Mansoura University Faculty of Engineering Specific programs Physics 1 (MTH011)		Final Exam 04 January 2020 Time: 2 Hours. TOTAL MARK: 50

ATTEMPT ALL QUESTIONS

Q1 (16 mark)

1-a) Write the dimensions of each of the following: (3 marks)
(i) Sin (ωt), (ii) Thermal stress, (iii) Rate of heat flow by conduction.

(b) The acceleration of a particle depends upon time t, according to the equation $a=b+ct+dt^2$. Write the dimensions of b, c, and d. (3 marks)

(c) A copper wire of length 2m is observed to stretch by 2mm when a weight of 100 N is hung from one end. (i) What is the stress in the wire? (ii) What is the diameter of the wire? (iii) What is the maximum load that could be suspended without permanently deforming the wire? (iv) Calculate the working stress if the safety factor equal 2. (v) Calculate the shear modulus?
[$E= 10^{11} N/m^2$, $\sigma_y = 2x10^8$ Pa, $\nu = 0.35$] (10 marks)

Q2 (12 mark)

2-a) Sketch: (i) The variation of the kinetic energy, potential energy, and total energy as a function of position for simple harmonic motion. (ii) The variation of under-damped, over-damped, and critical-damped displacement with time. (6 marks)

(b) A 2 kg block is attached to a spring, with spring constant k=200 N/m. The block is given an initial velocity of 10 m/s in the positive direction with no initial displacement from the equilibrium position.

i) What is the amplitude of the resulting harmonic motion?

ii) Find the equation that gives the position of the block as a function of time.

iii) Find the total energy at t=0.2T. (6 Marks)

Q3 **(10 marks)**

3(a) State the following: (i) Thermocouple thermometer, (ii) Heating curve of water, (iii) Heat transfer by conduction. (6 Marks)

(b) A long-thin wire of steel was fixed at 30 °C between two rigid points separated by a distance equals the wire length. What is the type and magnitude of the thermal stress developed in the wire if the temperature changes to the two cases; (i) 50 °C and (ii) 20 °C.
(Take, for steel, $\alpha=1.2\times10^{-5}\ ^{\circ}C^{-1}$, $E=5\times10^{11}\ N/m^2$). (4 Marks)

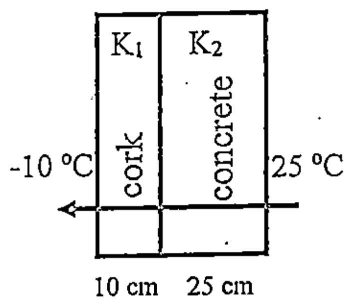
Q4 **(12 marks)**

4(a) A 50g of ice at 0 °C is added to 400g of water at 10 °C. Find the final temperature and composition of the mixture (take $c_{ice}=0.5$ cal/g°C, $c_{water}=1$ cal/g°C, $L_{f\ ice}=80$ cal/g. (4 Marks)

(b) At what rate is the energy radiated by a sphere at 1000 K and with an emissivity of 0.5 (Stefan's constant = $6\times10^{-8}\ W/m^2\,K^4$). (4 Marks)

(c) The wall of a freezing plant is composed of 10 cm of corkboard inside 25 cm of solid concrete. (a) If the temperature of the inner wall of the corkboard is -10°C and that of the outer wall is 25°C, find the temperature of the corkboard-concrete interface. (b) Calculate the heat flow in kilocalories per square meter per second. (4 Marks)

(Take, $K_1=1\times10^{-5}$ Kcal/m.s.°C, $K_2=4\times10^{-4}$ Kcal/m.s.°C).



Good luck

Examiners: Prof. Abed Nasr, Prof. Somia Elhefnawy, A.Prof. Mirvat Abo-Elkhier, Dr. Hany Alnattar

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MODEL ANSWER

Q1 **(16 mark)**

1- (a) Write the dimensions of each of the following: *(3 marks)*

(i) $[\sin(\omega t)]$ = dimensionless

(ii) Thermal stress (σ_{th}) = F/A

$[\sigma_{th}] = [F]/[A] = [m][a]/[A] = [M][L]/[T]^2[L]^2 = [M]/[T]^2[L]$

(iii) Rate of heat flow by conduction (q) = energy/time

$[q] = [M][L]^2/[T]^2[T] = \boxed{[M][L]^2/[T]^3}$

(b) The acceleration of a particle depends upon time t, according to the equation $a=b+ct+dt^2$. Write the dimensions of b, c, and d. *(3marks)*

The dimensions of each term in the equation equal the dimensions of acceleration $[L]/[T]^2$, so

$[b] = [a] = [L]/[T]^2$,

$[ct] = [L]/[T]^2$, assume the dimension of $c = [L]^x[T]^y$

$[L]/[T]^2 = [ct] = [L]^x[T]^y[T] \longrightarrow X = 1, Y = -3$

$[c] = [L][T]^{-3}$

$[dt^2] = [L]/[T]^2$, assume the dimension of $d = [L]^m[T]^n$

$[L]/[T]^2 = [dt^2] = [L]^m[T]^n[T]^2 \longrightarrow m = 1, n = -4$

$[d] = [L][T]^{-4}$

(c) A copper wire of length 2m is observed to stretch by 2mm when a weight of 100 N is hung from one end. (i) What is the stress in the wire? (ii) What is the diameter of the wire? (iii) What is the maximum load that could be suspended without permanently deforming the wire? (iv) Calculate the working stress if the safety factor equal 2. (v) Calculate the shear modulus? **[$E= 10^{11}$N/m^2, $\sigma_y = 2\times10^8$ Pa, $\nu = 0.35$]** *(10 marks)*

F = 100 N, Lo = 2 m, $\Delta L = 2\times10^{-3}$ m

$\sigma = F/A$, $\sigma = E\varepsilon$

(i) $\sigma = 10^{11} \times 2\times 10^{-3}/2 = 10^8$ N/m^2

(ii) $\sigma = F/(\pi r^2) \longrightarrow r^2 = F/\sigma\pi$

r = 5.6×10^{-4} m = 0.56 mm , d = 1.128 mm

(iii) $F_{max} = \sigma_y A = 2\times10^8 \times 10^{-6} = 2\times10^2 = 200$ N

(iv) $\sigma_w = \sigma_y / s.f. = 10^8$ N/m^2

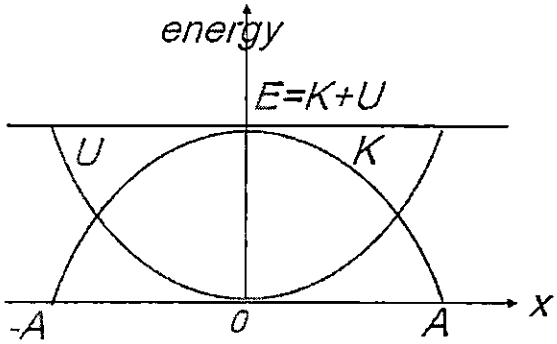
(v) $E = 2G(1+\nu) \longrightarrow G = 3.7\times10^{10}$ N/m^2

Q2 (12 mark)

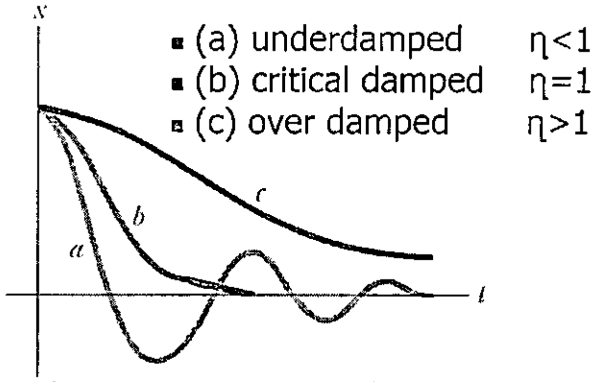
2-a) Sketch: (i) The variation of the kinetic energy, potential energy, and total energy as a function of position for simple harmonic motion. (ii) The variation of under-damped, over-damped, and critical-damped displacement with time.

(6 marks)

(i)



(ii)



(b) A 2 kg block is attached to a spring, with spring constant k=200 N/m. The block is given an initial velocity of 10 m/s in the positive direction with no initial displacement from the equilibrium position.

(i) What is the amplitude of the resulting harmonic motion?
(ii) Find the equation that gives the position of the block as a function of time.
(iii) Find the total energy at t=0.2T. *(6 Marks)*

At $t = 0, x = 0, V = 10$ m/s, So $V_{max} = 10$ m/s

$\omega = (K / m)^{1/2} = (200 / 2)^{1/2} = 10$ rad/sec

(i) $V_{max} = 10 \text{ m/s} = \omega A \Longrightarrow A = 1$ m

(ii) Assume $X(t) = A \sin(\omega t + \phi)$

$0 = \sin\phi$, $\therefore \phi = 0$

$X(t) = \sin(10t)$

(iii) Total energy in SHM doesn't depend on time, so

$E = \frac{1}{2} k A^2 = \frac{1}{2} \times 200 \times 1 = 100$ J

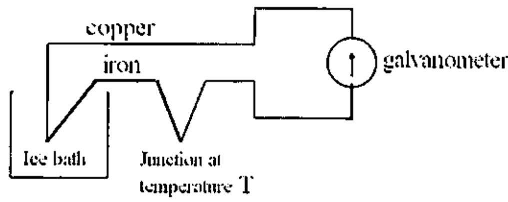
Q3 (10 mark)

3(a) Discuss each of the following: (i) Thermocouple thermometer, (ii) Heating curve of water, (iii) Heat transfer by conduction. *(6 Marks)*

(i) Different metals contain different numbers of free electrons per unit volume. The thermometer is made by joining one pair of ends (electrons can move freely from one to the other, an electromotive force is set up across the junction) and placing these where the temperature is to be determined and the other junction at a fixed reference temperature (ice bath) as shown in figure. The galvanometer deflection is proportional to the electromotive force.

Thermocouple thermometer can be used to

- measure fluctuating temperatures;
- It has a very large range, from -200C to 1500 oC depending upon the metals used for the thermocouple;
- It can measure the temperature at a point.



(ii) Heating curve of water

- A heating curve graphically represents the phase transitions that a substance undergoes as heat is added to it.
- The Arrows on the curve mark the phase changes. The temperature remains constant during these phase transitions.
- Water has a high boiling point because of the strong hydrogen bonds between the water molecules; it is both a strong hydrogen bond donor and acceptor.
- The first change of phase is melting, during which the temperature stays the same while water melts. The second change of phase is boiling, as the temperature stays the same during the transition to gas.

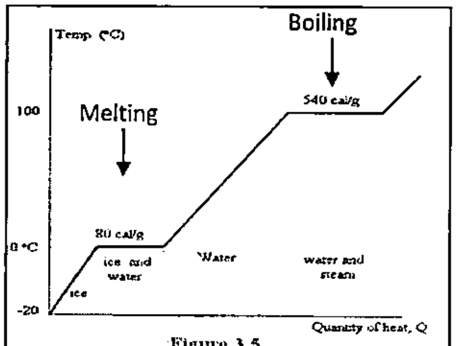
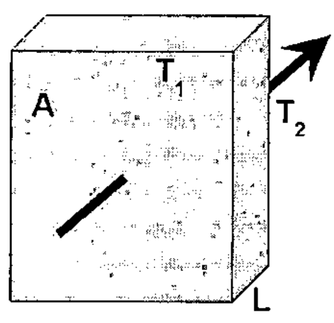


Figure 3.5

- (iii) Heat transfer by conduction: The process in which heat energy is transferred by adjacent molecular collisions throughout a material medium. The medium itself does not move.



- $H = \frac{Q}{t} = KA\frac{\Delta T}{L}$
- Where H represents the quantity of heat transferred per unit time,
- K is the thermal conductivity = QL/At ΔT

(b) A long-thin wire of steel was fixed at 30 °C between two rigid points separated by a distance equals the wire length. What is the type and magnitude of the thermal stress developed in the wire if the temperature changes to the two cases; (i) 50 °C and (ii) 20 °C.

(For steel, $\alpha=1.2\times10^{-5}\ {}^{o}C^{-1}$, $E=5\times10^{11}\ N/m^2$). ***(4 Marks)***

(i) There is no stress at 50 °C, $\sigma = 0$ because the length of the wire will increase and sag.

(ii) At 20 °C, $\sigma = E\,\alpha\,\Delta t = 5 \times 10^{11} \times 1.2 \times 10^{-5} \times 10$
$= 60 \times 10^{6}$ Pa = 60 MPa Tensile stress

Q4 (12 mark)

4(a) A 50g of ice at 0 °C is added to 400g of water at 10 °C. Find the final temperature and composition of the mixture (take c_{ice} =0.5 cal/g°C, c_{water} = 1 cal/g°C, $L_{f\ ice}$ = 80 cal/g.
(4 Marks)

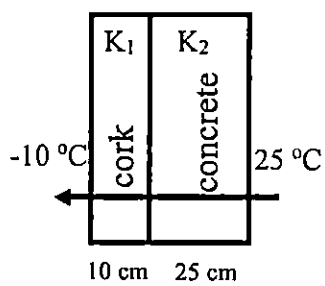
The heat required to melt the ice completely (Q_{ice})=$m_{ice}\,L_f$ = 50 x 80 = 4000 cal
The quantity of heat lost by water if its temp. changes from 10 °C to 0 °C
(Q_w) = $m_w\,C_w\,\Delta t$ = 400 x 1 x 10 = 4000 cal, So, $Q_{ice} = Q_w$
∴ The final temperature is 0 °C and the composition is water only.

(b) At what rate is the energy radiated by a sphere at 1000 K and with an emissivity of 0.5 (Stefan's constant = 6x 10^{-8} W/m^2 K^4).
(4 Marks)

The rate of energy radiated $q = \sigma\,A\,\varepsilon\,T^4$
The rate of energy radiated per unit area $q / A = \sigma\,\varepsilon\,T^4 = 6 \times 10^{-8} \times 0.5 \times 1000^4$
$= 3 \times 10^{4}$ W /m^2

(c) The wall of a freezing plant is composed of 10 cm of corkboard inside 25 cm of solid concrete. (i) If the temperature of the inner wall of the corkboard is -10°C and that of the outer wall is 25°C, find the temperature of the corkboard-concrete interface. (ii) Calculate the heat flow in kilocalories per square meter per second.
(4 Marks)

(Take, K_1=1x10^{-5} Kcal/m.s.°C, K_2=4x10^{-4} Kcal/m.s.°C).



(i) Assume that the temperature of the corkboard-concrete interface is T

$q_1 = (T + 10) / R_{th1}$, $q_2 = (25 - T) / R_{th1}$
$R_{th1} = 10 \times 10^{-2} / A\,(10^{-5})$, $R_{th2} = 25 \times 10^{-2} / A\,(40\times10^{-5})$
$q_1 = q_2$, $(T + 10) / R_{th1} = (25 - T) / R_{th1}$
$T + 10 = 16\,(25 - T)$ ⟹ $T = 22.94$ °C

(ii) $q/A = (25 + 10) / (10.625 \times 10^{3}) = 3.294 \times 10^{-3}$ kcal/m^2.s
$= 3.294$ cal/m^2.s