MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Mechanical Engineering

Test-6 : Section A : Renewable Sources of Energy + Industrial & Maintenance Engg.

Section B : Production Engineering & Material Science-1 + Theory of Machines-2

Name : .....

Roll No :

Test Centres	Student's Signature
Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	38
Q.2	—
Q.3	42
Q.4	42
Section-B	
Q.5	43
Q.6	31
Q.7	—
Q.8	—
Total Marks Obtained	196

Signature of Evaluator ..... Cross Checked by .....

Keep up this consistent effort

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

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Section A : Renewable Sources of Energy + Industrial and Maintenance Engg.

Q.1 (a) A PV system feed a dc motor to produce 2 hp power at the shaft. The motor efficiency is 90%. Each module has 36 multicrystalline silicon solar cells arranged in 9 × 4 matrix. The cell size is 135 × 135 mm and the cell efficiency is 14%. Calculate the number of modulus required in the PC array. Assume global radiation incident normally to the panel as 1 kW/m^2.

[12 marks]

Given data

Power developed by solar plane (P)

$P = \text{[illegible]} \times 0.\text{[illegible]}8225 \times 0.14 \times 9 \times 4 \times$ no of modules (N)

$P_{solar} = \text{[illegible]} \times N$ → (1)

0.091854

746 watt

$P_{required\ to\ feed\ D.C\ Motor} = \dfrac{2 \times 0.736}{0.9} = 1.635\,55$ → (2)

$N = 17.8054 \simeq 18$ Modules required

10

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Q.1 (b) Calculate the volume of a cooking based biogas plant required for cooking needs of a family of five adults and lighting needs with three 100 CP lamps for five hour daily. Also calculate the required number of cows to feed the plant. Use the data provided if required

- Biogas required for cooking - 0.227 m^3/person/day
- Biogas required for lighting 100 CP (candle power) mantle lamp - 0.126 m^3/hr
- Dung produced - 10 kg/cow/day
- % of dung that can be collected - 70%
- Solid content in cow dung - About 18%
- Gas yield (m^3 per kg dry matter) - 0.34 m^3/kg dry matter
- Density of slurry - 1090 kg/m^3
- Required retention time - 50 days
- Volume of digester - 90% of slurry and 10% empty space for gas formed

[12 marks]

Sol) Given data

5-person

5 hour → 100CP lene [3 CP]

the required Biogas

Biogas total = (5×0.227) + (5×0.126×3)

= 3.025 m^3/day → (1)

6

→ Biogas extracted to be = 10×0.7×0.18×0.34×N

= 0.4284N → (2)

from (1) and (2)

no. of cows required = $\frac{3.025}{0.4284}$ = 7 cows

→ mass of slurry = mass of kleter/cow + mass of cow dung/day

[Assuming both are taking equal proportion]

= 49 + 49

= 98 kg

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$$\text{Volume of slurry} = \frac{\text{mass of slurry}}{\rho}$$

$$= \frac{98}{1090}$$

$$= 0.08990\ m^3$$

$$\text{Retention period} = 50 = \frac{\text{Volume of slurry in digester}}{\text{Volume of slurry added per day}}$$

$$50 = \frac{0.9\,V_{dis}}{0.08990}$$

Volume of digester required $= 4.9949\ m^3$

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Q.1 (c) (i) Why do we need inventory? Also, explain why the order quantity should be optimized.

(ii) A particular item has a demand of 10,000 units/yr. The cost of one procurement is Rs.100 and the holding cost per unit is Rs.2.5 per year. The replacement is instantaneous and no shortages are allowed. Determine:

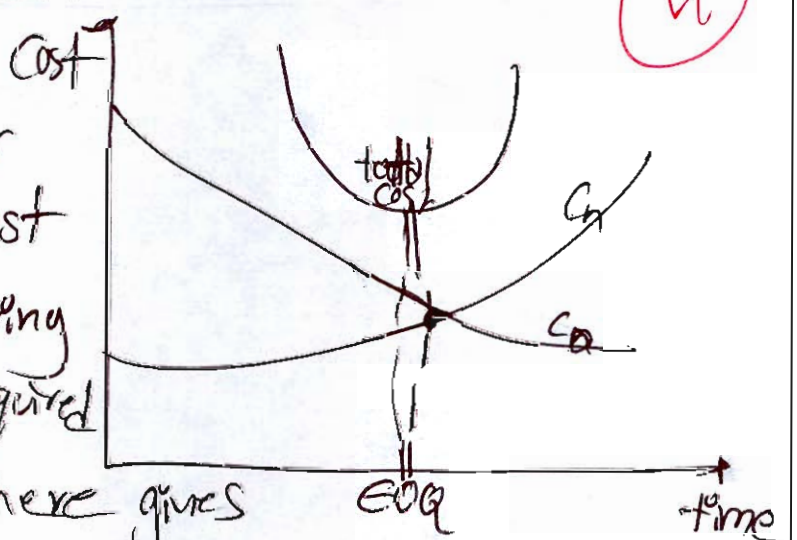
1. The economic lot size
2. The number of orders per year and time between orders.
3. The total cost per year if the cost of one unit is Rs.1

[6 + 6 = 12 marks]

i) Inventory is a raw materials, semi-processed goods or finished products. Inventory are required to make consumer goods and to meet supply and demand.

→ the order quntity to be optimized to reduce to the total cost of production and associated cost of order

4



→ optimied order quentity gives cost required for ordering equel to cost required carring goods, where gives the quantities is known as economic order quentity. where total cost is Minimum

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ii) $D = 10,000$

$C_o = ₹100$

$C_h = ₹2.5$

1) $EOQ = \sqrt{\frac{2DC_o}{C_h}}$

$Q^* = \sqrt{\frac{2 \times 10000 \times 100}{2.5}}$

$Q^* = 894.427 \simeq 894$ units

2) N = number of order per year

$N = \frac{Q^* D}{Q^*} = \frac{10,000}{894.427} = \boxed{11.180}$ orders

time between order (cycle time)

Assume working days 365

$T = \frac{365}{11.18} = \boxed{32.6475}$ days

3) Total cost (T.C) = purchasing cost + ordering cost + carrying

$= 10000 + \sqrt{2DC_oC_h}$

$= 10,000 + \sqrt{2 \times 10000 \times 100 \times 2.5}$

$T.C = \boxed{₹ 12236.067}$

6

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Q.1 (d) Estimate the monthly average of the daily global solar radiation on a horizontal surface at Agra (27°10′ N, 78°05′E) during the month of February. If the average sunshine duration is 8 hour per day.

Use the following correlation:

$$\frac{\overline{H}_g}{\overline{H}_0} = a + b\left(\frac{\overline{n}}{\overline{N}}\right)$$

where, a = 0.25 and b = 0.57 and $\overline{H}_g$ = monthly average, daily total radiation on a horizontal surface at a location; $\overline{H}_0$ = monthly average, daily extra-terrestrial radiation that would fall at the location on a horizontal surface; $\overline{n}$ = monthly average, daily hours of bright sunshine obtained from actual records at the location; $\overline{N}$ = monthly average of maximum possible daily hours of sunshine.

For the month of February, use the 16th day of the month as the day for which H_0 is equal to $\overline{H}_0$.

[12 marks]

Given data

$\phi = 27.166°$

$n = 47$

$\delta = 23.45 \left[\sin \frac{360}{365}(284+n)\right]$

$\delta = -12.9546$

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Sun-shine hour angle = $\omega_s = \cos^{-1}(-\tan\phi \tan\delta)$

$= \cos^{-1}(-\tan 27.166^\circ \tan(-12.954^\circ))$

$\omega_s = 83.2204^\circ$ or 1.452477 radian

$\bar{N} = \frac{2\omega_s}{15} = 11.096$ hr

$\bar{H}_0 = \frac{3600 \times 24}{\pi} \times 1.367 \left[1 + 0.033 \cos\frac{360n}{365}\right] \left[\cos\phi \cos\delta \sin\omega_s + \sin\phi \sin\delta \omega_s\right]$

$= 37595.198 \left[1.02277\right] \left[0.86098 + (-0.143677)\right]$

$\bar{H}_0 = 27388.945$ KJ/m²-day

$\therefore \bar{H}_g = \bar{H}_0 \left(a + b\left(\frac{\bar{n}}{\bar{N}}\right)\right)$

$= 27388.945 \left[0.25 + 0.57\left(\frac{8}{11.096}\right)\right]$

$\bar{H}_g = 18102.970$ KJ/m²-day

12

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Q.1 (e) What is the basic purpose of Production Planning and Control? Also, briefly mention its various functions.

[12 marks]

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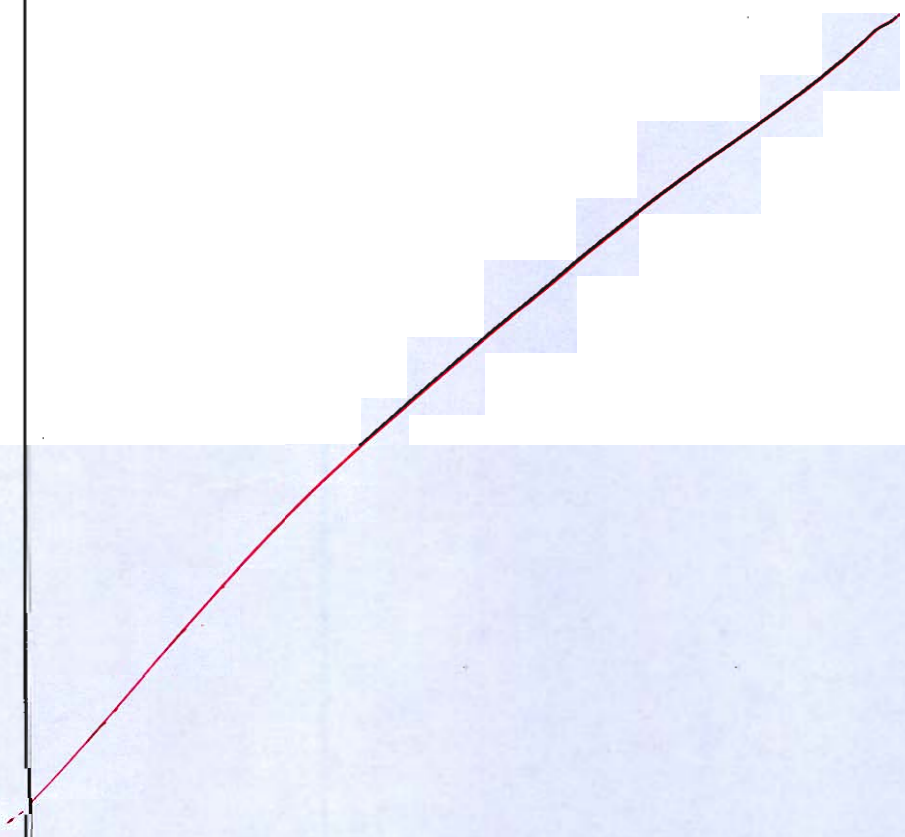

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Q.2 (a) **(i)** With the help of a neat sketch, explain the working of a Vertical Axis Wind Turbine (VAWT). Describe the function of its main components. Also, discuss the key advantages of VAWTs.

(ii) A propeller type wind turbine has following data

Speed of free wind at a height of 10 m = 15 m/s ; Air density = 1.23 kg/m^3;
α = 0.15; Height of tower = 120 m; Diameter of rotor = 85 m;

Wind velocity at the turbine reduces by 25%; Generator efficiency = 90%

Find :

(i) Total power available in wind.
(ii) Power extracted by the turbine.
(iii) Electrical power generated.
(iv) Axial thrust on the turbine.
(v) Maximum axial thrust on the turbine.

[10 + 10 = 20 marks]

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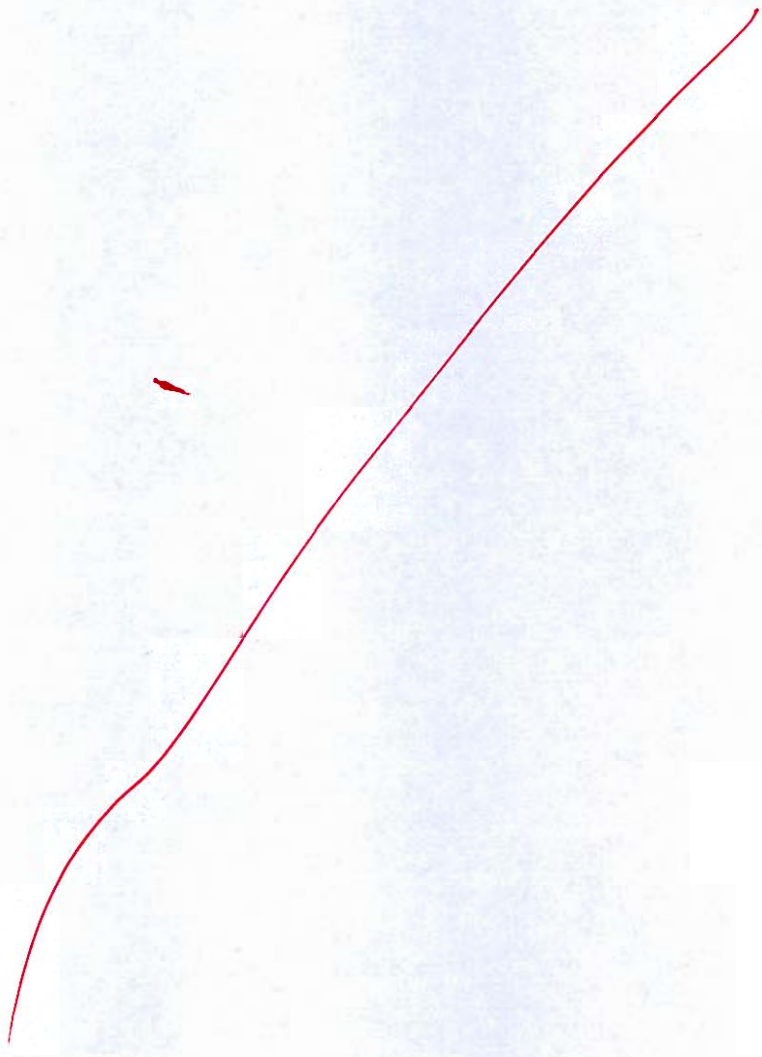

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Q.2 (b) What are the differences between destructive and non-destructive tests? Explain with examples. Also, briefly explain various non-destructive testing methods used in engineering practice.

[20 marks]

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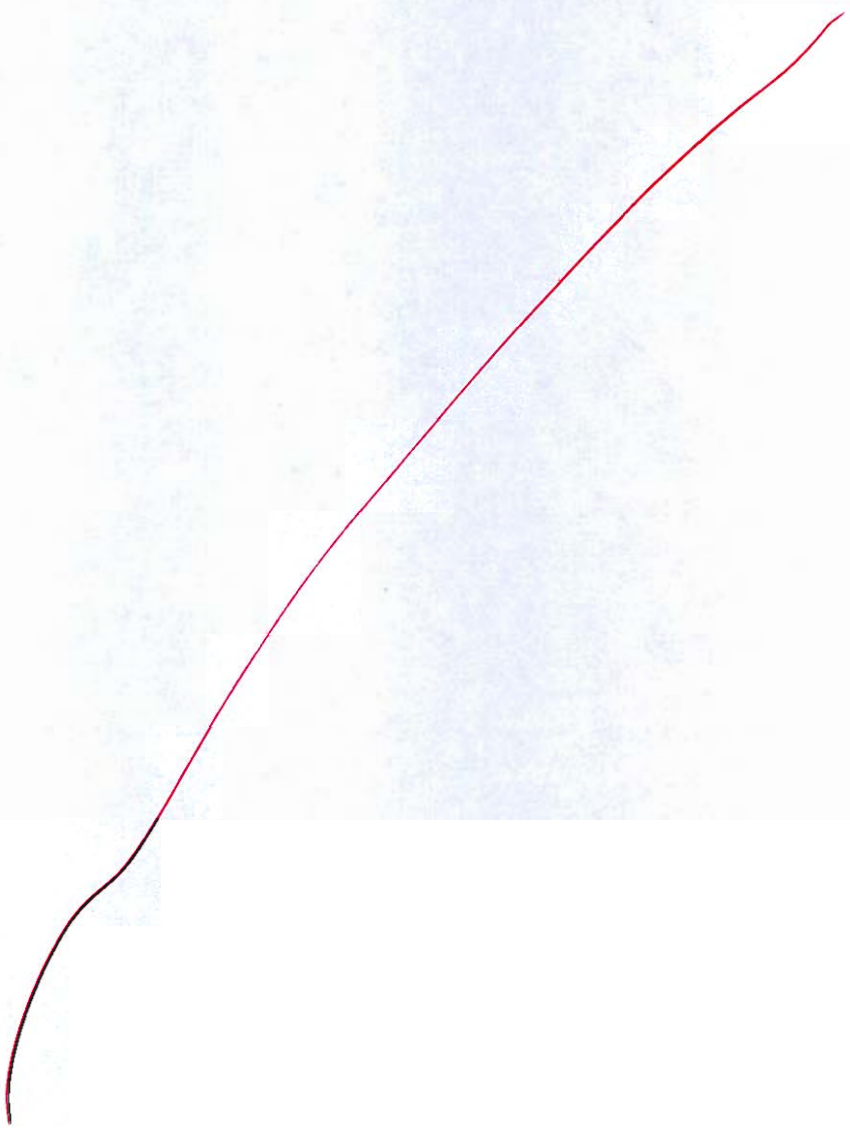

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Q.2 (c) (i) Discuss the various condition monitoring technique used in engineering systems. Explain the principles and application of vibration, noise and wear debris monitoring.

(ii) What is a Flexible Manufacturing System (FMS)? What are its importance and advantages in manufacturing and automation?

[10 + 10 = 20 marks]

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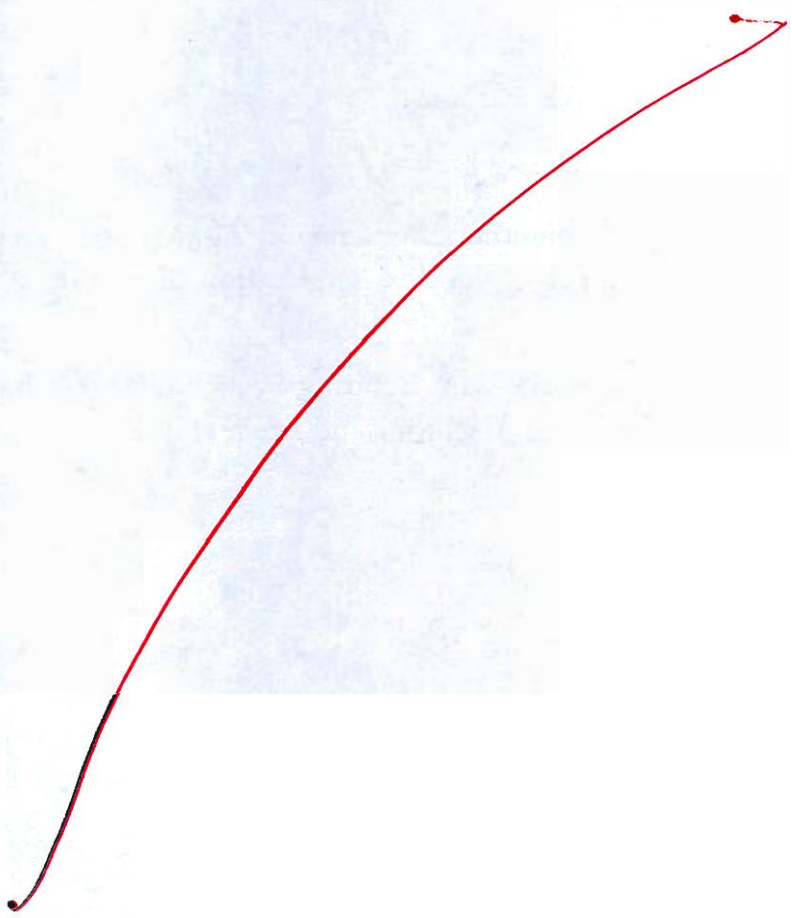

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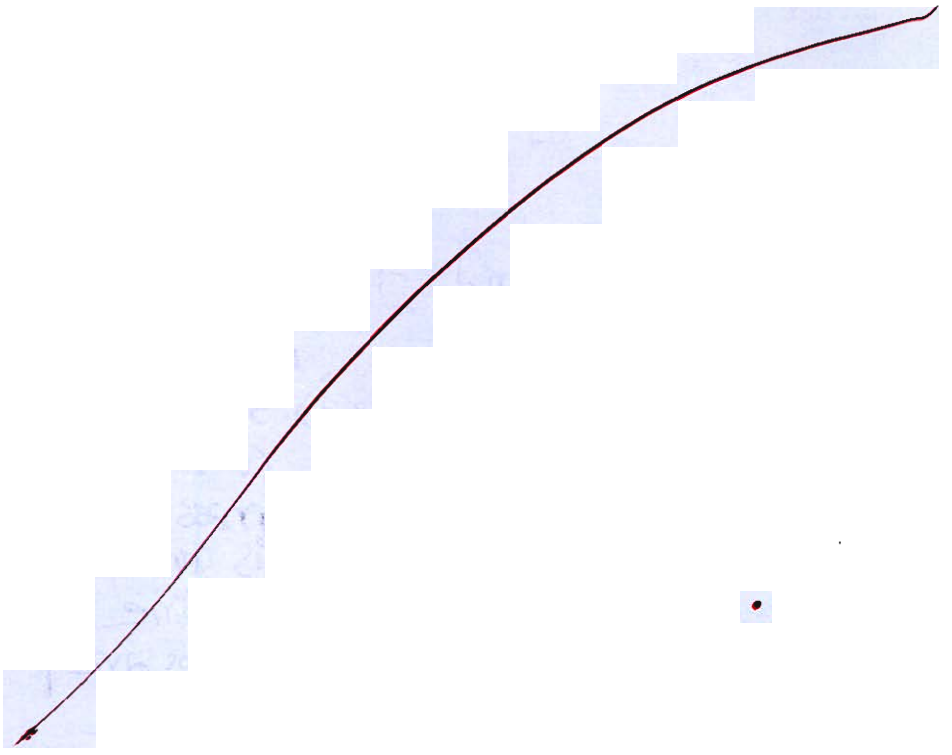

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Q.3 (a) Using actuator disk theory, derive the expression for thrust and power developed by horizontal axis wind turbine. Obtain the power coefficient C_p as a function of axial induction factor and determine the condition for maximum power extraction. Hence, prove that the maximum power coefficient (Betz limit) is $\frac{16}{27}$ and show that the corresponding maximum thrust coefficient, C_f is $\frac{8}{9}$. Clearly, state the all the assumptions involved in the analysis.

[20 marks]

Sol) For horizontal axis wind turbine

V_i = velocity of wind initially

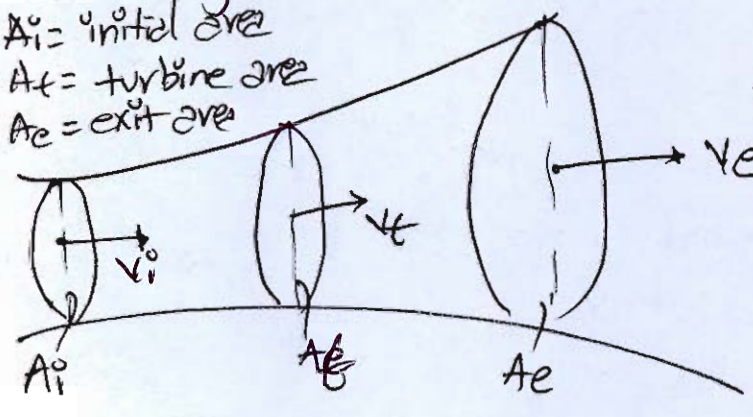
V_e = velocity of wind at exit of turbine

V_t = velocity of wind at turbine

A_i = initial area

A_t = turbine area

A_e = exit area



Assumption

1) Swept area is constant
2) mass flow rate is constant over turbine
3) blades are properly teetered
4) material of wind blades are homogeniey

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Power developed is equal to change in kinetic energy. $P = \frac{1}{2}\dot{m}\left[V_i^2 - V_e^2\right]$ — (1)

F_c → circumferential thrust force

$$P = F_c V_t \rightarrow \dot{m}(V_i - V_e)V_t \quad (2)$$

from (1) and (2)

$$\frac{1}{2}\dot{m}(V_i^2 - V_e^2) = \dot{m}(V_i - V_e)V_t$$

$$\boxed{V_t = \frac{V_i + V_e}{2}}$$

→ a = axial interference factor or axial induction factor $\Rightarrow a = \frac{V_i - V_t}{V_i}$

$\therefore V_t = (1-a)V_i$

$V_e = (1-2a)V_i$

By substituting V_t and V_e in equ (2) give

$$P_{\text{extracted}} = \rho a V_t (V_i - V_e) V_t$$

$$= \rho a[(1-a)V_i]^2 (V_i - (1-2a)V_i)$$

$$\boxed{P = 4a(1-a)^2 \frac{1}{2}\rho a V_i^3}$$ → power developed (or) power extracted by turbine

where $\boxed{C_p = 4a(1-a)^2}$

For maximum power, differentiating power coefficient w.r.t a

C_p = Maximum power coefficient

$$\frac{dC_p}{da} = 0 \rightarrow \frac{d}{da}(4a(1+a^2-2a)\ldots$$

$\frac{d}{da}(4a - 4a^3 - 8a^2)$

$4 + 12a^2 - 16a = 0$

$a = \frac{1}{3}$

$a = 1$ [give zero power] ∴ Neglecting

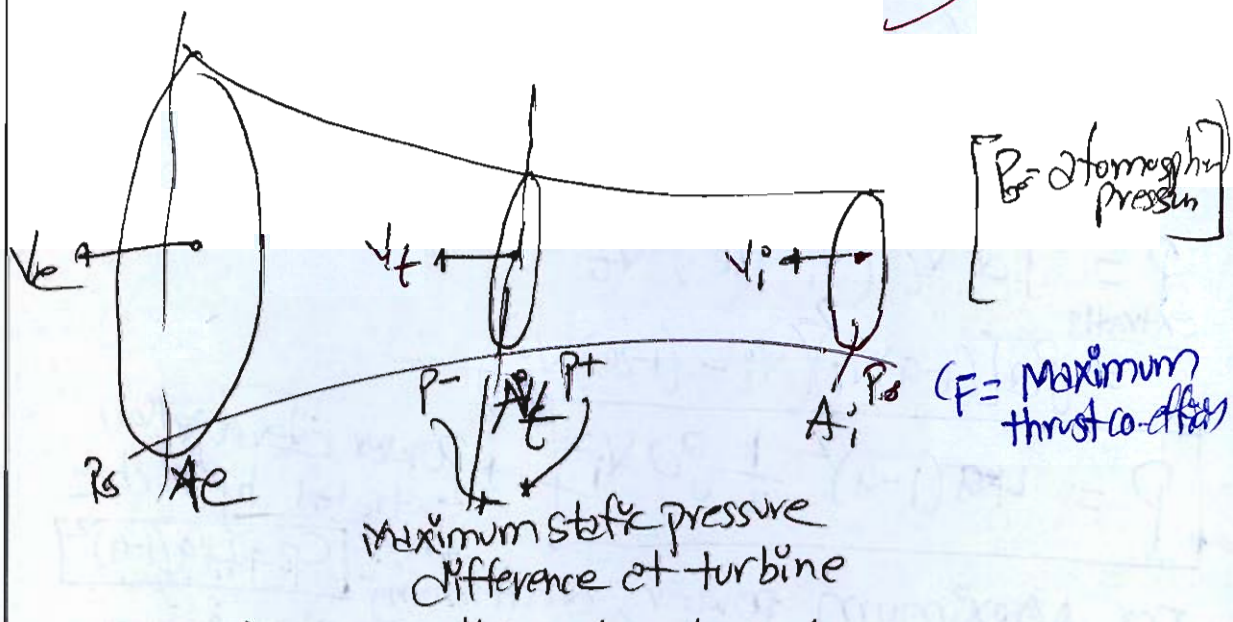
∴ $\boxed{a = \frac{1}{3}}$ for maximum power

→ put a in C_p value → $C_p = 4a(1-a)^2$

$\boxed{C_p = \frac{16}{27} = 0.5925}$

ie Maximum of 59.25% of kind power can be extracted

→ For expression of thrust



By apply Bernoulli's rule at i, t

$$\frac{P_+}{\rho g} + \frac{V_t^2}{2g} = \frac{P_i^2}{2g} + \frac{P_\infty}{\rho g} \quad -(1)$$

By applying Bernulli's principle at ∞, e

$$\frac{P_\infty}{\rho g} + \frac{V_\infty^2}{2g} = \frac{P_e}{\rho g} + \frac{V_e^2}{2g} \quad \text{--- (2)}$$

from (1) and (2)

$$\frac{P^+}{\rho g} - \frac{P^-}{\rho g} = \frac{V_i^2 - V_e^2}{2g}$$

[$P^+ - P^-$ = static pressure difference]

$$\frac{F_{thrust}}{\rho A} = \frac{1}{2}(V_i^2 - V_e^2)$$

F_{thrust} = thrust force developed by turbine

$$\boxed{F_{thrust} = \frac{1}{2}\rho A (V_i^2 - V_e^2)} \quad \text{--- (1)}$$

at $V_e = 0$, $F_{thrust} = (F_{thrust})_{max}$

$$F_{circumferential} = \dot{m}(V_i - V_e)$$

$$\boxed{F_{circ} = \dot{m}\rho_\infty V_t (V_i - V_e)} \quad \text{--- (2)}$$

20

from (1) and (2)

$$\boxed{V_t = \frac{V_i + V_e}{2}}$$

a = axial induction factor $\Rightarrow a = \dfrac{V_i - V_t}{V_i}$

$\therefore V_t = (1-a)V_i$

$V_e = (1-2a)V_i$

substituting above value in equation (3)

$F_{thrust} = \rho_\infty (1-a) V_i \left[V_i^2 - (1-2a)^2 V_i^2\right]$

$$\boxed{F_{thrust} = 4a(1-a)\frac{1}{2}\rho_\infty V_i^2}$$

where $C_p = 4a(1-a)$

Maximum thrust, differentiating C_p w.r.t a

$\frac{d}{da}(4a(1-a)^2) = 0$

$\frac{d}{da}(4a - 4a^2 + 4a^2) = 0$

$\boxed{a = \frac{1}{3}}$

$\therefore (C_p)_{max} = \frac{4}{3}\left(1 - \frac{1}{3}\right)$

$(C_p)_{max} = \frac{8}{9}$ ***

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Q.3 (b) Discuss the classification of fuel cells based on electrolyte type, chemical nature of electrolyte and operating temperature. With the help of a neat labelled diagram, describe the construction and working of a Proton Exchange Membrane Fuel Cell (PEMFC). Also, state the electro-chemical reactions occurring at the electrodes.

[20 marks]

Sol 1) Based on electrolyte type

a) proton exchange membrane fuel cell
b) Phosphoric acid fuel cell
c) Alkaline fuel cell
d) molten carbonate fuel cell
e) solid oxid fuel cell

2) Based one chemical nature of electrolyte

a) Acidic fuel cell
b) Alkaline fuel cell
c) Neutral fuel cell

3) Based on operating temperature

a) lower operating temperature fuel cell [~~70~~150°C]
b) Medium operating temperature fuel cell [300°C-700°C]
c) higher operating temperature fuel cell [900°-1200°C]

Proton exchange Membrane fuel cell

Anode reaction

$$H_2 \xrightarrow{\text{catalyst}} 2H^+ + 2e^-$$

Cathode reaction

$$2H^+ + 2e^- + \frac{1}{2}O_2 \longrightarrow H_2O$$

Overall reaction

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$$

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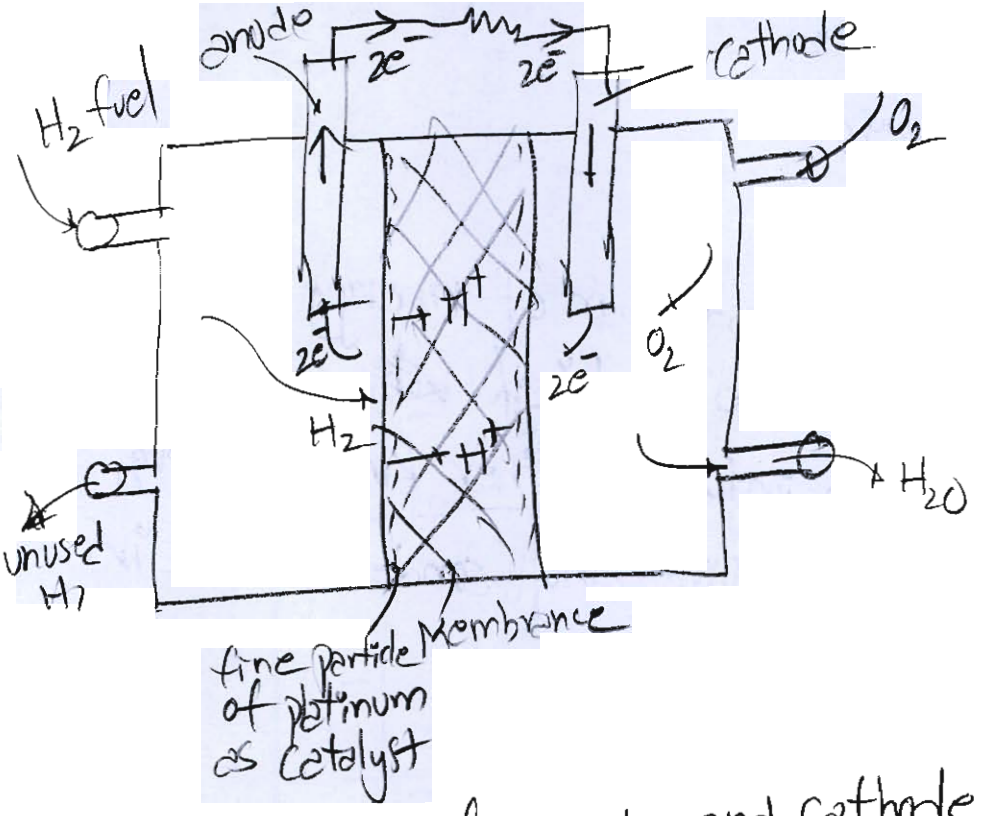

→ It consists of Anode and cathode of Nickel or copper material. Its operating temperature 150°C

→ fuel used as H_2, when H_2 make a contact with finely divided platinum particel, It gives reaction and two electrons will release [Ionization]

→ the two electron moves through circuit from anode to cathod, after combining with outside supplied oxygen and Hydrogen ions leads to Water.

→ Here byproduct is Water, therefore It gives cleanest form of Energy.

Application

1) laptops
2) mobile phones

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3) Video camera

4) In Railways

Advantage

1) It gives cleanest form of energy directly from chemical to electrical without any transformation into any other kind of energy

2) It does not require any condenser like in conventional power plant

3) It has high efficiency

disadvantage

1) high cost

16

Q.3 (c) (i) A microwave transmitter has exhibited a constant failure-rate of 0.00034 failure per operating hour. The reliability function is given by

$R(t) = e^{-0.00034t}$

1. Determine the reliability over a 30 day continuous period.
2. If a second redundant transmitter is added in parallel to the system, then find the reliability function for the parallel system and its hazard rate function. Also calculate the reliability over a 30 day continuous period.

(ii) Old hens can be bought for Rs 2 but young ones cost Rs 5 each. The old hens lay 3 eggs/week and the young ones lay 5 eggs/week. Each egg being worth 30 paise. A hen cost Rs 1 per week to feed. If a person has only Rs 80 to spend on the hens, how many of each kind should he buy to get a profit of more than Rs. 5.8 per week assuming that he cannot use more than 20 hens. Solve using graphical method.

[10 + 10 = 20 marks]

Sol) i) Given data

$\lambda = 0.00034/hr$

1) reliability for 30 days → 720 hrs

$R(t) = e^{-0.00034 \times 720}$

$R(t) = 0.7828$ i.e 78.28%

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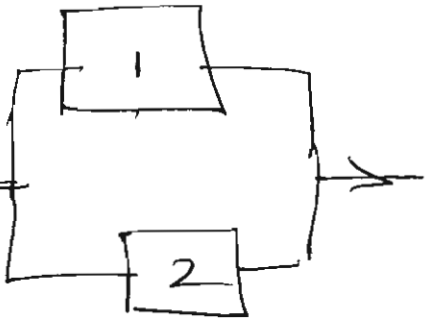
2) reliability for 30 days



$R(t) = 1 - [(1 - R(t_1))(1 - R_2)]$

$R(t) = 1 - [(1 - (0.7828))(1 - 0.7828)]$

$[R(t) = 0.952824$ ie $95.28]$ for 30 days

6

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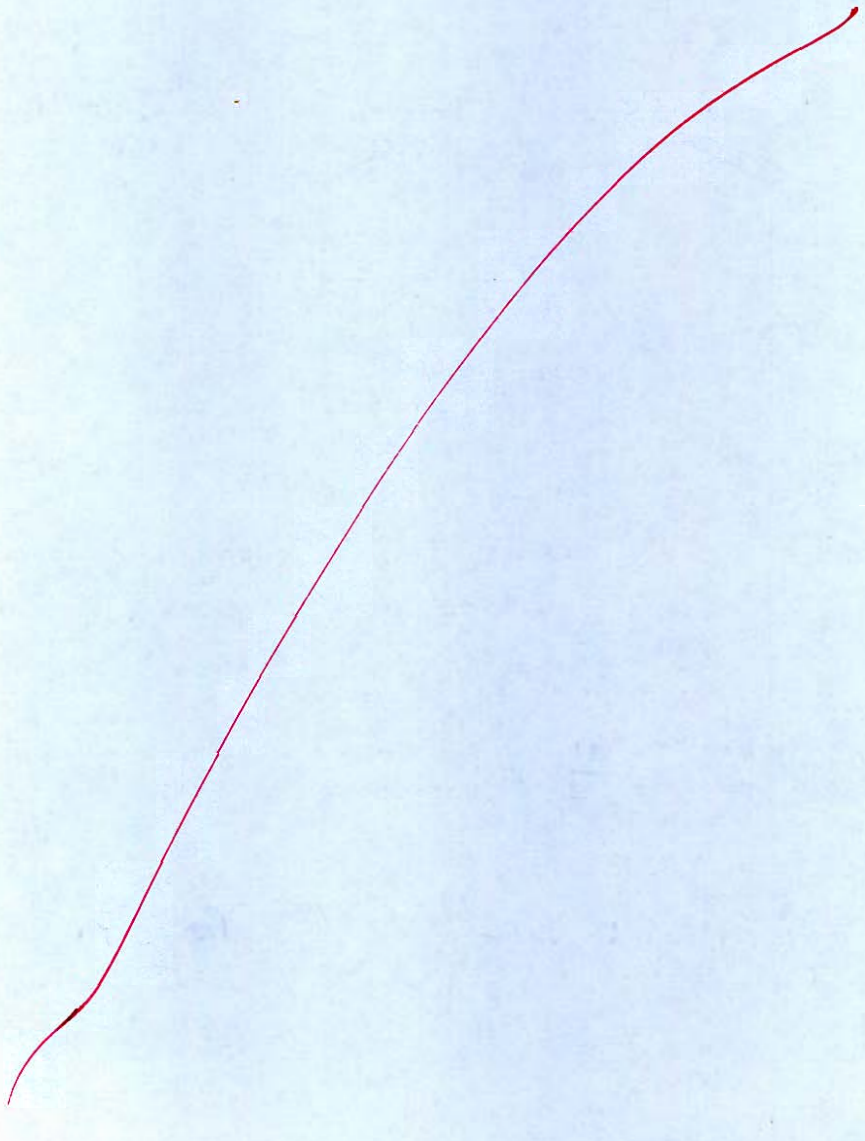

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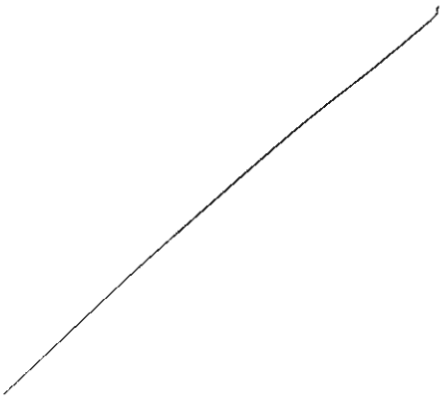

Q.4 (a) The time estimates (in weeks) for the activities of a PERT network are given below:

Activity	t_0	t_m	t_p
1 - 2	1	1	7
1 - 3	1	4	7
1 - 4	2	2	8
2 - 5	1	1	1
3 - 5	2	5	14
4 - 6	2	5	8
5 - 6	3	6	15

(i) Draw the project network and identify all the paths through it.

(ii) Determine the expected project length and calculate the standard deviation and variance of the project length.

(iii) What is the probability that the project will be completed

1. at least 4 week earlier than expected time.
2. no more than 4 week later than expected time.

[20 marks]

Sol) i) Constructing the Network diagram

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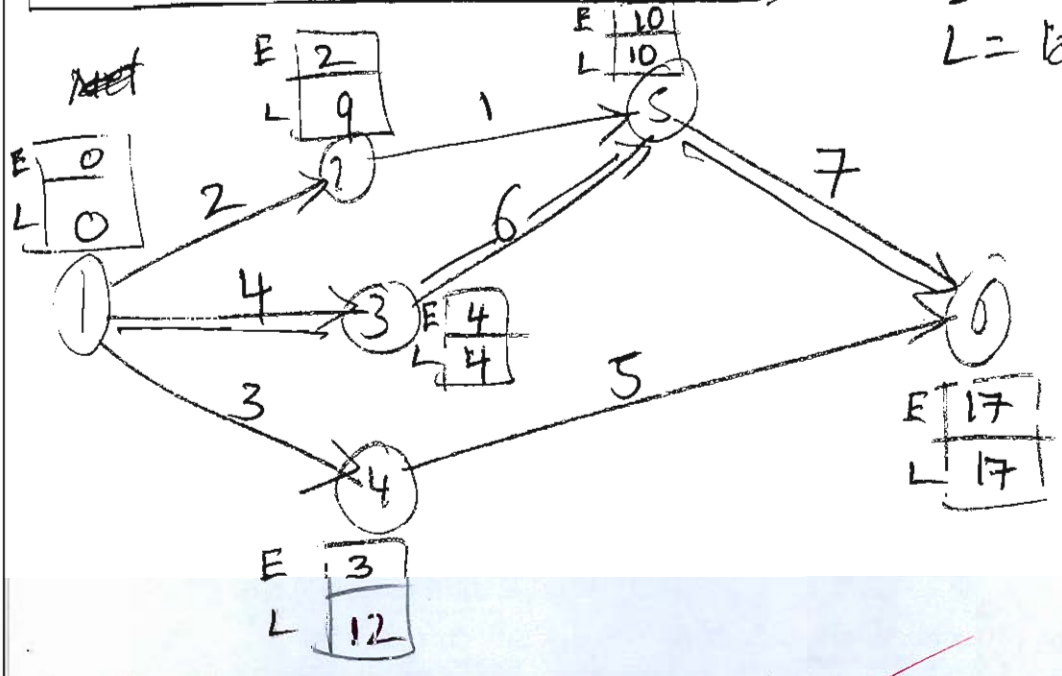
Activity	$t_E = \frac{t_p + 4t_m + t_o}{6}$	Variance $= \left(\frac{t_p - t_o}{6}\right)^2$
1-2	2	1
1-3	4	1
1-4	3	1
2-5	1	0
3-5	6	2
4-6	5	1
5-6	7	2

E = earlist time
L = latest time



Critical path = 1-3-5-6

(ii) expected project length is on critical path

ie 17 weeks

Variance $\Rightarrow \sigma^2 = \sigma_{1-3}^2 + \sigma_{3-5}^2 + \sigma_{5-6}^2$

$= 1^2 + 2^2 + 2^2$

$= 9$

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Standard deviation $\sigma = \sqrt{\text{variance}}$

$\sigma = 3$ weeks

iii) Probability at $t_S = 13$ weeks

$$z = \frac{t_S - t_E}{\sigma} = \frac{-4}{3}$$

$P = 0.09121$ i.e 9.121%

probability at $t_S = 21$

$$z = \frac{t_S - t_E}{\sigma} = \frac{4}{3}$$

$P = 0.90879$ i.e 90.879%

90

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Q.4 (b) A manufacturer of complex electronic equipment has just received a sizable contract and plans to subcontract part of the job. He has solicited bids for 6 subcontracts from 3 firms. Each job is sufficiently large and any firm can take only one job. The table below shows the bids as well as the cost estimates (in thousands of Rs) for doing the job internally. Not more than three jobs can be performed internally.

Firm \ Job	1	2	3	4	5	6
1	44	67	41	53	48	64
2	46	69	40	45	45	68
3	43	73	37	51	44	62
Internal	50	65	35	50	46	63

Find the optimal assignment that will result in minimum total cost. Also find total minimum cost.

[20 marks]

Sol)

44	67	41	53	48	64
46	69	40	45	45	68
43	73	37	51	44	62
50	65	35	50	46	63
0	0	0	0	0	0
0	0	0	0	0	0

∵ Matrix is not square, ∴ adding additional two rows with zero cells to make 6×6 Matrix

By doing subtraction of all row elements from their respective row minimum elements

3	26	10	12	7	23
6	29	⊘	5	5	28
6	36	⊘	14	7	25
5	30	⊘	15	10	28
0	⊘	⊘	⊘	⊘	⊘
⊘	0	⊘	⊘	⊘	⊘

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Matrix is same even after doing Minum column element subtraction for respective column.

→ no. of allocation - 3, i.e less than M(or) n(6)

∴ further ~~allocation~~ Optimization can be done

(3)	26	5	12	7	23
1	24	⊗	[0]	⊗	23
1	31	[0]	9	2	20
10	25	⊗	10	6	23
[0]	⊗	5	⊗	⊗	⊗
⊗	[0]	5	⊗	⊗	⊗

7

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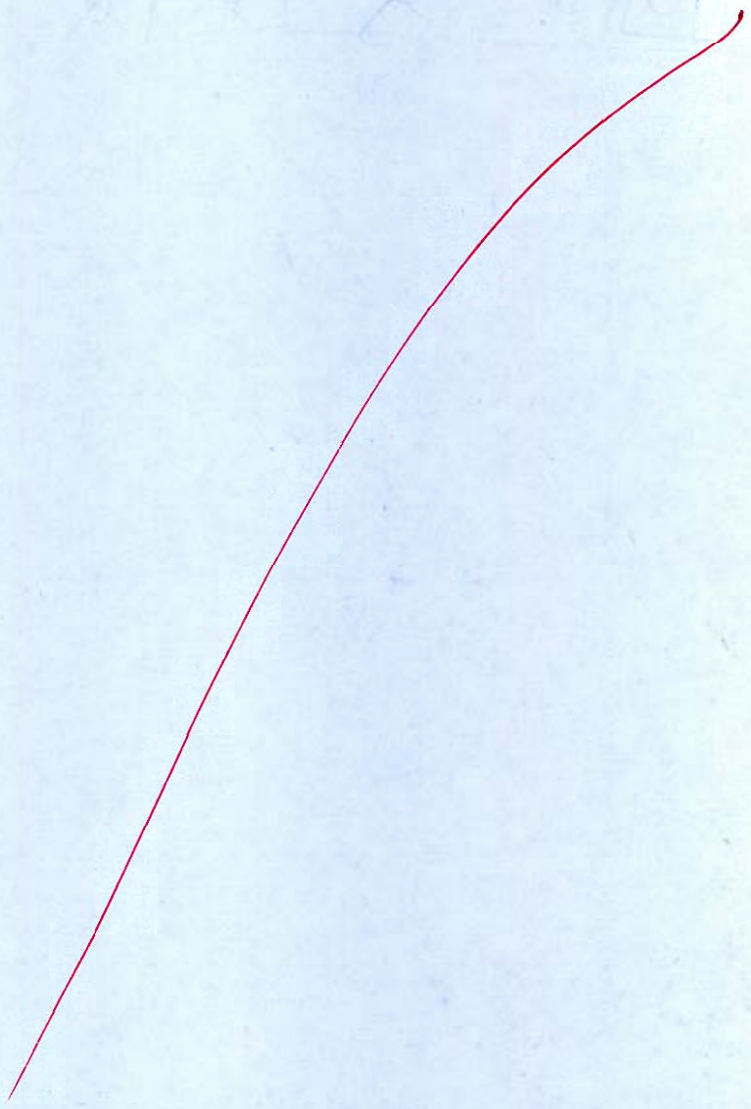

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Q.4 (c) Classify tidal power plants based on their mode of operation and basin arrangement. With the help of a neat schematic diagram, explain the working principle of a double-basin tidal power plant with linked-basin operation.

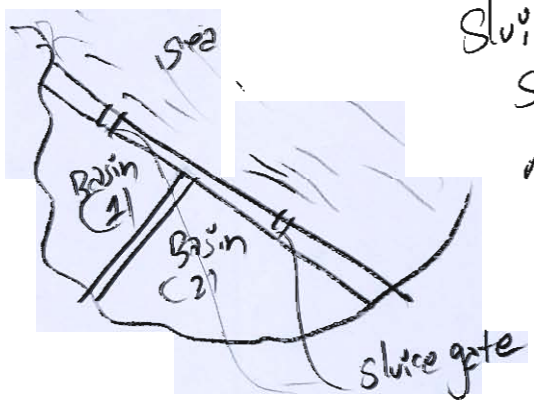
Also, describe the important components of a tidal power plant and list the types of turbines commonly used in tidal energy conversion systems.

[20 marks]

Classifying tidal power plant

1) based on no. basin provided
   a) single basin tidal power plant
   b) double basin tidal power plant
2) based on effect of power generation
   a) ebb generation tidal power plant
   b) flood generation tidal power plant
3) based on combined effect and basin
   1) single basin single effect
   2) single basin double effect
   3) double basin single effect
   4) double basin double effect

→ double basin tidal power plant



b) point 2' → turbine is closed and sluice gate opens. therefore sea water fills the basin. After reaching required head sluice gate closes and turbine starts to operate as head is sufficient to develop power

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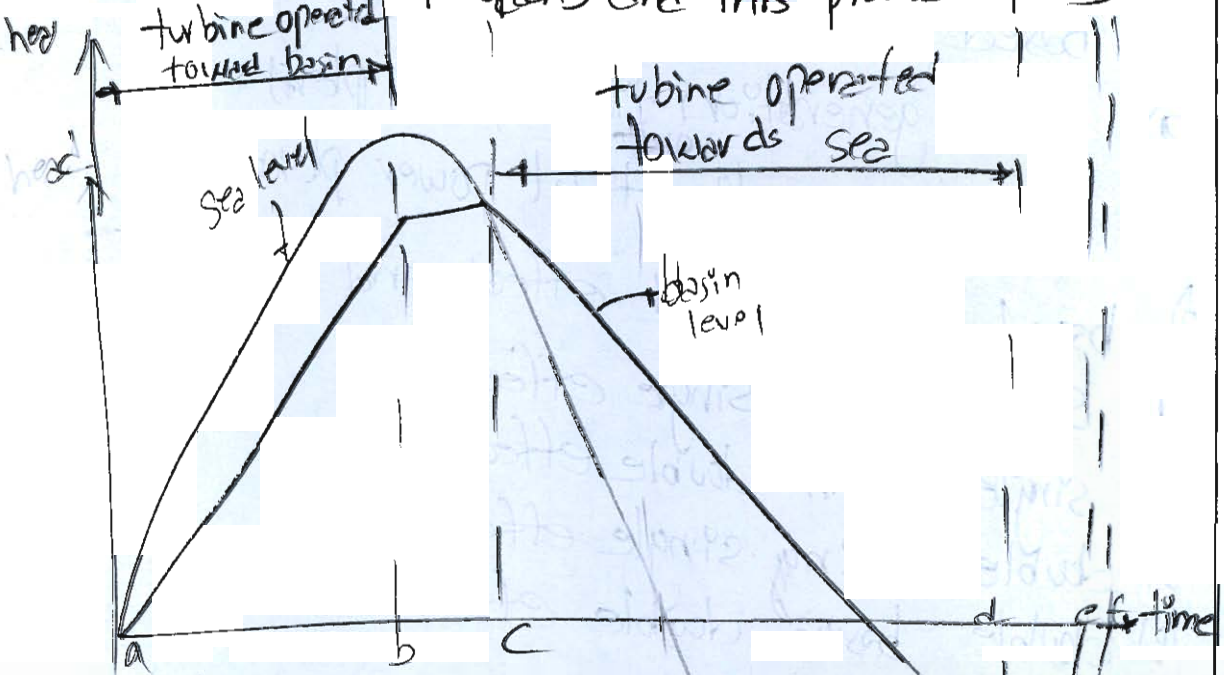
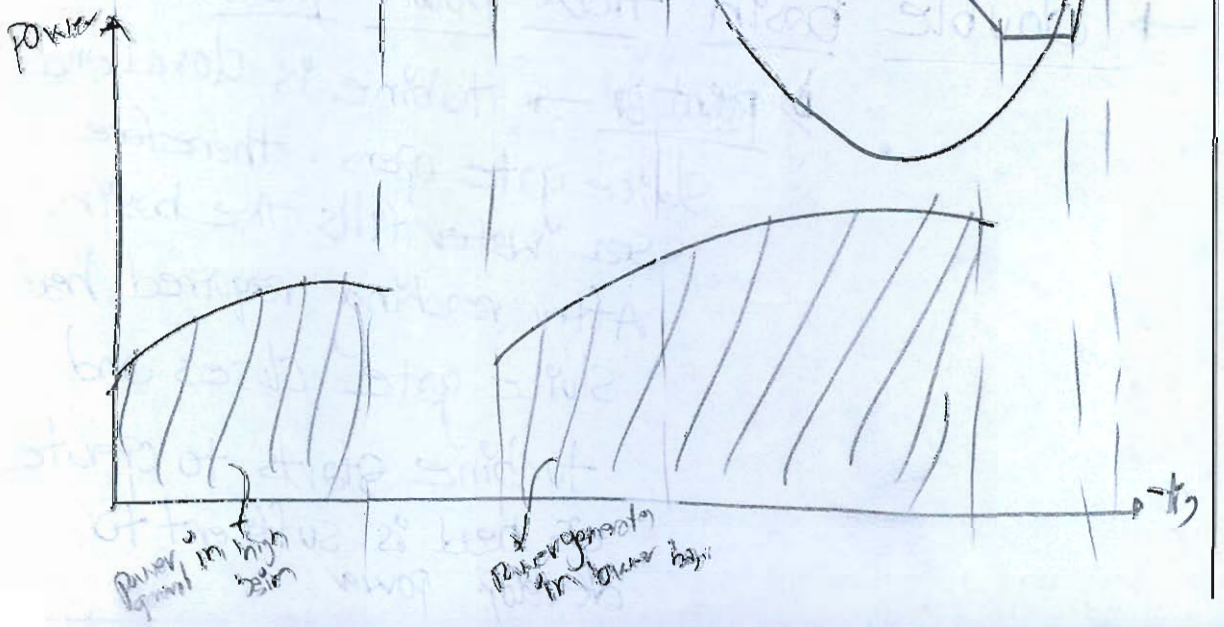
(a-b) = turbine opens and sluice gate close the turbine starts operating under minimum head in basin

(b-c) = both turbine and sluice gate close and head of sea water is building open to operate lower tubine

c-d :- tubine opens and sluice gate close :- turbine operate untill it reachs the minimum head in basin

e-f :- tubine closes and sluice opens :- water is discharge to ocean and this process repeats





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Components of tidal power plants

1) reservoir
2) sluice gate
3) turbine-generator equipment

list of turbine used

1) tangential flow impulse turbine [pelton wheel]
2) kaplan turbine
3) turbular turbine
4) propeller turbine

15

Section B : Production Engineering & Material Science-1 + Theory of Machines-2

Q.5 (a) A cylindrical billet of 40 mm diameter and 110 mm length is reduced by backward extrusion to a diameter of 15 mm. If the Johnson's equation constants are $a = 0.8$ and $b = 1.5$, the strength coefficient of material is 800 MPa and the strain hardening exponent $n = 0.17$. Determine the Extrusion ratio, Extrusion strain, Ram force.

[12 marks]

Given data $d =$

$$R = \frac{A_i}{A_f} = 7.111$$

$$\sigma_d = \sigma_0 (a + b \ln R)$$

$$\varepsilon_T = \ln\left(\frac{A_i}{A_f}\right)$$

$$\varepsilon_T = 1.9619$$

$$\sigma_d = \frac{K(\varepsilon_T)^n}{n+1} (0.8 + 1.5 \ln(7.111))$$

$$= 766.743 \left[3.74225\right]$$

$$\sigma_d = 2869.533 \text{ MPa}$$

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1) Extrusion ratio

$R = 7.111$

2) Extrusion strain $= 1.9619$

3) $F = \sigma_d \frac{\pi}{4}(D_i^2 - d_f^2)$

$= \left(2869.533 + \frac{4K'L}{D_i}\right) \times \frac{\pi}{4}(4^2 - 1.5^2)$

$= 11669.533 \times 1079.922$

$F = 12.6021\ MN$

9

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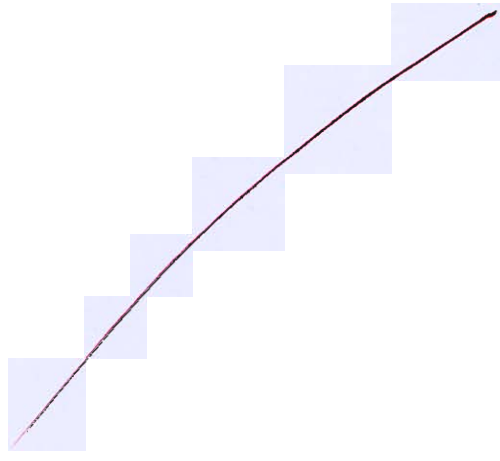
Q.5 (b) (i) Calculate the gating dimensions with gating ratio of 1 : 2 : 3 for ductile iron-casting of section thickness 12 mm weighing 30 kg. Assume a sprue height of 200 mm. Given pouring time $(t) = k\sqrt{w}$, $k = 2.3$, for thickness = 12 mm, flow/discharge factor, $C_d = 0.9$, w = weight of casting(kg), density of iron = 7900 kg/m^3.

(ii) For BCC iron, compute the interplanar spacing and the differaction angle for the (220) set of planes. The lattice parameter for Fe is 0.28 nm. Also, assume that monochromatic radiation having a wavelength of 0.18 nm is used and order of reflection is 1.

[6 + 6 = 12 marks]



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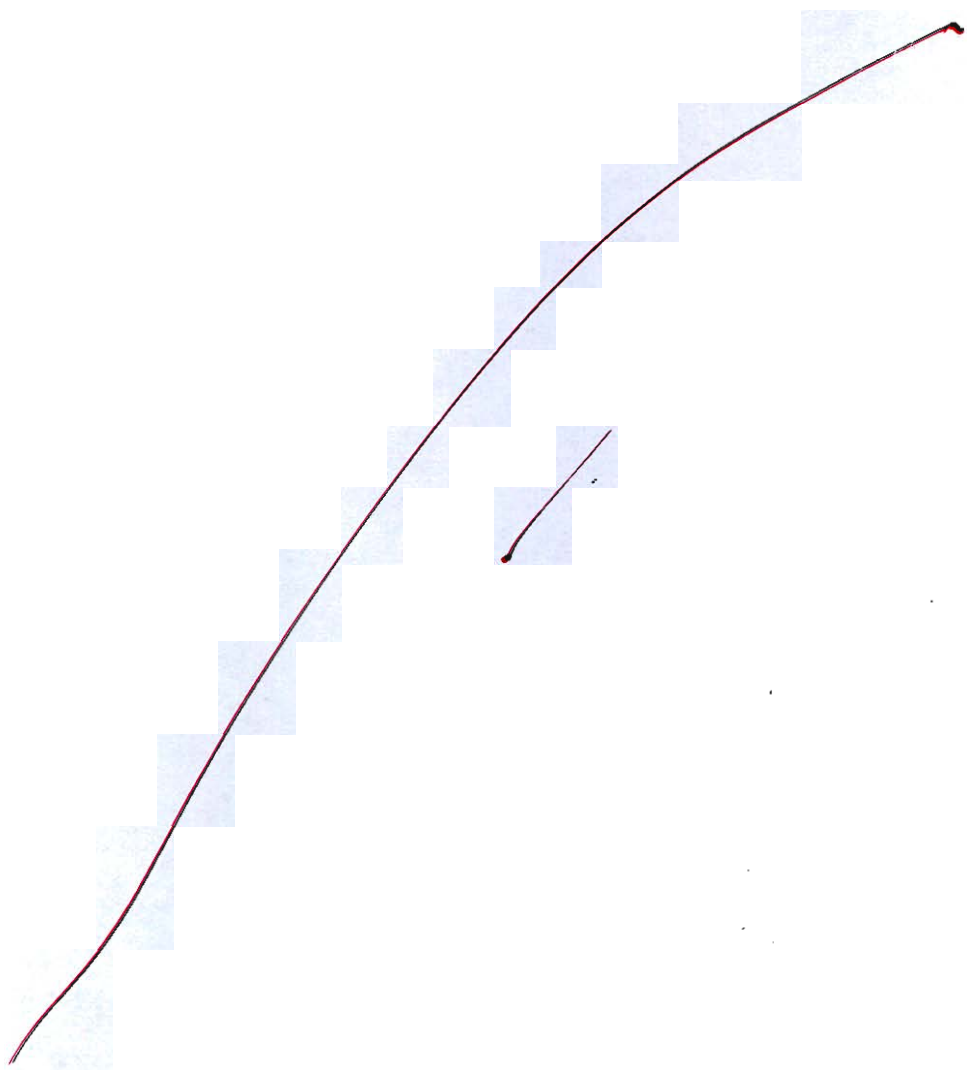

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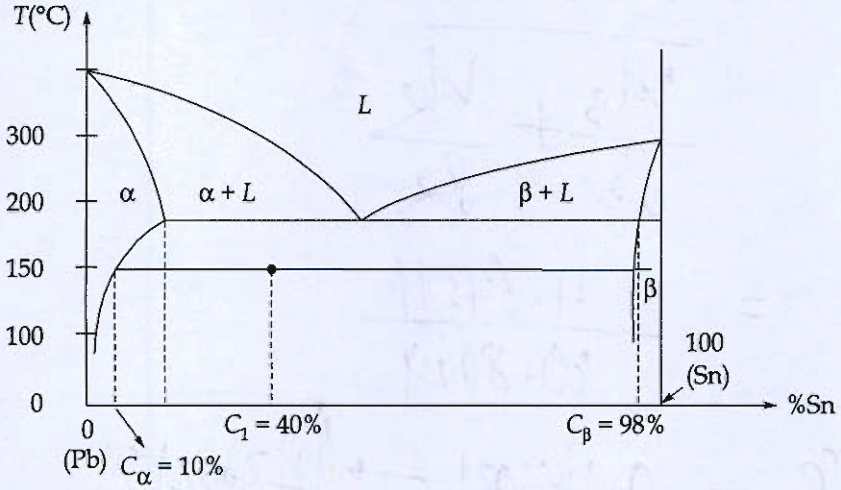
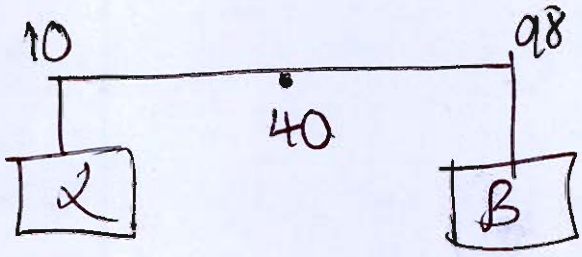
Q.5 (c) Determine the mass fraction and volume fraction of each phase for a 40% by wt. Sn. and 60% by wt. Pb alloy at 150°C.

Take; $\rho_{Sn} = 7.24$ g/cm^3; $\rho_{Pb} = 11.23$ g/cm^3



[12 marks]

mass



$$\text{mass fraction} = \alpha = \frac{98-40}{98-10} = 65.90\%$$

$$\text{mass fraction } \beta = \frac{40-10}{98-10} = 34.09\%$$

$$\text{Volume } \alpha = \frac{\frac{W_\alpha}{\rho_\alpha}}{\frac{W_\alpha}{\rho_\alpha} + \frac{W_B}{\rho_B}}$$

$$\frac{1}{\rho_\alpha} = \frac{1\times0.1}{7.24} + \frac{1\times0.9}{11.23}$$

$$\rho_\alpha = 10.6434 \text{ g/cm}^3$$

$$\frac{1}{\rho_B} = \frac{0.98}{7.24} + \frac{1\times0.02}{11.23}$$

$$\rho_B = 7.2918 \text{ g/cm}^3$$

$$\text{Volume } \alpha = \frac{0.1916}{10.8669}$$

$$(\text{Volume})_\alpha = 56.979\%$$

Vol

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$$\text{Volume}_\beta = \frac{k I_B / \rho_B}{\frac{k I_B}{\rho_B} + \frac{k I_2}{\rho_2}}$$

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$$\text{Volume}_\beta = \frac{4.67511}{10.8669}$$

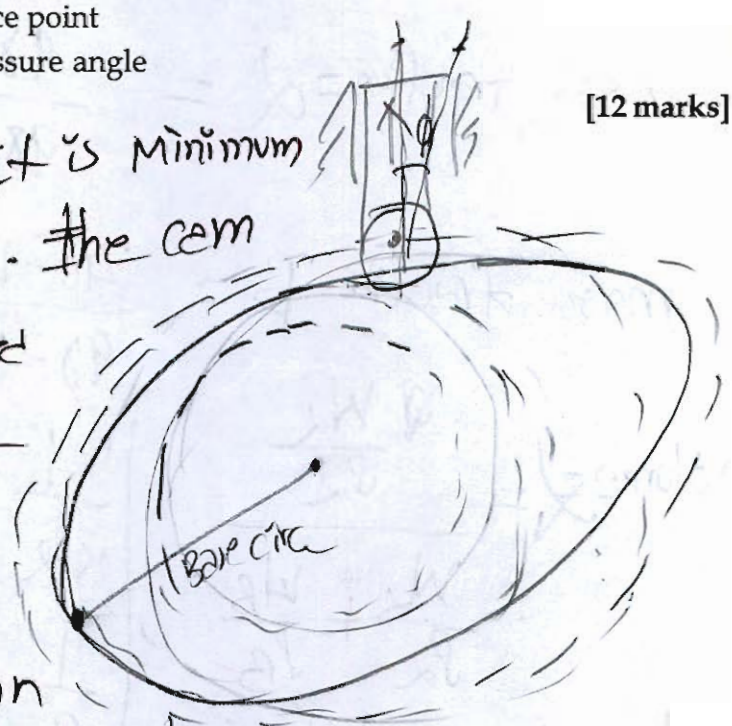
$$\text{Volume}_\beta = 0.43021 \rightarrow 43.021\%$$

Q.5 (d) Define the following terms commonly used in laying out the cam profiles with a neat sketch.

(a) Base circle (b) Trace point

(c) Pitch curve (d) Pressure angle

[12 marks]



1) Base circle :- It is minimum radius of circle. The cam is generally specied by radius of Base circle

b) trace point:-
It is the point on follower, when follower is moved around the cam surface It traces the profile of cam surface.

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c) the locus of point of trace gives the pitch curve. pitch curve will be similar to cam profile

d) pressure angle = It the angle between line of action of follower to follower Motion axis.
generally the cam have less pressure angle to reduces the lift force and thrust and wear.

10

Q.5 (e) A pinion of 20° involute teeth rotating at 300 rpm meshes with a gear and provides a gear ratio of 2.4. The number of teeth on the pinion is 20 and module is 8 mm. If the interference is just avoided, determine (i) addenda on the wheel and the pinion (ii) path of contact and (iii) the maximum velocity of sliding on both sides of the pitch point.

[12 marks]

Given data $\phi = 20^0$

$T = 48$

$f = 20$

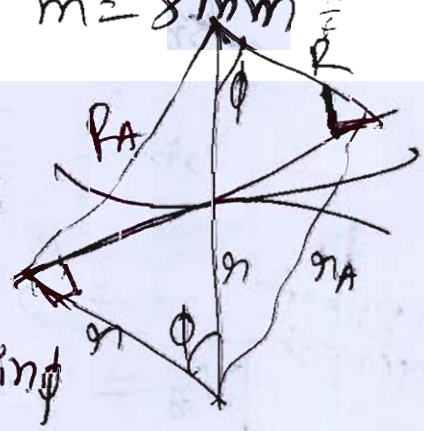
$m = 8\,mm$

$\omega_p = 31.4159$ rad/s

$\therefore r = 80$

$R = 192$ $G = 2.4$

$\therefore \omega_G = 13.0899$ rad/s



$KP = \sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi$

$r\sin\phi = \sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi$

$27.3616 = \sqrt{R_A^2 - 192^2(\cos 20)^2} - 192\sin 20$

$R_A = 202.943\,mm$

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Addendum wheel = $R_A - R$

$= 10.9931$ mm

→ $R\sin\phi = \sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi$

$192\sin 20 = \sqrt{r_A^2 - 80^2(\cos 20)^2} - 80\sin 20$

$r_A = 119.60$ mm

∴ Addendum pinion = $r_A - r$

$= 119.60 - 80$

$= \boxed{39.606 \text{ mm}}$

ii) path of contant = $192\sin 20 + 80\sin 20$

$= 93.0294$ mm

iii) ~~$V_{sliding} = \frac{60}{2\pi}(N_1+N_2)$~~

$(V_{sliding}) = \frac{2\pi}{60}(N_1+N_2)(a \cdot p)$

$= (31.415 + 13.089)(192\sin 20)$

on path of approach $\boxed{V_{sa} = 2.092 \text{ m/s}}$

on path of recess $V_{sr} = (31.415 + 13.089)(80\sin 20)$

$\boxed{V_{sr} = 1.2177}$

12

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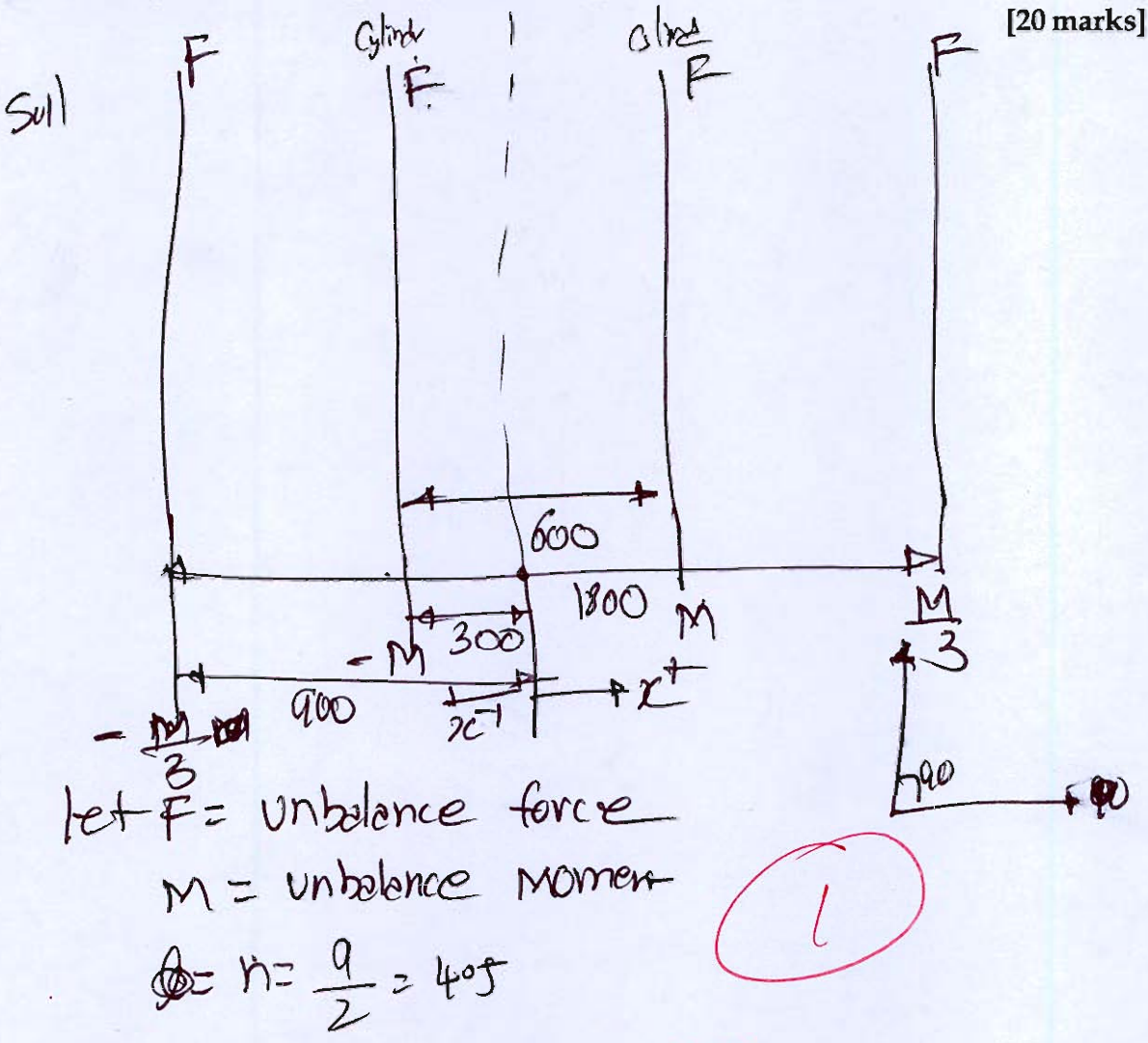
Q.6 (a) The intermediate cranks of a four-cylinder symmetrical engine, which is in complete primary balance, are at 90° to each other and has a reciprocating mass of 400 kg. The centre distance between intermediate cranks is 600 mm and between extreme cranks, it is 1800 mm. Length of the connecting rods and the cranks are 900 mm and 200 mm respectively. Calculate the masses fixed to the extreme cranks with their relative angular positions. Also, find the magnitude of the secondary forces and couples about the centre line of the system if the engine speed is 150 rpm.

[20 marks]



let F = unbalance force

M = unbalance moment

$\theta = n = \frac{q}{2} = 40°$

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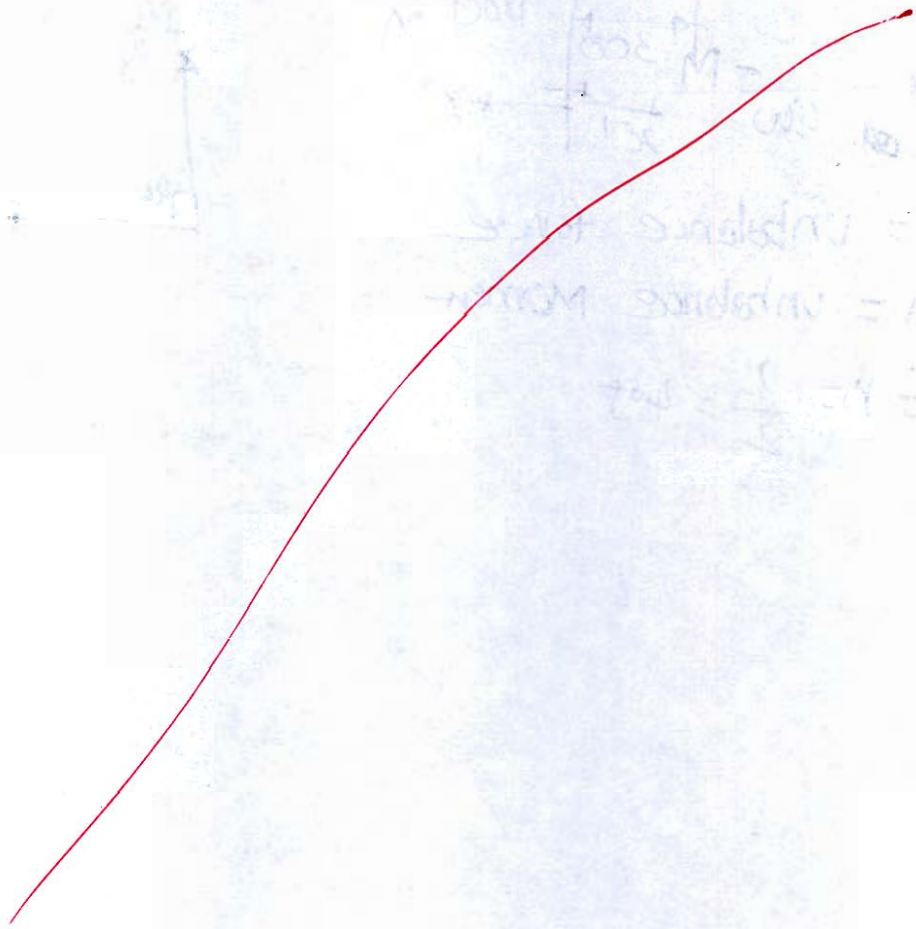

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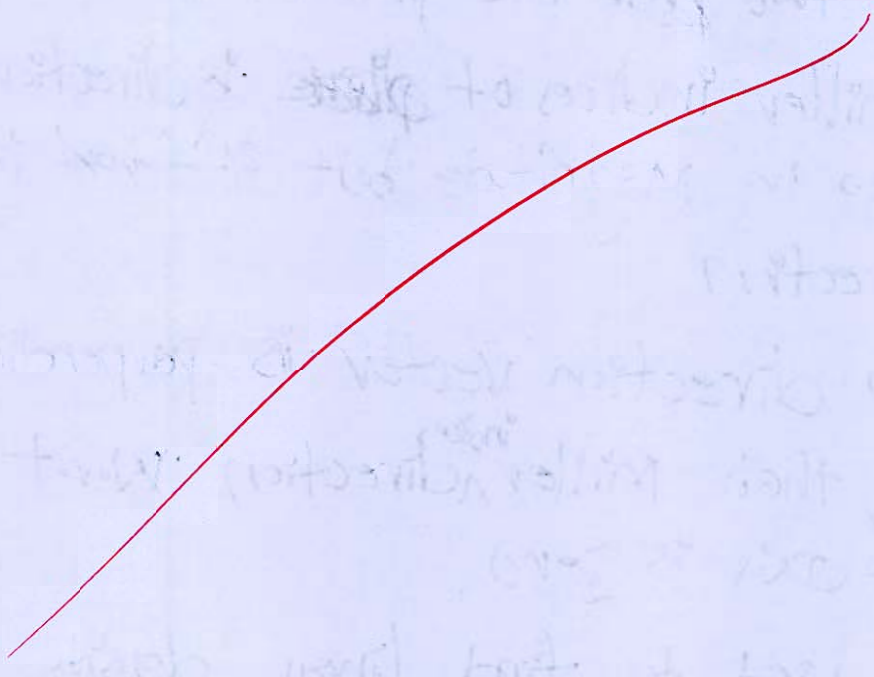

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Q.6 (b) (i) Write the various characteristics of miller indices of plane as well as direction.
(ii) Define planar and linear density. Also calculate the planar and linear density of 111 plane and direction respectively of BCC and FCC crystal structure along with suitable diagrams.

[8 + 12 = 20 marks]

i) Characteristic of miller indices

1) When two planes are parallel to each other their miller indices of plane is same in magnitude but different in their direction

2) When plane is parallel to axis, their miller indices of plane w.r.t to that axis is zero

3) It is used to find the planer density

4) It is used to find closed packed plane

5)

ii) Characteristic of miller direction

direction vector

1) When two plane are parallel to each other their miller indices of direction is same in magnitude but different in their direction

2) When direction vector is perpendicular to axis, their miller indices direction w.r.t to that axis is zero

3) It is used to find linear density

4) It is used to find closed packed direction

5)

6

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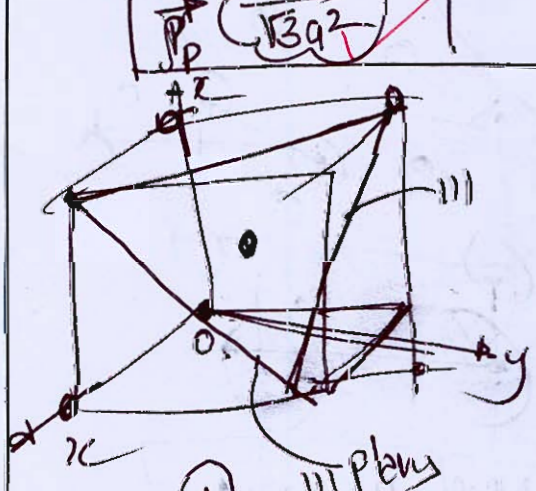
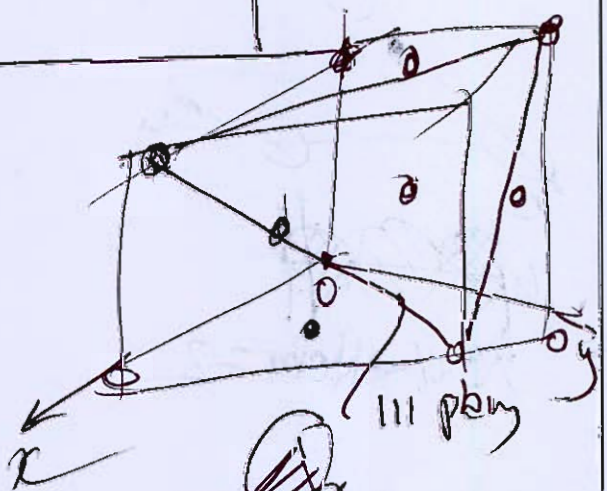
Planer density :- Average number of atoms per area of plane

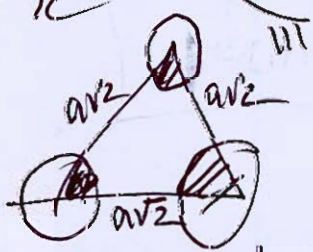
liner density : Average number of atoms per direction vector

planer density	BCC	FCC
plane 111	$\rho = \frac{\frac{1}{2}}{\frac{\sqrt{3}a^2}{2}}$	$\rho = \frac{2}{\sqrt{3}a^2}$

12





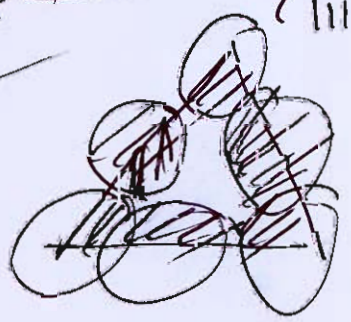


$360° \rightarrow 1$ atom

$60° \rightarrow \frac{1}{6}$ atoms

No. of atom $= \frac{1}{6} \times 3 = \frac{1}{2}$

$A = \frac{\sqrt{3}}{4}(a\sqrt{2})^2 = \frac{\sqrt{3}a^2}{2}$



No. of atom $= \frac{1}{6} \times 3 + 1$

$= \frac{1}{2} + 3$

$= \frac{4}{2} = 2$

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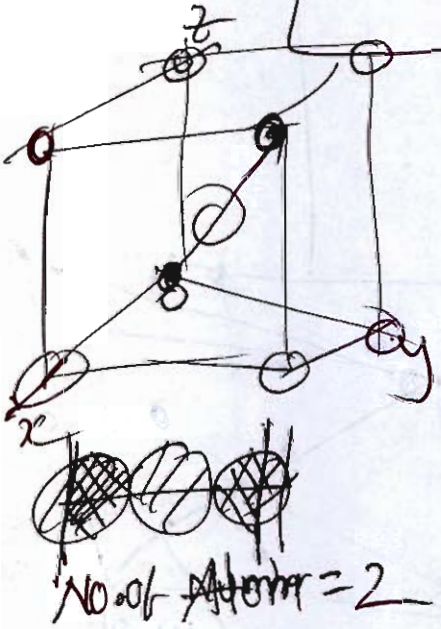
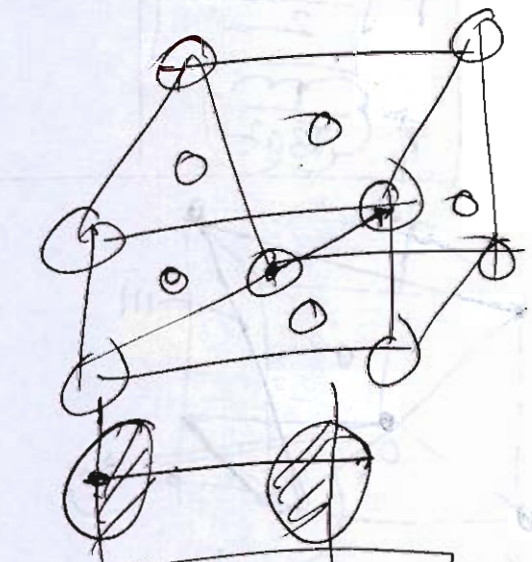
linear density

	BCC	FCC
111 direction	$\frac{2}{\sqrt{3}a}$	$\frac{1}{\sqrt{3}a}$



No. of Atoms = 2



No. of Atoms = 1

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Q.6 (c) In a wire drawing operation after passing through a conical portion, the wire passes through a die land of 4 mm length. The incoming wire diameter is 8 mm and outgoing diameter is 6 mm. The semi-die angle is 8° and co-efficient of friction is 0.05. If nominal strength of the material is 30 MPa. Calculate the pull required to draw the wire.

[20 marks]

Given data

$l = 4mm$

$A_i = 5.0265 \times 10^{-5}\ m^2$

$A_f = 2.8274 \times 10^{-5}\ m^2$

$\mu = 0.05$ $\quad B = \mu \cot\alpha$

$\sigma_0 = 30MPa$ $\quad = 0.3557$

drawing stress [plane stress $k' = \frac{\sigma_0}{2}$ [neglecting back-stress]

$$\sigma_d = 2k'\left(\frac{1+B}{B}\right)\left[1-\left(\frac{A_f}{A_i}\right)^B\right]$$

$$= 2\times\frac{30}{2}\left(\frac{1.3557}{0.3557}\right)\left(1-\left(\frac{2.8265\times10^{-5}}{5.0274\times10^{-5}}\right)^{0.3557}\right)$$

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$\bar{\sigma}_f = 21.6144$ MPa

→ actual drawing stress $\bar{\sigma}_f' =$

$$\bar{\sigma}_f' = \bar{\sigma}_0 - (\bar{\sigma}_0 - \bar{\sigma}_f) e^{\frac{-2\mu L}{D_f}}$$

$$= 30 - (30 - 21.614) e^{\frac{-2 \times 0.05 \times 4}{3}}$$

$$= 22.6607 \text{ MPa}$$

12

∴ Pull force required = $\bar{\sigma}_f' \times A_f$

$$= 22.6607 \times 2.8274 \times 10^{-5}$$

$$= 6407.11 \text{ N}$$

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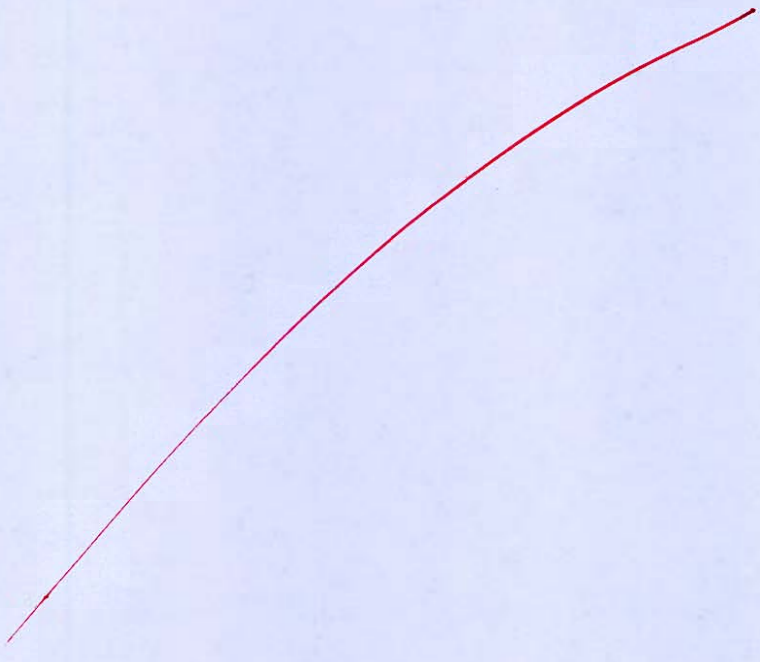

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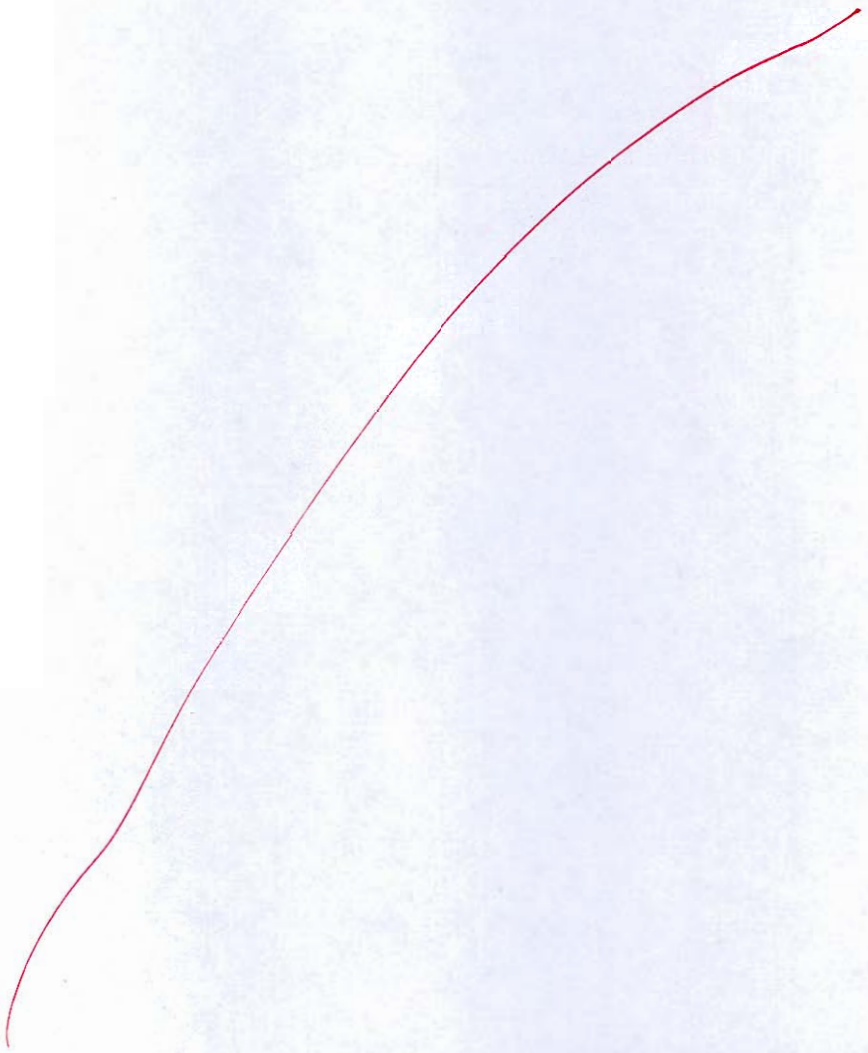
Q.7 (a) (i) What are the basis of Bravais crystal structures? Enlist different unit cell and space lattices under Bravais crystal systems.

(ii) Zinc has atomic radius of 0.133 nm and atomic weight of 65.39 g/mol. Calculate the theoretical density of zinc [HCP structure]

[10 + 10 = 20 marks]



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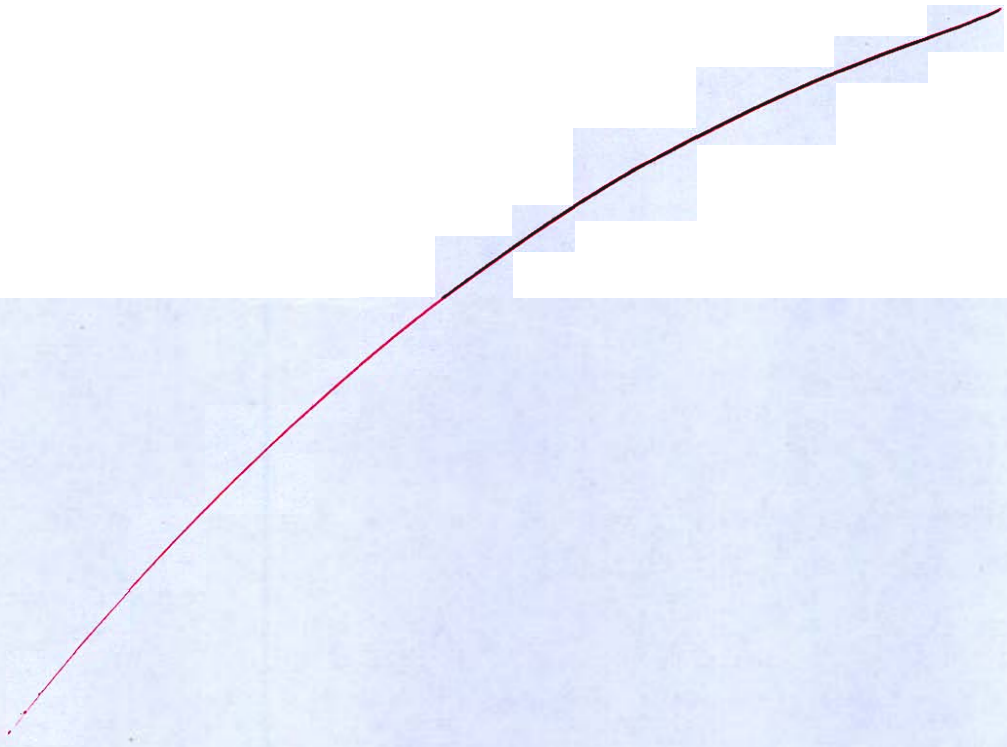

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Q.7 (b) What are various Rapid-Prototyping techniques? Briefly explain Stereolithography and Selective-Laser Sintering. Also mention their advantages and disadvantages.

[20 marks]

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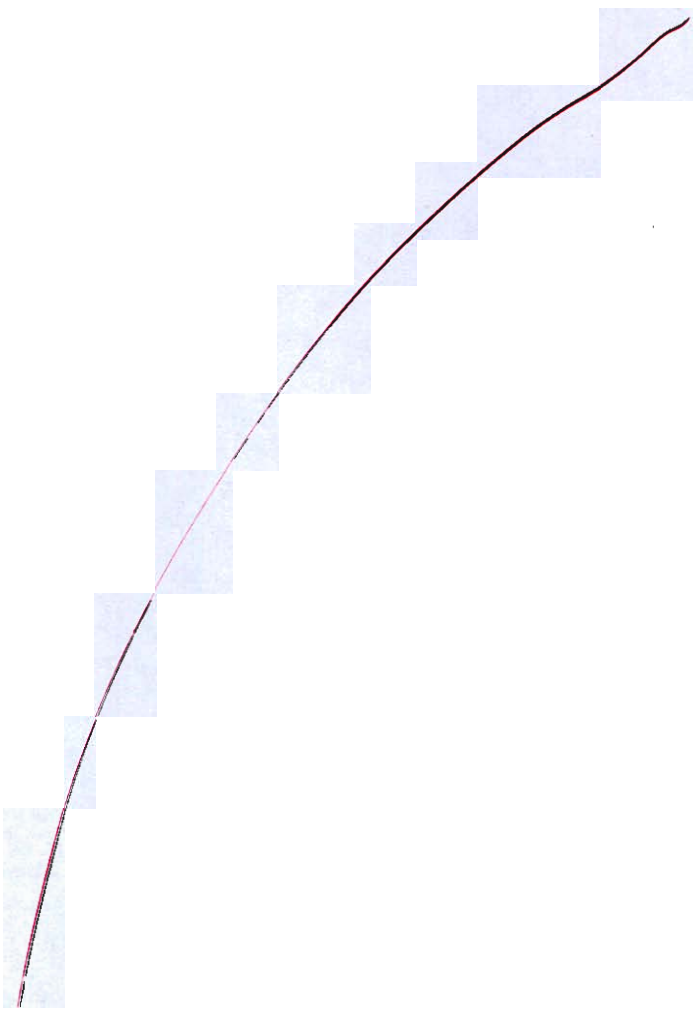

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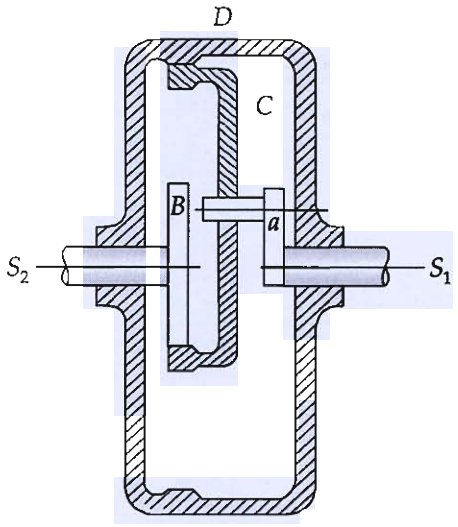
Q.7 (c) (i) Each wheel of a motorcycle is of 650 mm diameter and has a moment of inertia of 1.3 kg.m^2. The total mass of motorcycle and the rider is 200 kg and the combined centre of mass is 590 mm above the ground level when the motorcycle is upright. The moment of inertia of the rotating parts of the engine is 0.2 kgm^2. The engine speed is 6 times the speed of the wheels and is in the same sense. Determine the angle of heel necessary when the motorcycle takes a turn of 30 m radius at a speed of 50 km/h.

(ii) In the epicyclic gear train shown in figure, a gear C which has teeth cut internally and externally is free to rotate on a arm driven by the shaft S_1. It meshes externally with the casing D and internally with the pinion B. The gears have the following number of teeth:



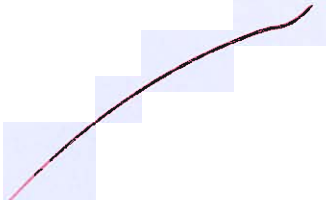
$T_B = 24$, $T_C = 30$ and 36, $T_D = 44$

Find the velocity ratio between

1. S_1 and S_2 when D is fixed
2. S_1 and D when S_2 is fixed

What will be the torque required to fix the casing D, if a torque of 300 Nm is applied to the shaft S_1?

[10 + 10 = 20 marks]



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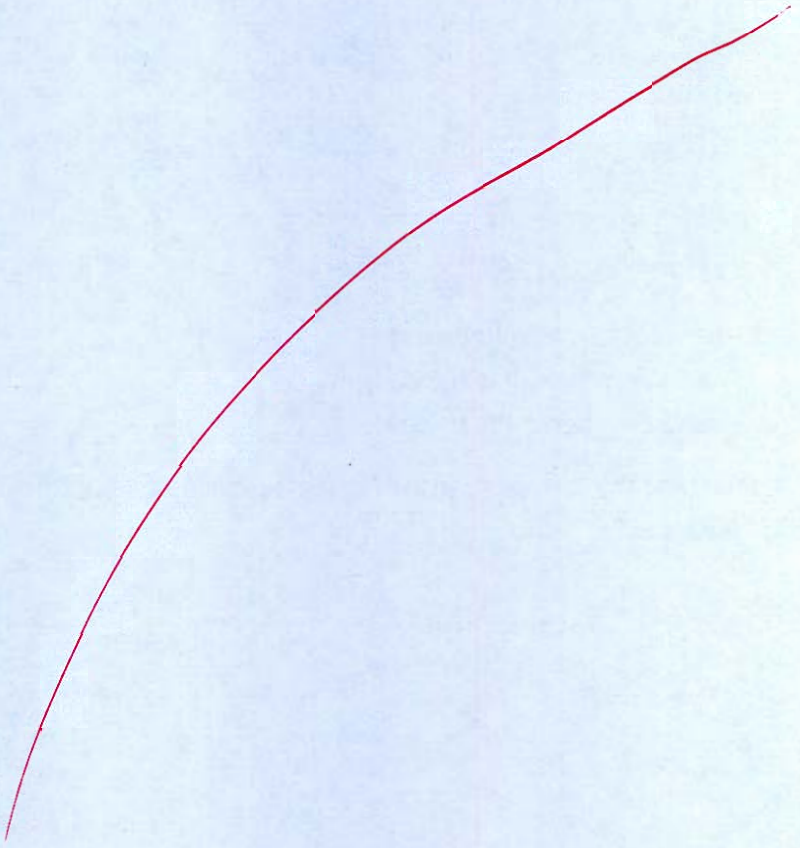

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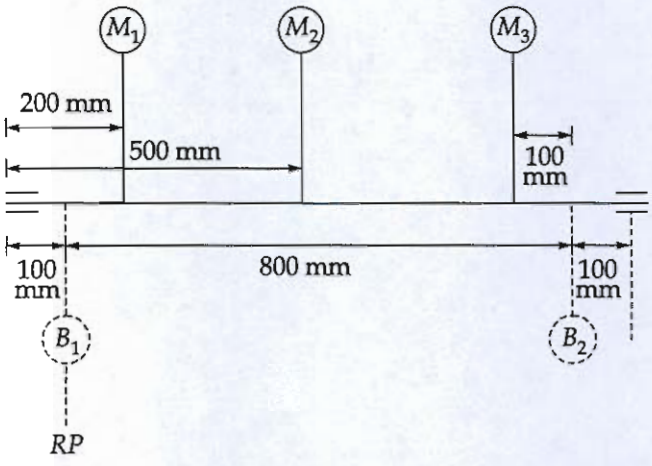
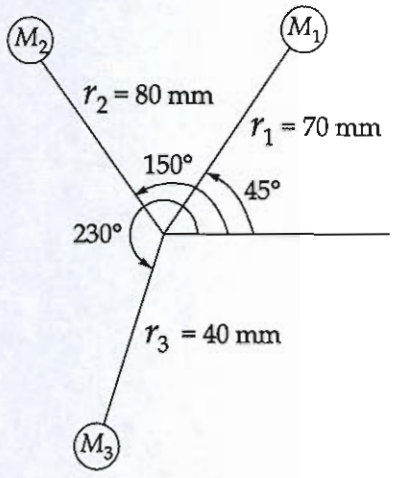
Q.8 (a) Three masses M_1 = 5 kg, M_2 = 6 kg and M_3 = 5 kg are rotating in different planes as shown in figure. Two balancing masses are B_1 and B_2 are placed at 100 mm from each at 80 mm radius. Find the magnitude and angular positions of the balancing masses.





[20 marks]

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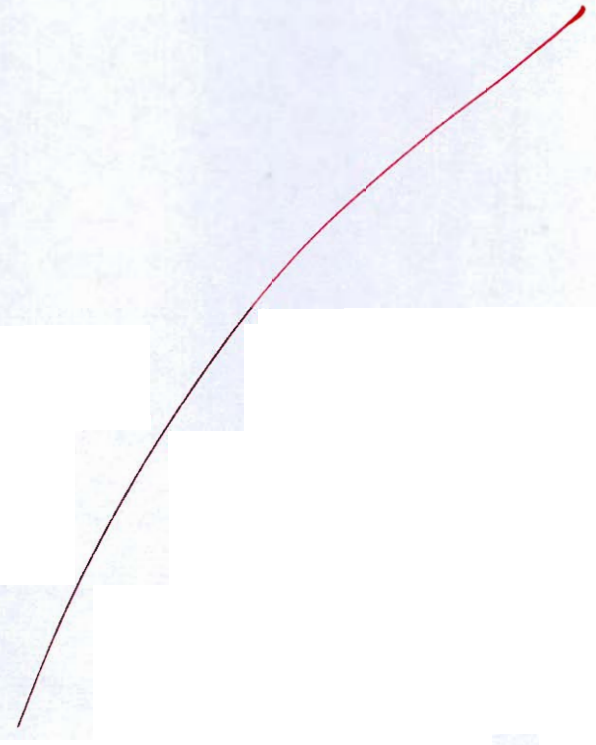
Q.8 (b) For a continuous and oriented fiber reinforced composite, the moduli of elasticity in longitudinal and transverse directions are 33 GPa and 3.65 GPa, respectively. If the volume fraction of fibers is 0.30. Determine the moduli of elasticity of fiber and matrix phases. Derive the relation used for modulus of elasticity in transverse direction.

[20 marks]



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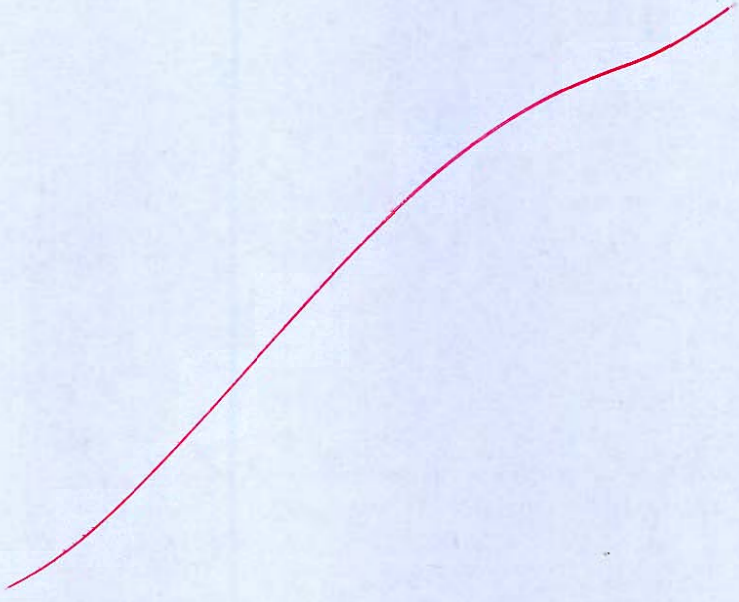

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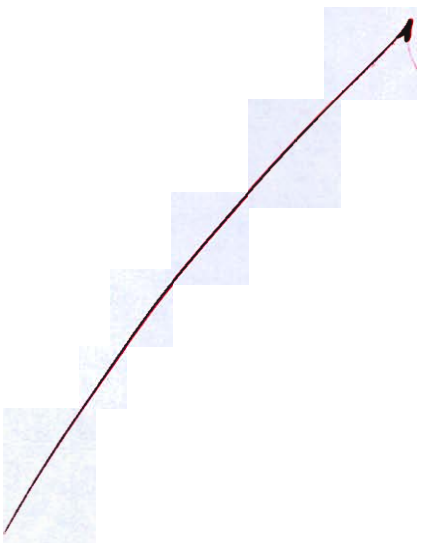
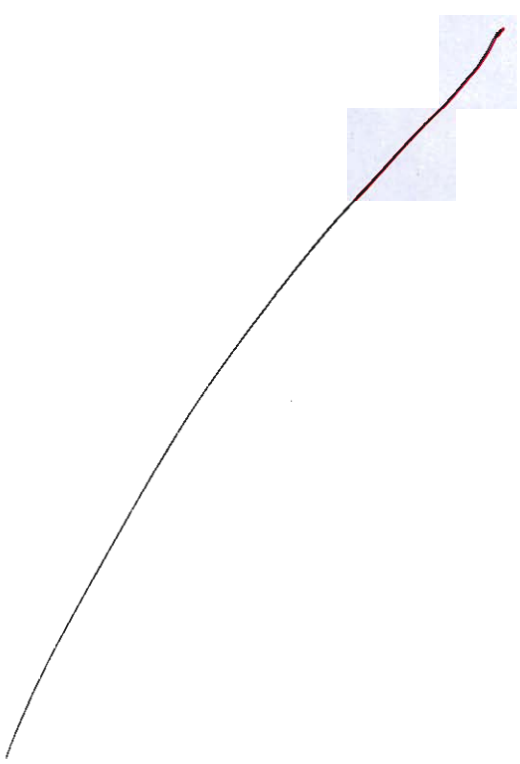


Q.8 (c) Why are Non-Ferrous Materials Important in engineering applications? Briefly discuss Aluminium, Copper, Zinc and Magnesium.

[20 marks]



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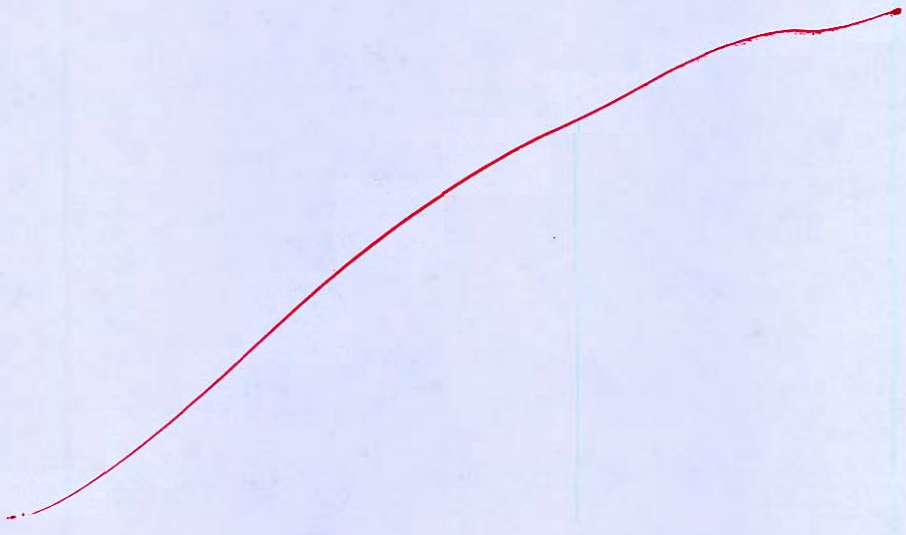

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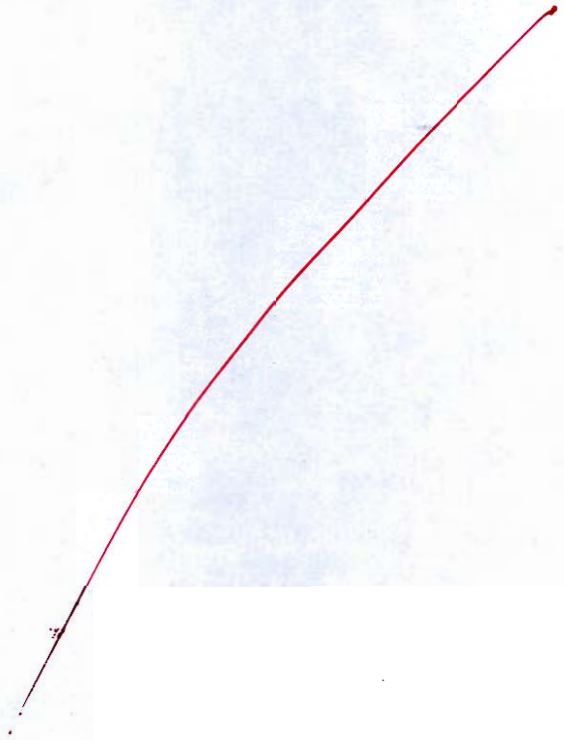

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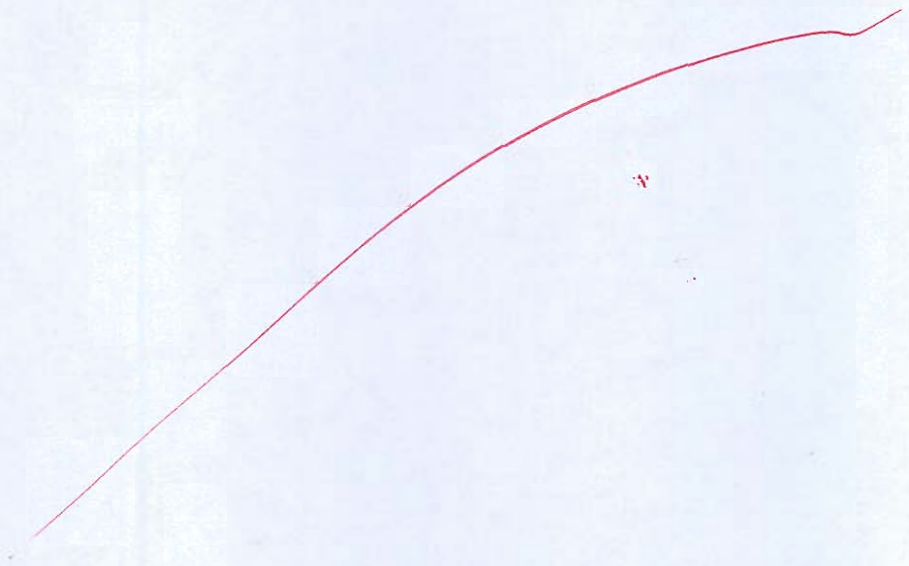

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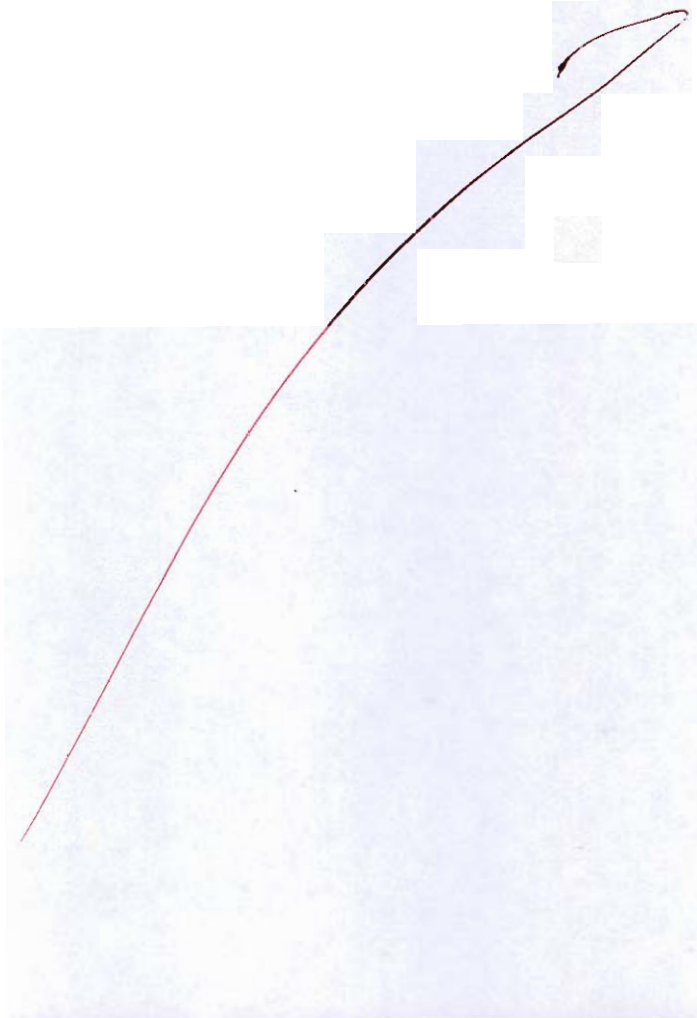

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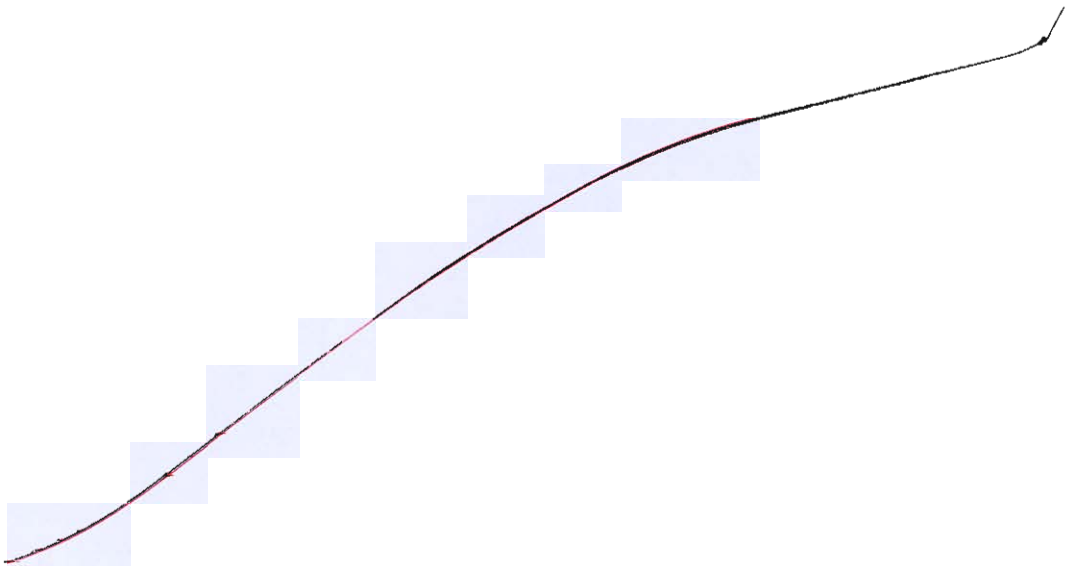

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