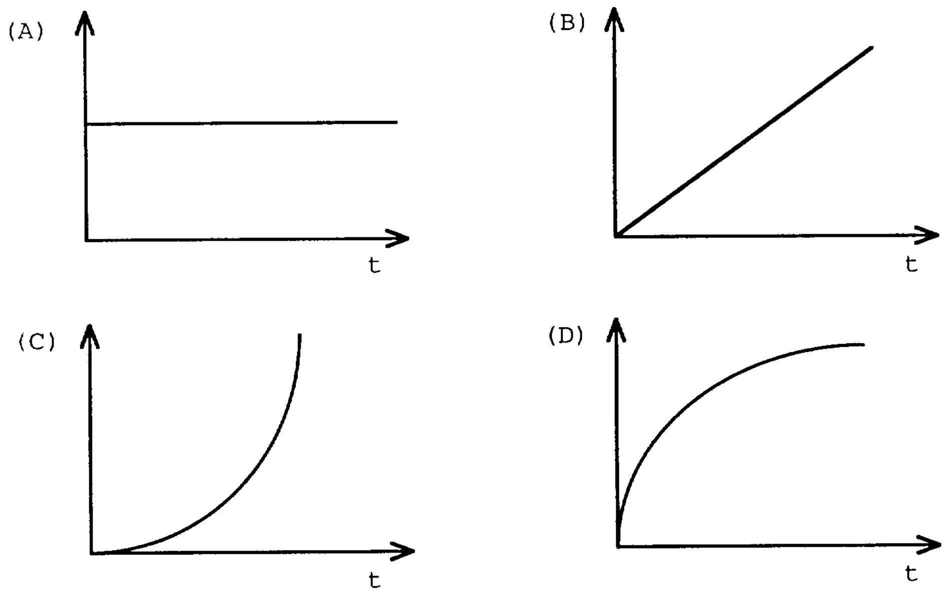
(THIS QUESTION IS COMPULSORY.)

QUESTION 1.

a. Write the answers to the following multiple choice questions in your examination booklet. Show working where appropriate.

i. An object is dropping under gravity .

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

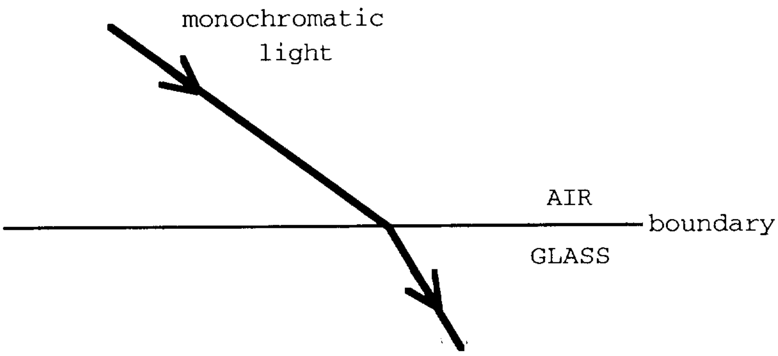


ii. On a boating picnic a child (whose mass is much less than the boat) dives off the back of a stationary boat. What happens to the boat?

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.

QUESTION 1 (contd.)

iii. The figure below shows a ray of monochromatic light passing from air into glass.



Which of the following best describes the changes that take place when the ray passes from air into glass?

A. Frequency and speed change, wavelength remains the same.
B. Wavelength and frequency change, speed remains the same.
C. Speed and wavelength change, frequency remains the same.
D. Frequency, speed and wavelength all change.
E. Only speed changes.

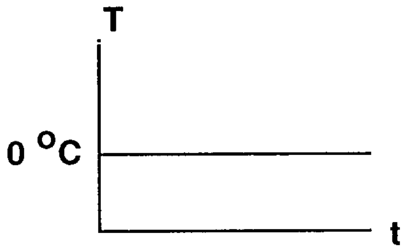
iv. The brakes of a car bring it uniformly to rest from 20 m/s in 5 seconds. The distance travelled is:

A. 4 m B. 50 m
C. 100 m D. 150 m

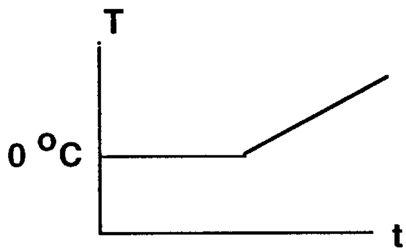
QUESTION 1 (contd.)

v. A cup contains water at 0 °C. Heat is transferred uniformly to the water. Which of the following graphs of temperature (T) against time (t) would be obtained if before the end of the time interval the water has started to boil.

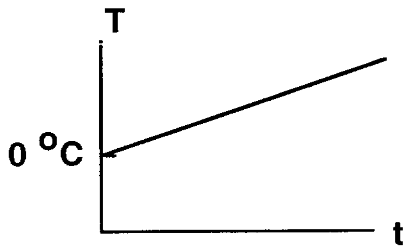
A.



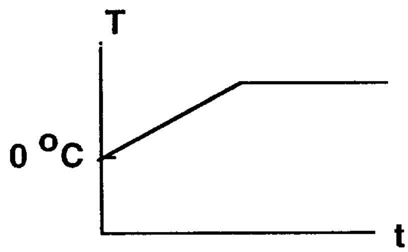
B.



C



D.



E. None of the above

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

A. 0 °C & 50 °C

B. 50 °C & 90 °C

C. -10 °C & 30 °C

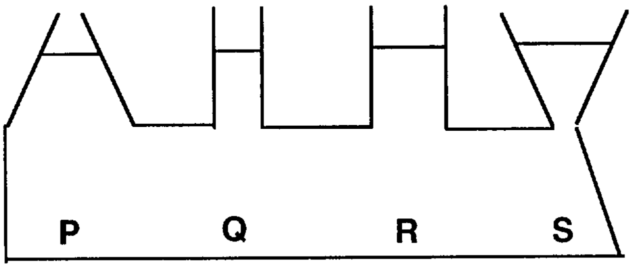
D. 30 °C & 60 °C

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

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

QUESTION 1 (contd.)

vii The pressure at the points at the bottom of the vessels will be



A. Greater at P than at Q, R and S

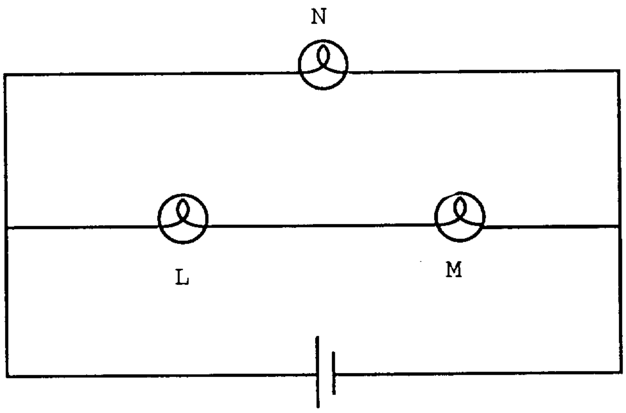
B. Greater at Q than at P, R and S

C. Greater at R than at P, Q and S

D. Greater at S than at P, Q and R

E. The same at P, Q, R and S

viii. In the circuit below there are 3 identical lamps, L, M and N powered by an ideal battery.



M is removed from its socket. What will happen to N?

A. N will go out.

B. N will become much brighter.

C. N will remain much the same.

D. N will become much dimmer.

10

QUESTION 1 (contd.)

b. In an experiment to measure the coefficient of linear expansion, α, of a metal rod of length 1.8 m and originally at a temperature of 20 °C, the following readings were obtained. By plotting a suitable graph on the graph paper provided and using the formula ($\Delta L = L_o \alpha \Delta T$), determine α.

T (°C)	ΔL (mm)
40	0.9
60	1.9
80	2.9
100	4.0
120	4.8

ii. A student is given a 5 m tape measure, a stopwatch, a 1.2 m length of string and a 50 gram mass. She is to measure the acceleration due to gravity by two different methods. Describe two methods, along with the equations you could use, to measure the acceleration due to gravity.
(Hint the following equations may be helpful:
$v = u + at$, $s = ut + 0.5\,at^2$, $v^2 = u^2 + 2\,as$, and $T = 2\pi\sqrt{\frac{l}{g}}$).
Which measurement would be the more accurate? Explain.

10

20

SECTION B

Attempt any 5 (five) questions in this Section.

QUESTION 2. **Marks**

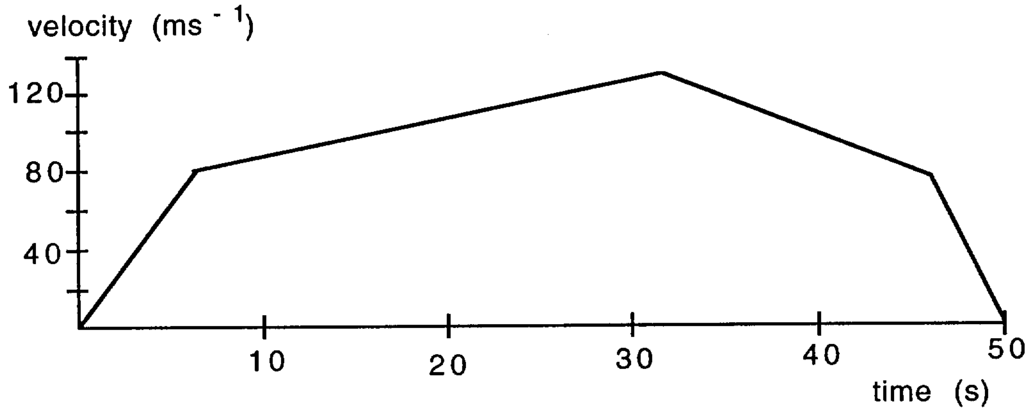
a. i. Explain, with the aid of an example, what is meant when an equation is said to be "*dimensionally consistent*".

ii. The velocity, v, of a wave along a stretched string depends upon the tension, T, in the string and the mass per unit length, μ, of the string. Use dimensional analysis to find a dimensionally consistent equation relating v to T and μ.

6

b. Consider the following graph which describes the motion of a body

Velocity - time graph for the motion of a body



Using the graph above calculate:

i. the instantaneous acceleration of the body at time = 40 s

ii. the value for the distance travelled by the body between time = 0 s and time = 20 s

iii. the average acceleration of the body between time = 20 s and time = 50 s.

5

c. A force, $\underline{F}$, applied to a body and the displacement, $\underline{s}$, of the body are represented by

$\underline{F} = -3\underline{i} + 6\underline{j}$ N and

$\underline{s} = 6\underline{i} + 8\underline{j}$ m

What is the angle between $\underline{F}$ and $\underline{s}$?

QUESTION 2 (contd.) Marks

d. A ball is thrown from the roof of a building with a velocity of 20 m/s in a direction 60° above the horizontal. If the ball begins its motion at a height of 100 m above the ground,

i. what is the ball's maximum height above the ground ?

ii. how long will it take to reach the ground?

iii. what will be its velocity just before it hits the ground?

6

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QUESTION 3. **Marks**

a. A resultant force of 30 N gives a body of mass m_1 an acceleration of 8.0 m s^{-2}, and a body of mass m_2 an acceleration of 24 m s^{-2}.
What acceleration will this force cause the two masses to acquire if they are now joined together?
4

b. Two drivers, one with a large Volvo and the other with a small Daihatsu Charade, have an argument. The Charade owner says that his car can pull as hard as the Volvo.
They chain the two rear bumpers together in an empty parking lot and each driver gets into his car and applies full power. The Volvo pulls the Charade all over the parking lot!
The driver of the Charade then claims that his car was pulling on the chain as hard as the Volvo all the time.
How does Newton's third law resolve this argument? (Assume the chain has negligible mass.)
4

c. At sea level, a nitrogen molecule in the air has an average kinetic energy of 6.2×10^{-21} J.
Its mass is 4.7×10^{-26} kg.
If the molecule could shoot straight up without striking other air molecules,
i. how high would it rise?
ii. what is the molecule's initial speed?
6

d. The uranium-238 nucleus is unstable and decays into a thorium-234 nucleus with the emission of an alpha particle. The alpha particle is emitted with a speed of 1.4×10^6 m s^{-1}.
The uranium, thorium and alpha particle masses are in the ratios of 238:234:4, respectively.
i. What is the recoil speed of the thorium-234 nucleus, given that the uranium-238 is at rest at the time of decay?
ii. Is this decay process elastic or inelastic? Explain.
6
20

QUESTION 4. **Marks**

a. i. For solids, a Physical Data Handbook gives the values for α, the coefficient of linear expansion, whereas, for liquids, it gives values for β, the coefficient of volume expansion.

α. How can you calculate β for a solid?

β. Why are values of α for liquids not listed?

ii. A piece of wire ($\alpha = 1.8 \times 10^{-5}\ K^{-1}$) is put through the 35 mm glass wall ($\alpha = 0.7 \times 10^{-5}\ K^{-1}$) of a vacuum chamber and sealed with the temperature at 20 °C. In this way current can flow into the vacuum chamber without the loss of vacuum.

When the temperature rises to 250 °C.

α. Calculate the new thickness of the glass wall

β. Calculate the new length of the 35 mm length of wire in the glass

γ. The difference in the lengths will cause problems. How can this be overcome?

6

b. Water (specific heat capacity 4190 J $kg^{-1}\ K^{-1}$) of mass 0.61 kg is in a 0.34 kg metal container (specific heat capacity = 465 J $kg^{-1}\ K^{-1}$). The container and the water are placed in a freezer and cooled from 20 °C to -8 °C. How much heat did the freezer remove if the specific heat capacity of ice is 2110 J $kg^{-1}\ K^{-1}$ and the heat of fusion for water is 3.35×10^5 J kg^{-1}?

7

c. A cubical water storage tank (0.7 m x 0.7 m x 0.7 m) stores water at a temperature of 90 °C. The insulation on each face of the cube has a thickness of 12 mm and a thermal conductivity of 1.3 (in S.I. units). Determine

i. the mass of water in the tank if the density of water is 1000 kg m^{-3}

ii. the rate of heat loss from the water (specific heat capacity 4190 J $kg^{-1}\ K^{-1}$) in the tank when the room temperature is 20 °C

iii. the amount of heat energy lost from the water in the tank when the temperature of the water drops from 90 °C to 86 °C

iv. the time taken for the water in the tank to drop from 90 °C to 86 °C if the rate of heat loss is the same as in part ii.

7

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Marks

QUESTION 5.

a. A tyre contains a constant volume of 6.9 litres of air. The pressure in the tyre is 300 kPa and the temperature is 18 °C.

i. How many molecules of air are in the tyre?

ii. If the tyre heats up to 74 °C, what is the new pressure?

5

b. A lift of mass 620 kg is supported by a steel cable (Young's modulus = 2.0×10^{11} Nm^{-2}) of diameter 38 mm. When the length of the cable is 58 m, determine

i. the extension of the cable if the lift is stationary and empty.

ii. the extension of the cable if the lift is accelerating upwards at a rate of 3.1 ms^{-2} with 18 people on board (average mass 75 kg).

5

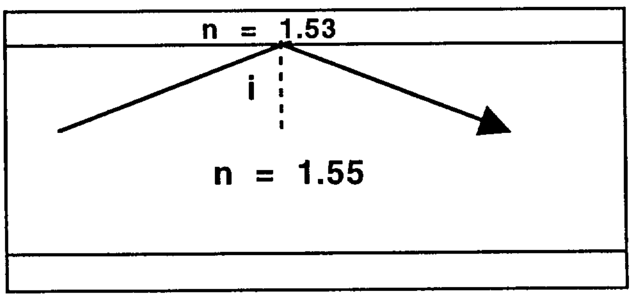
c. i. α. A ship's barometer reads 758 mm of mercury. What is the atmospheric pressure if the density of mercury is 13,550 kg m^{-3}?

β. What would be the total pressure 12m below the surface of the ocean (density of sea water = 1030 kg m^{-3})?

ii. What fraction of an iceberg (density = 900 kg m^{-3}) is below the surface of the ocean (density of sea water = 1030 kg m^{-3})?

7

d. The following diagram shows an optical fibre. Light going from the higher refractive index material (n = 1.55) to the lower refractive index material (n = 1.53) is required to be totally internally reflected. What is the minimum angle of incidence for total internal reflection to occur?



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QUESTION 6. **Marks**

a. A lecturer wants to develop a new experiment on simple harmonic motion by having students attach masses to a spring clamped in a vertical position. She has a spring which extends 25 mm when a force of 5 N is applied to it.

i. What is the force constant of the spring?

ii. If there are five 50 gram masses available, what will be the maximum extension in the experiment?

iii. What would be the period of the simple harmonic motion when the full 250 grams were attached?

iv. If the attached mass were reduced from 250 gram, would the period increase, decrease or stay the same? Explain your answer.

6

b. The equation

$$y = 0.37 \sin (1.8 x - 8.4 t)$$

represents the motion of a progressive wave where y and x are in metres and t is in seconds.

i. What is

α. its direction (positive or negative x direction),

β. its amplitude,

γ. its wavelength,

δ. its frequency, and

ε. its velocity?

ii. What is the equation of a wave which when combined with the one above will produce

α. annulment,

β. a standing wave?

8

QUSTION 6 (contd.) Marks

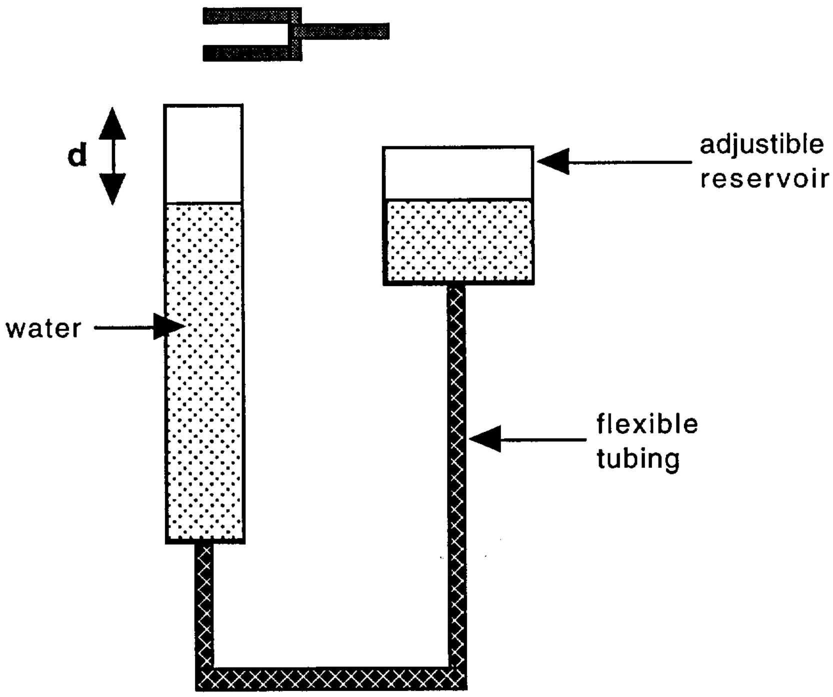
c. A class decides to measure the speed of sound in air (334 ms^{-1}), using 2 different methods.

In the first method sound is bounced off a wall and the time is measured for the echo (reflected sound) to arrive at the detector.

In the second method a resonance tube (see diagram) is used with a 512 Hz tuning fork.

i. Because of error considerations the time measurement in the first method must be at least 2.0 seconds. What must be the minimum distance to the wall so that the echo takes at least 2.0 seconds to arrive?

ii. In the second method, what would be two distances (d in the diagram) at which we would expect to hear resonance (standing waves created) in the resonance tube?



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QUESTION 7. **Marks**

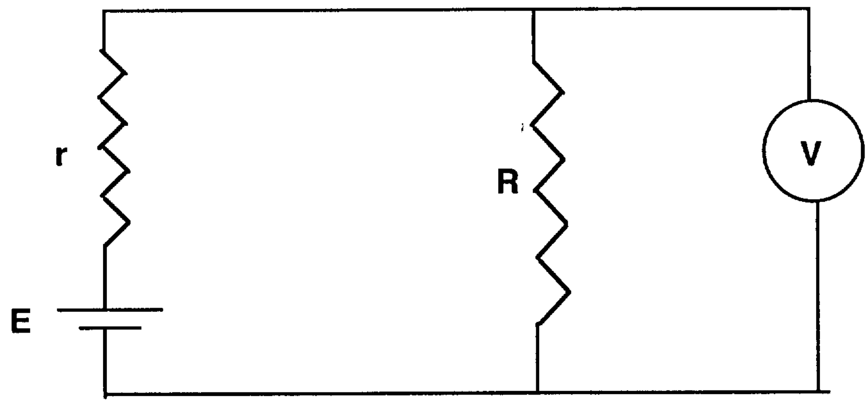
a.

i. Why does the resistance of a copper wire increase when you raise its temperature?

ii. The resistance of a copper wire is 1.25 Ω at 120 °C. If the temperature coefficient of resistance of the wire is 3.9×10^{-3} °C^{-1}, determine the resistance of the wire at 0 °C.

5

b. Consider the circuit below, in which the battery has an emf, E, and an internal resistance, r. The battery is connected to an external resistor, R.



When R is set to 50 Ω the voltmeter reads 6.88 V and when R is set to 30 Ω the voltmeter reads 6.07 V . Use this information to determine the emf and the internal resistance of the cell, assuming the voltmeter is ideal.

4

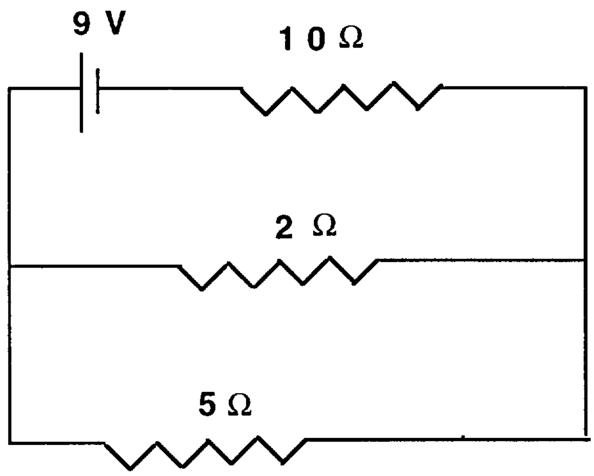
c. i. Explain what is meant by resistivity.

ii. A wire of resistance 20 Ω is stretched to 5 times its original length. Assuming the resistivity of the wire remains unchanged, calculate the resistance of the stretched wire.

6

QUSTION 7 (contd.) **Marks**

d. Determine the current through, and the voltage across, each resistor in the circuit. below.



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Mechanics Equation Sheet

$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

$F = ma$

$F = \mu N$

$F = -ks$

$W = Fs$

$W = -\frac{1}{2} ks^2$

$PE = mgh$

$P = Fv$

$KE = \frac{1}{2} mv^2$

$p = mv$

$I = Ft$

$\bar{v}_{ac} = \bar{v}_{ab} + \bar{v}_{bc}$

$s = ut + \frac{1}{2} at^2$

$v = u + at$

$v^2 = u^2 + 2as$

$c^2 = a^2 + b^2 - 2ab \cos C$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

$\theta = \omega_o t + \frac{1}{2} \alpha t^2$

$\omega = \omega_o + \alpha t$

$\omega^2 = \omega_o^2 + 2\alpha\theta$

$s = R\theta$

$v = R\omega$

$a = R\alpha$

$a_n = \frac{v^2}{R} = \omega^2 R$

$T = Fr$

$I_C = Mk^2$

Solid cylinder $I_C = \frac{1}{2} MR^2$

Hollow cylinder $I_C = \frac{1}{2} M(R^2 + r^2)$

Sphere $I_C = \frac{2}{5} MR^2$

Rod $I_C = \frac{1}{12} Ml^2$

$L = I\omega$

$\Delta L = Tt$

$W = T\theta$

$KE = \frac{1}{2} I\omega^2$

$P = T\omega$

Thermal Equation Sheet

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

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

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

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

$PV = \frac{Nm\overline{v^2}}{3}$ $\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$ $H = -qA\,(T - T_S)$

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

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

$W = \frac{P_iV_i - P_fV_f}{\gamma - 1}$ $W = nRT\ln\left(\frac{V_f}{V_i}\right)$

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

Properties of Matter/Fluids Equation Sheet

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

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

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

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

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

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

$$v = \sqrt{2gh}$$

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

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

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

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

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

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

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

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

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

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

Waves/Optics Equation Sheet

$F = -kx$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\omega^2 = \frac{k}{m}$

$U = \frac{1}{2}kx^2$

$x = A \sin(\omega t + \alpha)$

$y = A \sin(kx - \omega t + \phi)$

$y = 2A \sin kx \cos \omega t$

$c = f\lambda$

$c = \sqrt{\frac{F}{\mu}}$

$n_1 \sin i = n_2 \sin r$

$n_1 c_1 = n_2 c_2$

$d_a = \frac{d}{n}$

$P = 2\pi^2 A^2 f^2 \mu c$

$I = 2\pi^2 A^2 f^2 \rho c$

$\sin A + \sin B = 2 \sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$

$c = \sqrt{\frac{\gamma P}{\rho}}$

$\beta = 10 \log_{10}\left(\frac{I}{I_0}\right)$

$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$

$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$m = -\frac{i}{o}$

$d \sin\theta = m\lambda$

$a \sin\theta = m\lambda$

$a \sin\theta = 1.22\lambda$

$m_l = \frac{250}{f} + 1$

$\alpha = \frac{\pi a \sin\theta}{\lambda}$

$\beta = \frac{\pi d \sin\theta}{\lambda}$

$I = \frac{I_{max} \sin^2\alpha \cos^2\beta}{\alpha^2}$

$I = I_0 \cos^2\theta$

$m_\theta = \frac{f_o}{f_e}$

$R = \frac{\lambda}{\Delta\lambda} = mN$

$D = \frac{d\theta}{d\lambda}$

Electricity and Magnetism Equation Sheet

$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

$V = \frac{q}{4\pi\varepsilon_0 r}$

$E = \frac{q}{4\pi\varepsilon_o r^2}$

$U = \frac{q_1 q_2}{4\pi\varepsilon_o r}$

$E = -\frac{dV}{dx}$

$C = \frac{\varepsilon_o A}{d}$

$U_E = \frac{1}{2}CV^2$

$W = \frac{QV}{2}$

$W = VIt$

$R = \rho\frac{l}{A}$

$\oint \underset{\sim}{E}.d\underset{\sim}{A} = \frac{q}{\varepsilon_o}$

$\underset{\sim}{F} = q\underset{\sim}{v} \times \underset{\sim}{B}$

$\underset{\sim}{F} = i\underset{\sim}{l} \times \underset{\sim}{B}$

$\underset{\sim}{M} = i\underset{\sim}{A}$

$\underset{\sim}{\Gamma} = \underset{\sim}{M} \times \underset{\sim}{B}$

$\frac{F}{\ell} = \frac{\mu_o I_1 I_2}{2\pi a}$

$\oint \underset{\sim}{B}.d\underset{\sim}{l} = \mu_0 I$

$dB = \frac{\mu_0\, i\, dl \sin\theta}{4\pi r^2}$

$\phi_B = \int \underset{\sim}{B}.d\underset{\sim}{A}$

$\varepsilon = -\frac{d}{dt}(N\phi_B)$

$\varepsilon = -L\frac{di}{dt}$

$\varepsilon = -M\frac{di}{dt}$

$U_B = \frac{1}{2}Li^2$

$U_B = \frac{B^2}{2\mu_0}$

$\tau = \frac{L}{R}$

$\tau = RC$

$X_L = \omega L$

$X_C = \frac{1}{\omega C}$

$Z^2 = R^2 + (X_L - X_C)^2$

$\tan\phi = \frac{X_L - X_C}{R}$