King Saud University
College of Engineering
Mechanical Engineering Department
Midterm Examination - 2nd Semester (1428/1429)

Subject: Mechanical Measurements **ME 302**

Question (1) **[6+4+5]**

The force F (Newton) is an input signal to a force measuring system and its output is voltage E (volt). The input output relation can be represented by the relation.

$$E^2 = C\,F^n$$

The results of an experiment are

Output E volt	2	3	4	5
Input F Newton	12.5	37	80	145

- Draw a straight line using the relation between E and F and above data.
- Use the graph to find the value of C and the value of n
- Find the static sensitivity of this measuring system at F= 50 N

Question (2) **[1+8+2+2+2]**

a) What is Nyquist frequency?

b) The signal E = 12 sin (10π t) volt is to be sampled at f_s=6.67 Hz
- Draw the signal.
- Sample the signal at sampling frequency.
- Show the apparent signal.
- Write your comments.

c) Given the voltage signal E = 5 sin (300π t)+ 2 sin (1500π t)
- Find the proper sampling frequency.
- Find the number of points required.
- Draw the frequency spectrum for this voltage signal.

Question (3) **[10]**

A thermometer having a time constant of 10 seconds is subjected to a harmonic input given as

$$T = 20\sin\left[\frac{\pi * t}{8}\right]$$

Find the temperature after 20 seconds and the error at that time.

Question(4) [4+2+2+2]

1. Explain the following statements in detail.
"A wide range of sensors are based on change in the resistance of a sensing element. Also variations in inductance and capacitance are used frequently in sensor stage."

2. Give specific example for a sensor based on:
   a. Change in resistance.
   b. Change in inductance.
   c. Change in capacitance.

Question (5) [18+7]

(a) Three machines A, B and C have to be operated together at a place where atmospheric pressure and temperature are 101 and 27^0C respectively. Machines A and B are similar where as Machine C is different to these two machines. The sound pressure levels of these machines and environment as measured at a distance of 10m is as under.
SPL of Machine A and Machine B = 85 dB each.
SPL of Machine C = 90 dB
SPL of environment = 75 dB
Find the resulting sound pressure level (SPL) when these machines are in operation simultaneously.

(b) What will be sound power level (WPL), for part (a), at a distance of 5 m? The values of R and k are 287 J/kg-K and 1.4 respectively.

Mid Term II semester 1428/1429

QI

$$E^2 = CF^n$$

E Volt	F Newtn	log E	log F
2	12.5	0.3010	1.0969
3	37	0.4771	1.5682
4	80	0.6020	1.9031
5	145	0.6990	2.1614

(a) $E^2 = cF^n$

$$2\log E = \log c + n\log F$$

$$\log E = \frac{\log c}{2} + \frac{n}{2}\log F$$

Plot log E vs log F

(b) Intercept $= \log\frac{c}{2}$ slope $= \frac{n}{2}$

$$\frac{\log c}{2} = -0.035 \qquad \frac{n}{2} = \frac{5.3}{8}$$

$$C = \text{antilog}(-0.07) \qquad n = 1.325$$

$$C = 0.851 \qquad n = 1.325$$

$$\boxed{E^2 = 0.851\,F^{1.325}}$$

(c)

$$E^2 = CF^n$$

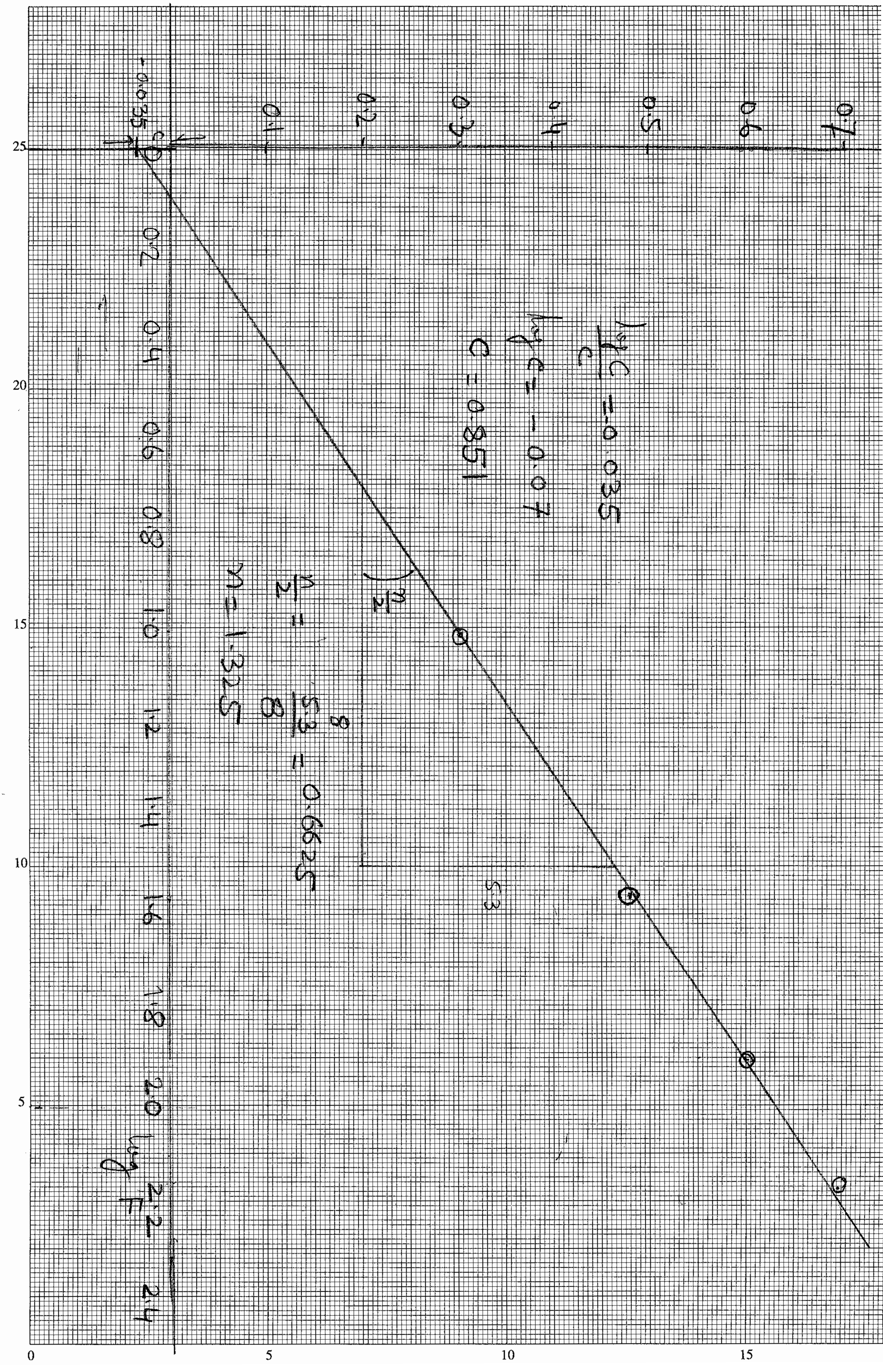
$$2E\,dE = Cn\,F^{n-1}\,dF$$

$$\frac{dE}{dF} = \frac{cnF^{n-1}}{2E}$$

$$K = \frac{dE}{dF} = \frac{cnF^{n-1}}{2cF^n} = \frac{n}{2F}$$

$$K \text{ at } F = 50N = \frac{1.325}{2\times 50} = \frac{1.325}{100}$$

$$\boxed{K = 0.01325}$$



25
20
15
10
5
0
5
10
15
0.1
0.2
0.3
0.4
0.5
0.6
0.7
n = 1.325
n/2 = 8/5.3 = 0.6625
C = 0.851

Q2

(a) Nyquist frequency = It is highest frequency that can be sampled by a given sampling frequency and is half of the value of sampling frequency

$E = A \sin\left(\frac{2\pi t}{T}\right)$

$E = 12 \sin(10\pi t)$

$\frac{2}{T} = 10$ $T = 0.2$ sec. $f = 5$ Hz

$A = 12$ units

t	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95	1.0	1.05
E	12	+0.02	-12	-0.04	12	0.06	-12	-0.08	12	0.10	-12	-0.31	12	0.14	-12	-0.15	12	0.17	-12.0	[illegible]	12

$f_s = 6.67$ Hz

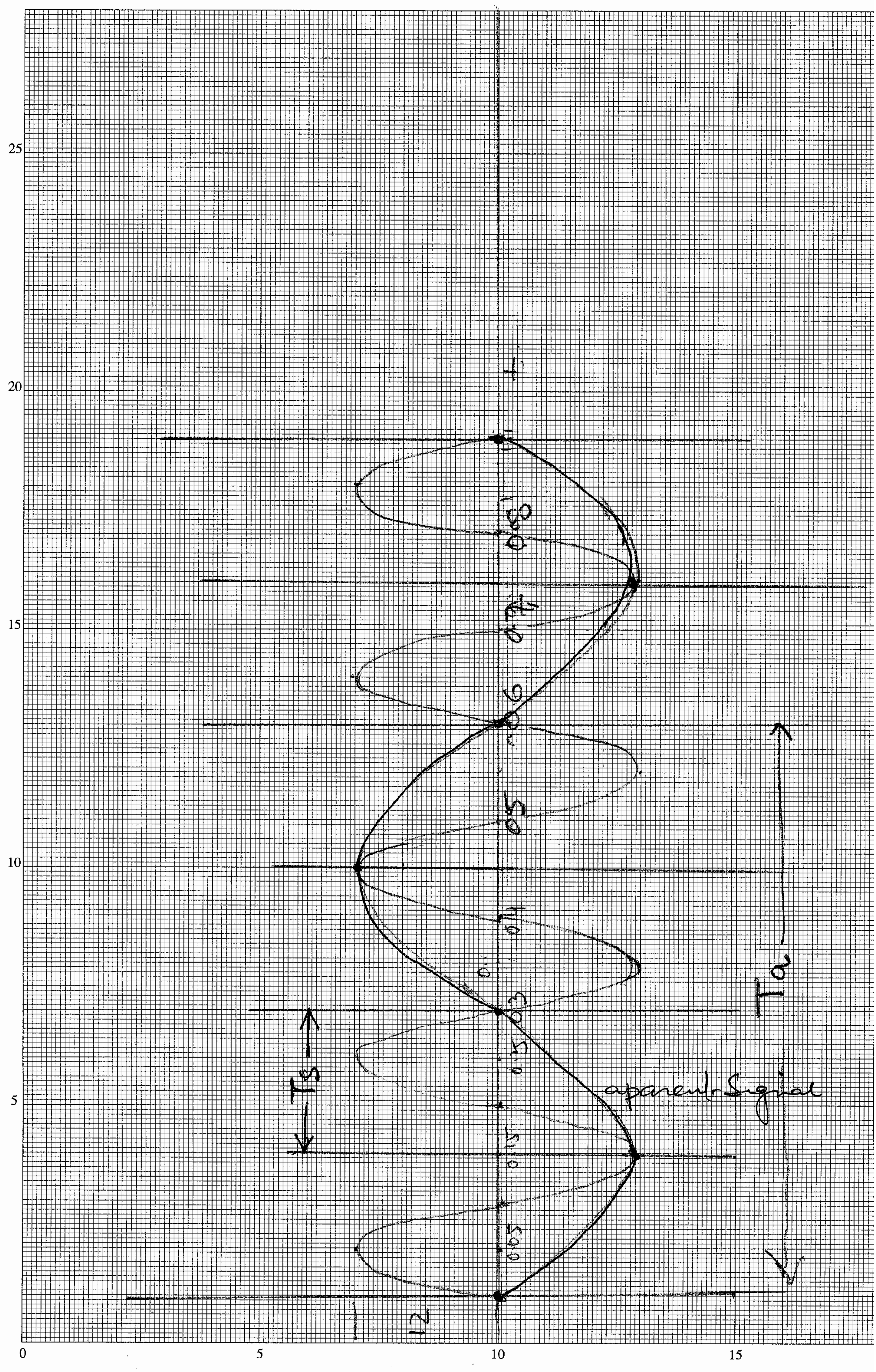
$T_s = \frac{1}{6.67} = 0.15$ sec

$T_a = 0.6$ sec

$f_s = \frac{1}{T_a} = 1.67$ Hz

$f_a = f_s - f = 6.67 - 5 = 1.67$ sec

Since $f_s < 2f$ ∴ aliasing is caused apparent wave quite different from given wave



aparent Signal
Ts
Ta
0
5
10
15
20
25

(b)

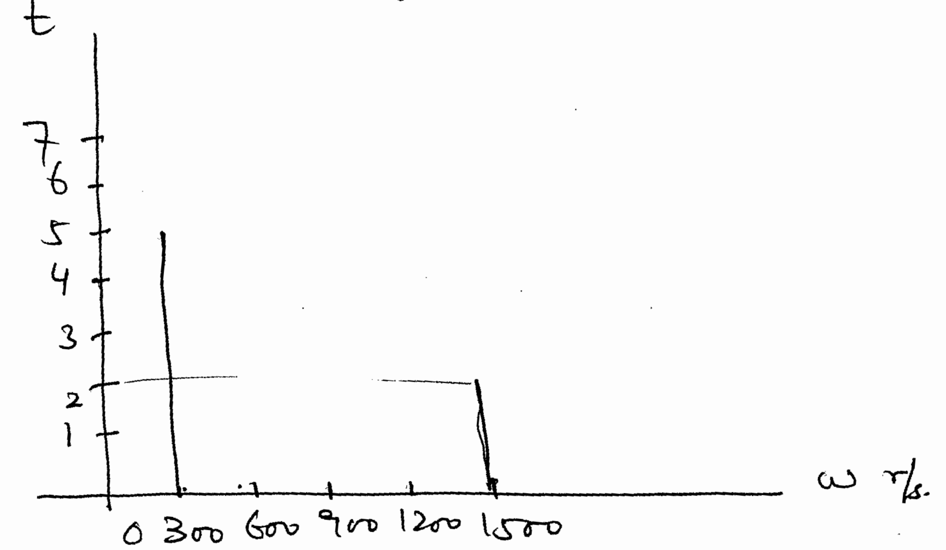
$E = 5\sin(300\pi t) + 2\sin(1500\pi t)$

$f_l = \frac{300}{2} = 150\ Hz \quad f_h = \frac{1500}{2} = 750\ Hz$

$f_s \geq 2 \times f_h = 2 \times 750 = 1500\ Hz$

let $f_s = 1600\ Hz \quad \Delta f = f_l$

$N = \frac{f_s}{\Delta f} = \frac{1600}{150} = 11$ points



Q(3)

$T = 20 \sin\left[\frac{\pi \times t}{8}\right] \qquad T = T_s \sin\left(\frac{2\pi t}{T}\right)$

$T_s = 20^\circ C \qquad \frac{2}{T} = \frac{1}{8} \quad T = 16\ sec$

$T = 16\ sec$

$f = 0.0625\ Hz \qquad \omega = 0.3925\ r/s$

$t = 20\ sec$

$T_i = 20 \sin\left[\frac{\pi \times 20}{8}\right] \quad \boxed{T_i = 20^\circ}$

$\frac{T_d}{T_s} = \frac{1}{\sqrt{1+(\omega\tau)^2}} = 0.247 \qquad \tau = 10\ sec$

$T_d = 4.938. \qquad \phi = \tan^{-1}(\omega\tau)$

$1.571\ r/s$

$\therefore T_o = 4.938 \sin\left(\frac{\pi t}{8} - 1.571\right)$

$t = 20$

$T_o = -0.02^\circ C \qquad \boxed{\Delta T = 20.02^\circ C}$

(Q4) Many sensors consist of sensing elements which are resistances, inductances and capacitances. When the value of input is changes their magnitude gets altered which can be measured as a measure of input. Examples are

Change in resistance → Strain guage.

change in Inductance → L.V.D.T.

change in capacitance → A diaphargm with capacitance as element of Secondary transducer.

(5)

(a)

SPL of A = 85 dB

SPL of B = 85 dB

SPL of C = 90 dB

SPL of E_n = 75 dB

$$SPL = 20 \log \frac{P}{P_0}$$

$$\log \frac{P}{P_0} = \frac{SPL}{20}$$

$$\Sigma \log \frac{P}{P_0} =$$

$$SPL \text{ of Combinat.} = 20 \log \left[\Sigma \text{anti} \frac{SPL}{20} \right]$$

$$SPL_{comb} = 20 \log \left[\text{antilog} \frac{85}{20} + \text{antilog} \frac{85}{20} + \text{antilog} \frac{90}{20} + \text{antilog} \frac{75}{20} \right]$$

$$\boxed{SPL_{comb} = 97.25 \text{ dB}}$$

$$SPL = 20 \log\left(\frac{P}{P_0}\right) = 97.25$$

$$\log \frac{P}{P_0} = \frac{97.25}{20}$$

$$\frac{P}{P_0} = \text{al.} \frac{97.25}{20}$$

$$P = \text{antilog} \frac{97.25}{20} \times P_0$$

$$P = \text{antilog} \frac{97.25}{20} \times 20 \times 10^{-6} = 1.456 \text{ Pa}$$

$$P_{rms} = \frac{P}{\sqrt{2}} = 1.0297 \text{ Pa}$$

$$P_{rms}^2 = 1.0603 \text{ Pa}$$

$$I = \frac{W}{A} = \frac{P_{rms}^2}{\rho C}$$

$$A = 4\pi r^2 = \pi \times 10^2 \quad 4 \times 314 \text{ m}^2$$

$$\rho = \frac{P}{RT} = \frac{101}{0.287 \times 300} \qquad P = 101 \text{ kPa}, \quad T = 27°C = 300 \text{ K}$$

$$\rho = 1.174 \text{ kg/m}^3$$

$$C = \sqrt{kRT} = \sqrt{1.4 \times 287 \times 300} = 347.19$$

$$W = \frac{P_{rms}^2 \times A}{\rho C} = ~~0.817~~ \; 3.268 \text{ W}$$

$$WPL = 10 \log\left(\frac{W}{W_{ref}}\right) = 10 \log\left[\frac{0.817}{10^{-12}}\right]$$

WPL = 1[illegible] dB

WPL is same as 5 m as at 10 m