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	37
Q.2	—
Q.3	42
Q.4	24
Section-B	
Q.5	35
Q.6	—
Q.7	27
Q.8	
Total Marks Obtained	165

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.

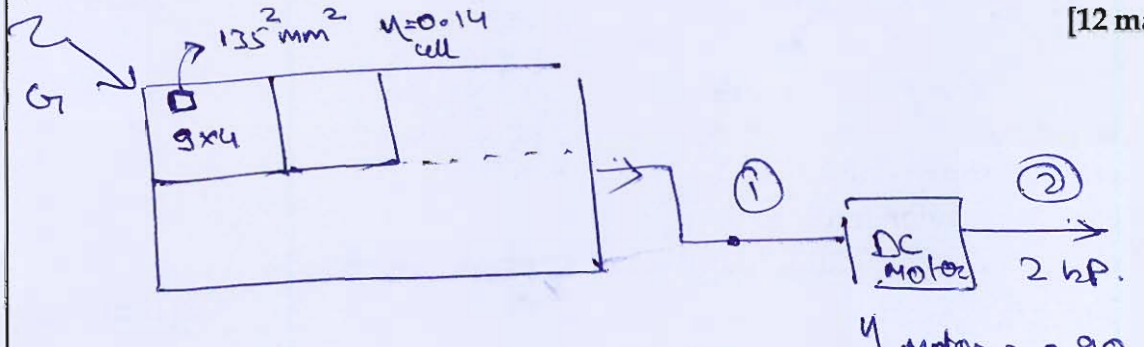
DO'S

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.

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]



$\eta_{motor} = 0.90$

$G_T = 1\ kW/m^2$

$1\ hp = 736\ W \rightarrow 746.$

$P_2 = 2\ hp = 2 \times 736 = 1472\ W$

$$P_1 = \frac{P_2}{\eta_{motor}} = 1635.555\ W$$

$$\eta_{cell} = 0.14 = \eta_{PV\ system} = \frac{P_1}{P_{i/p}}$$

$$P_{i/p} = \frac{1635.555}{0.14}$$

$$\left[(135^2 \times 10^{-6}) \times 10^3 \times 36\right] \times n = \frac{1635.555}{0.14}$$

$n = 17.806$

$n \approx 18$ Modules

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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]

Biogas requirement per day = Biogas Adults + Biogas 100 CP lamps

Biogas Adults = $5 \times 0.227\ m^3$

$= 1.135\ m^3$

Biogas CP lamps = $3 \times 0.126 \frac{m^3}{hr} \times 5$

$= 1.890\ m^3$

Biogas requirement per day $= 3.025\ m^3$ — (1)

Biogas produced by N cows $= N \times (10 \times 0.7) \times (0.18) \times (0.34)$

$= N \times 0.4284$ — (2)

eqn (1) = eqn (2)

$N = 7.061$ cows

$N \approx 8$ cows Ans

$$RT = 50 \text{ days} = \frac{V_{si}}{V_{s0}}$$

Collectable cow dung = $3 \times (10) \times 0.7$

= 56 kg.

Total mass for slurry (m) = 56 kg × 2

= 112 kg.

$$V_{s0} = \frac{m}{\rho_s} = \frac{112}{1090} \text{ m}^3 = 0.10275 \text{ m}^3$$

$$V_{si} = (50) \times \frac{112}{1090} = 5.1376 \text{ m}^3$$

$0.90\ V_{digester} = 5.1376$

$V_{digester} = 5.70846 \text{ m}^3$

12

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 needed ~~so that~~ —

(a) Production & consumption runs smoothly.

(b) Delay in the process is minimised.

(c) Cost of the process is optimised.

(d) Customer – shopkeeper relation is increased. i.e customer will ~~rely~~ believe on shopkeeper.

(e) To identify lead time & reorder level.

Ordered quantity should be optimised so, that total inventory cost ~~so~~ that ~~sto~~ includes stocking cost & ordering cost is minimised.

Which will lead to minimising the cost. (4)

(ii)

$D = 10,000$ unit/yr. $\quad C = ₹1$/unit

$C_0 = 100$ ₹

$C_h = 2.5$ ₹/unit/yr.

$$Q^* = EOQ = \sqrt{\frac{2C_0D}{C_h}}$$

$$\boxed{Q^* = 894.427 \text{ units}}$$

$$\boxed{N = \frac{D}{Q} = \frac{10,000}{Q^*} = 11.1803 \text{ order}}$$

$TN = 1$

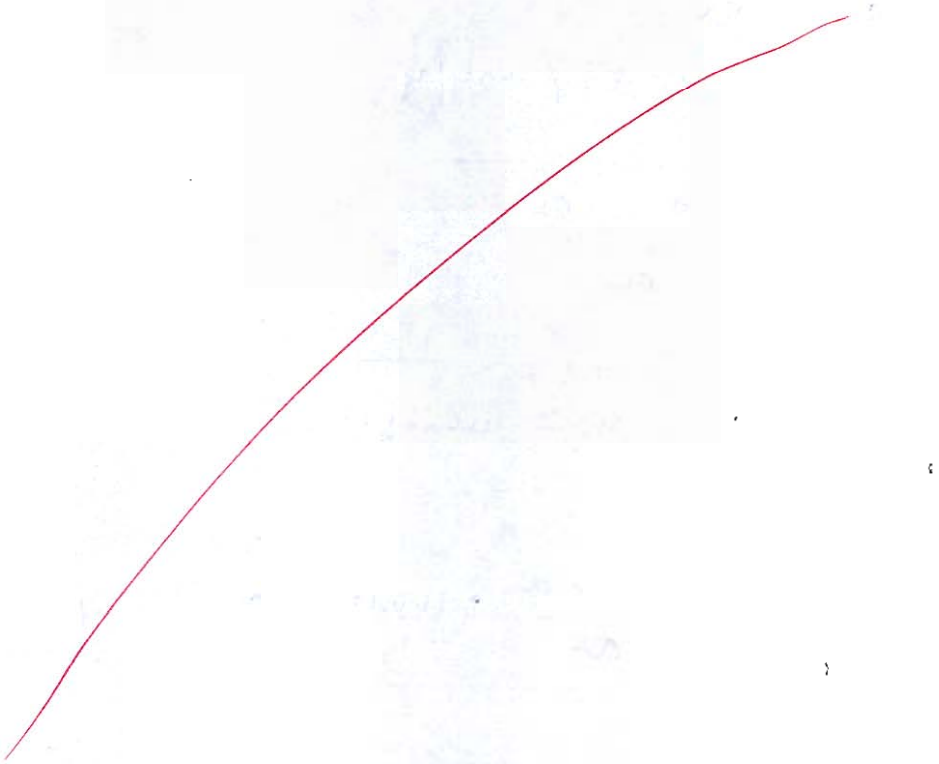
$T = \frac{1}{N} = 0.0894$ yrs. $\quad$ 1 yrs $\longrightarrow$ 365 days

$$\boxed{T = 32.646 \text{ days}}$$

$$TIC = \sqrt{2C_0DC_h} = 2236.067 \text{ ₹}$$

$$\boxed{TC = PXC + TIC = 12236.067 \text{ ₹}}$$

6



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]**

$\phi = 27°10' = 27.166°$

$n = 47$ (∵ 16th Feb)

$\overline{n} = ?$ (Not given)

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

$\delta = -12.954°$

$\omega_s = \frac{15°}{2} \times td = 60°$

$td = \frac{2}{15}\omega_s$

$\omega_s = 1.04719$ radians

~~$I_{ext} = I_{sc}\left[1 + 0.033\cos\left(\frac{360}{365}n\right)\right]$~~

~~$= I_{sc}[1 + 0.033\cos(\quad)]$~~

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

$\frac{kw}{m^2\text{-day}}$

$$\bar{H}_o = 24751.38102 \ \frac{kW}{m^2\text{-day}}$$

↳ $\bar{H}_o = H_o$ By Klein's recommendation

$$\bar{N} = \frac{2}{15} \omega_s = td$$

$$= 8 \text{ hrs.}$$

(5)

$$\frac{\bar{H}_g}{\bar{H}_o} = \left[0.25 + 0.57 \left(\frac{\bar{n}}{\bar{N}}\right)\right]$$

$$\bar{H}_g = (24751.38102) \left[(0.25) + (0.57)\left(\frac{\bar{n}}{\bar{N}}\right)\right]$$

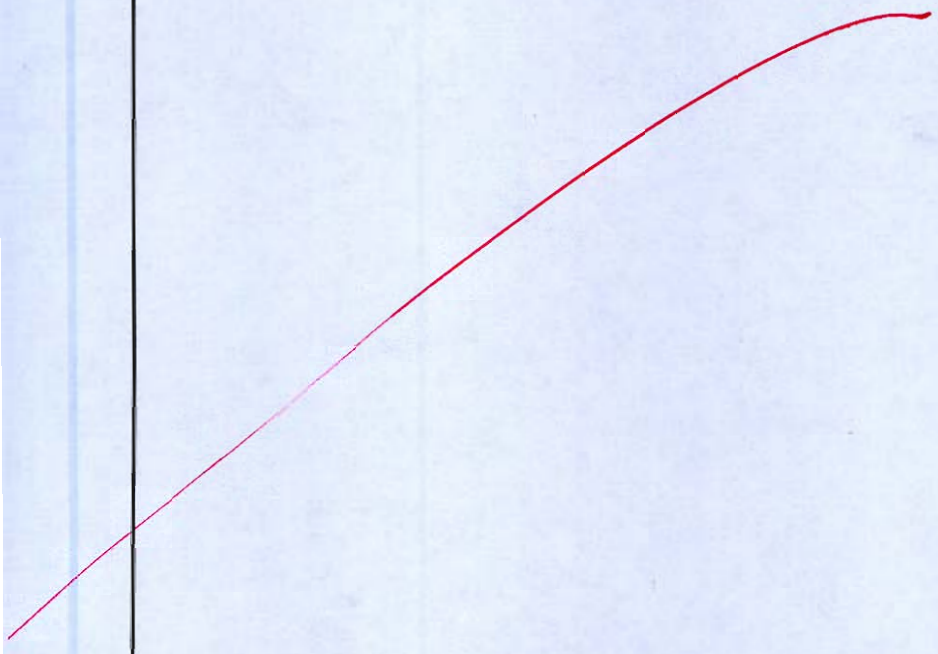
↳ $\frac{kw}{m^2\text{-day}}$

$\bar{n}$ is not given in question ∴ assuming $\bar{n} = \bar{N}$.

$$\bar{H}_g = 20296.13243 \ \frac{kW}{m^2\text{-day}}$$

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

[12 marks]



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.

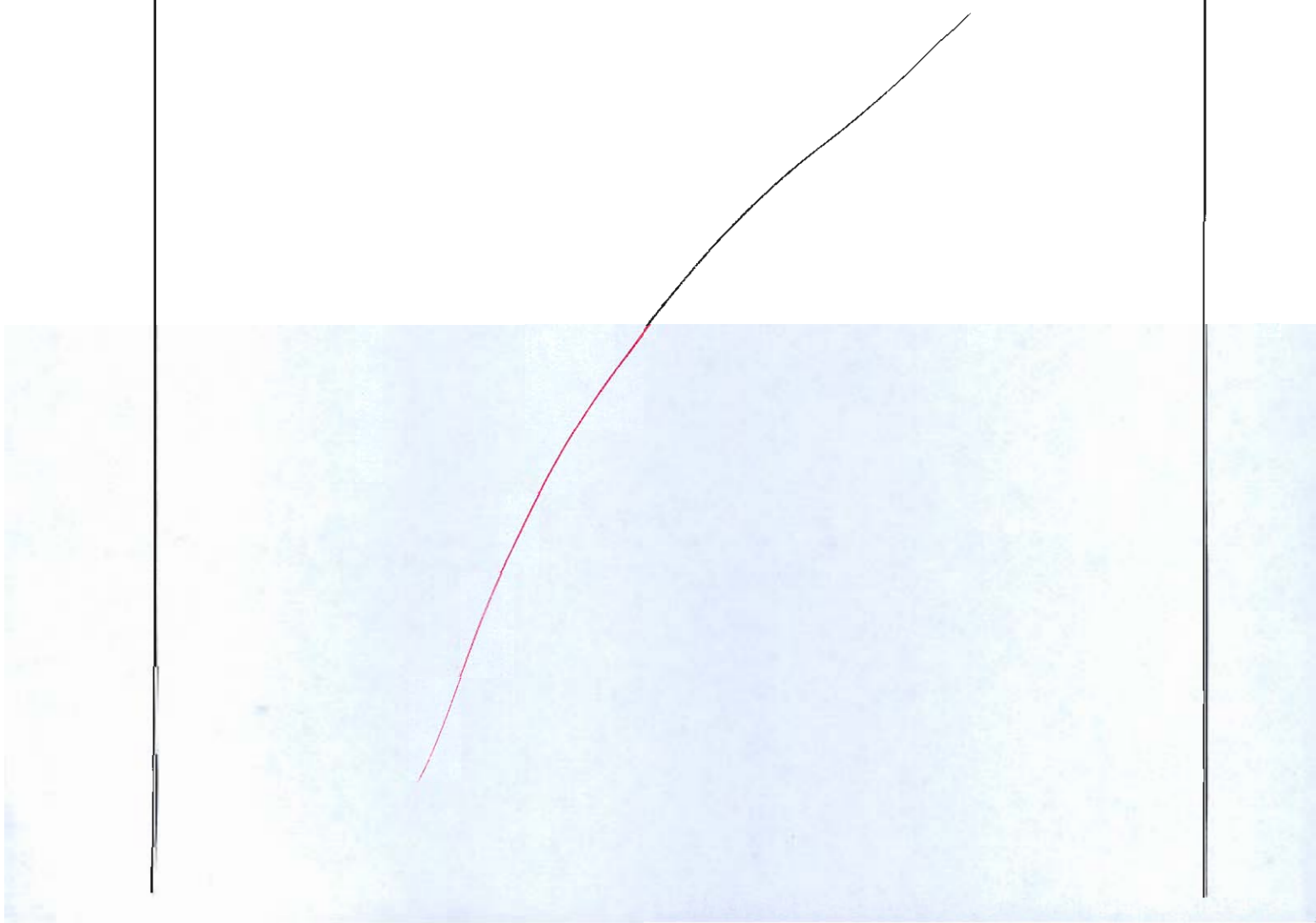
(ii) Power extracted by the turbine.

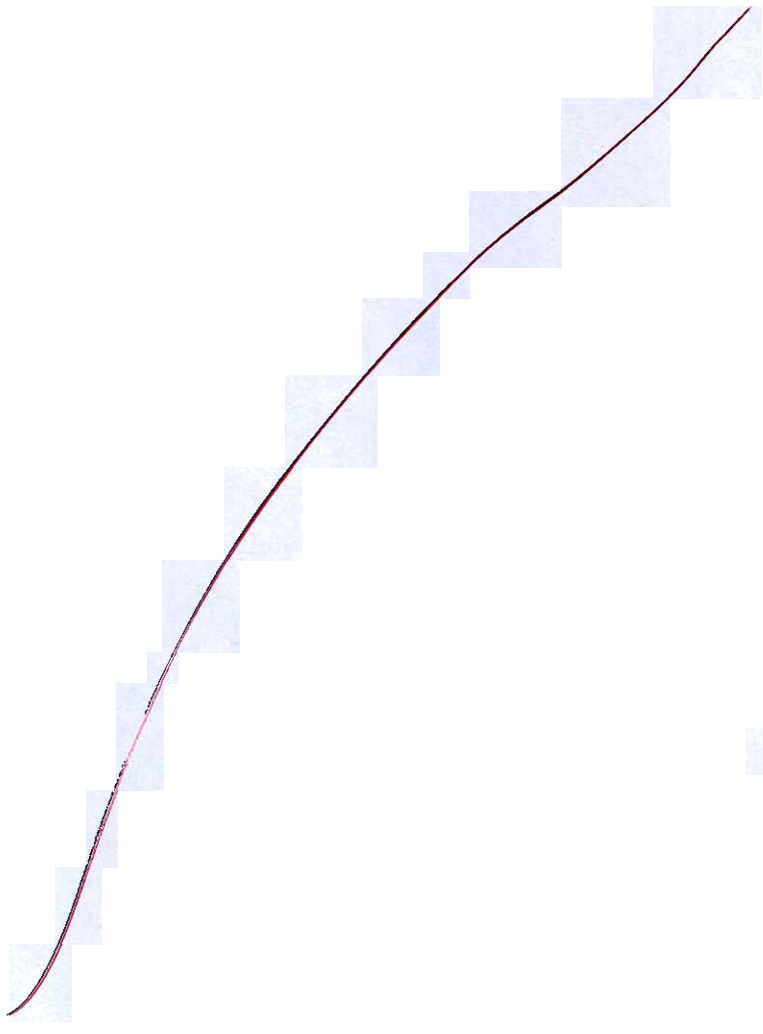
(iii) Electrical power generated.

(iv) Axial thrust on the turbine.

(v) Maximum axial thrust on the turbine.

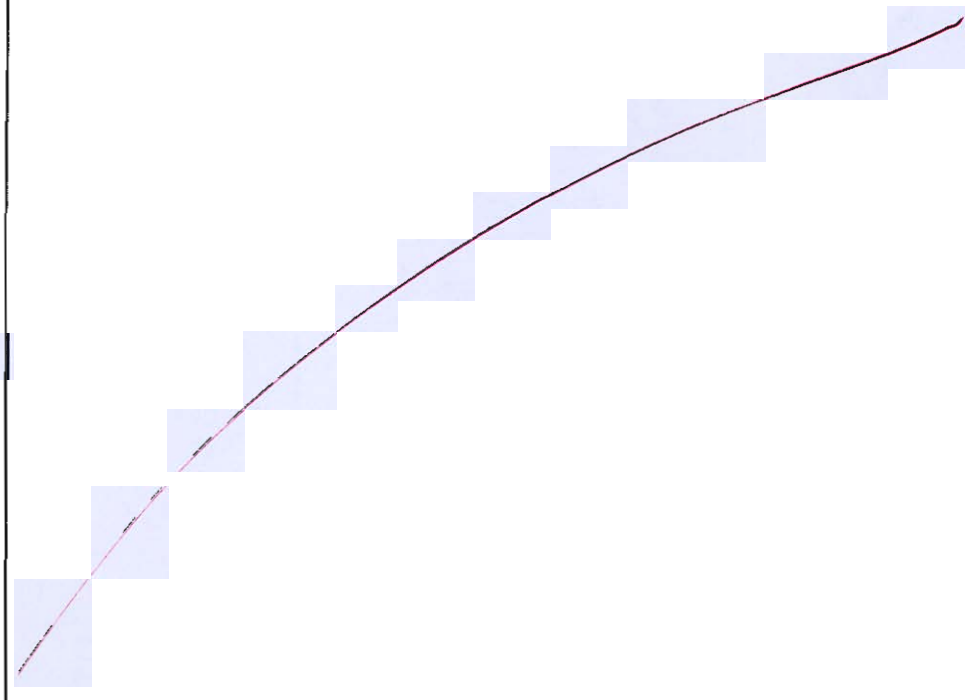
[10 + 10 = 20 marks]

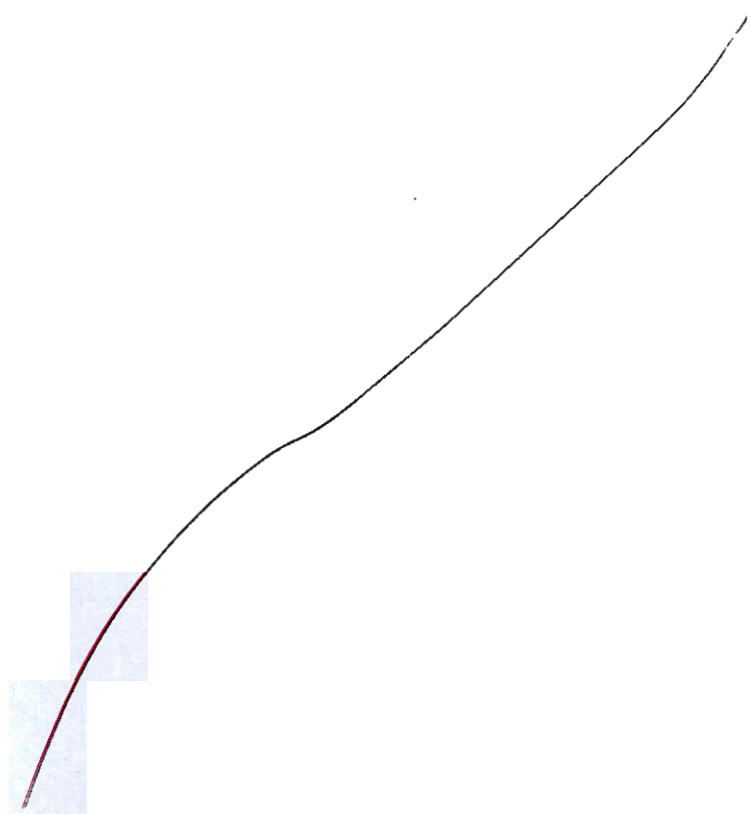


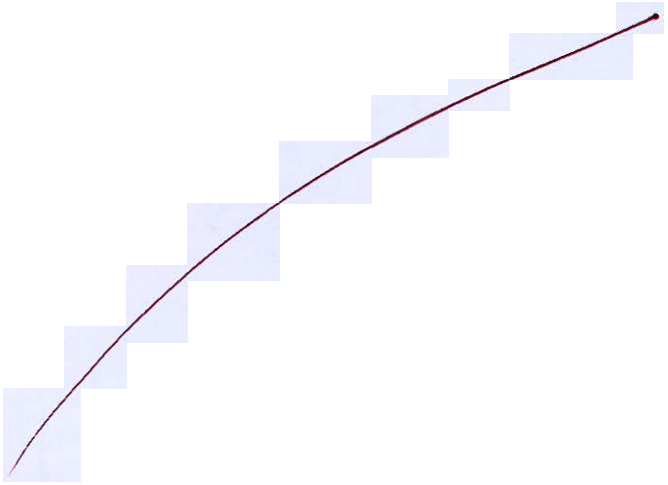


Q.2 (b) What are the differences between destructive and non-destructive tests? Explain with examples. Also, briefly explain various non-destructive testing methods used in engineering practice.

[20 marks]



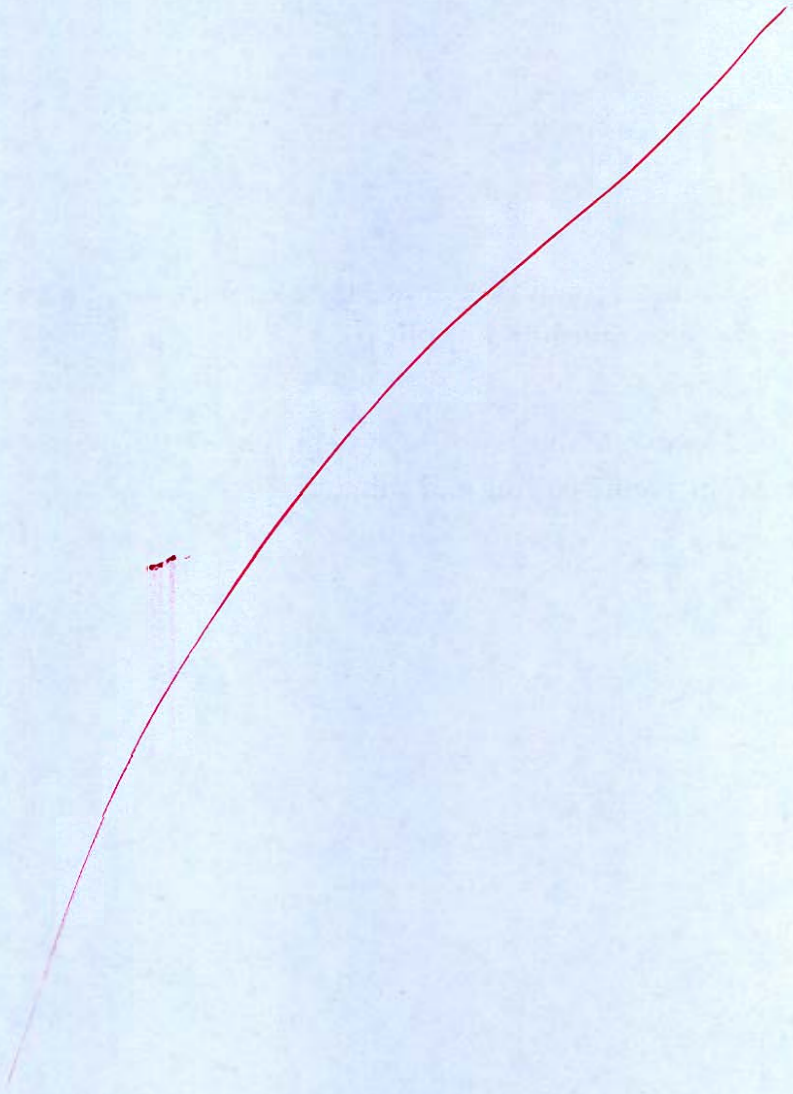




Q.2 (c) (i) Discuss the various condition monitoring technique used in engineering systems. Explain the principles and application of vibration, noise and wear debris monitoring.

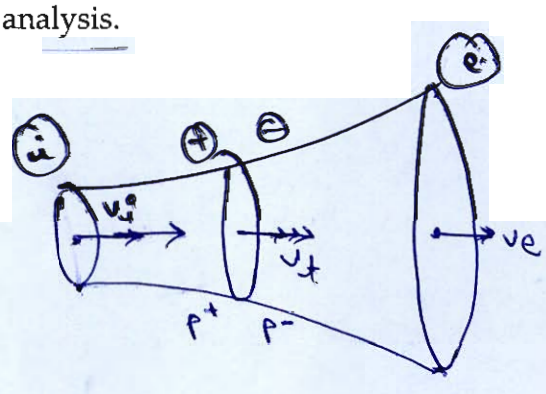
(ii) What is a Flexible Manufacturing System (FMS)? What are its importance and advantages in manufacturing and automation?

[10 + 10 = 20 marks]



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]



Axial Thrust = $\dot{m}(-v_e + v_i)$

$F_A = \dot{m}(v_i - v_e)$ — (A)

$\dot{m} = \rho_i A_i v_i = \rho_t A_t v_t = \rho_e A_e v_e$

$A_i v_i = A_t v_t = A_e v_e$.

$\rho_i = \rho_t = \rho_e$ (assume density of air same)

B/w ① → ④

$$P_i + \frac{1}{2}\rho v_i^2 = P^+ + \frac{1}{2}\rho v_t^2 \quad \text{(1)}$$

B/w ⑤ → ⑥

$$P^- + \frac{1}{2}\rho v_t^2 = P_e + \frac{1}{2}\rho v_e^2 \quad \text{(2)}$$

Add ① ④ ②

$$\frac{1}{2}\rho v_i^2 + \cancel{\frac{1}{2}\rho v_t^2} + P^- + \cancel{P_i} = P^+ + \cancel{P_e} + \cancel{\frac{1}{2}\rho v_t^2} + \frac{1}{2}\rho v_e^2$$

$$\frac{1}{2}\rho v_i^2 + P^- = P^+ + \frac{1}{2}\rho v_e^2$$

$$(P^+ - P^-) = \frac{1}{2}\rho (v_i^2 - v_e^2)$$

$$F_A = (P^+ - P^-) A_t = \frac{1}{2}\rho A_t (v_i^2 - v_e^2) \quad \text{(B)}$$

Eqn (A) = Eqn (B)

$$\dot{m}(v_i - v_t) = \frac{1}{2}\rho A_t (v_i - v_e)(v_i + v_e)$$

$$\cancel{\rho A_t} v_t (v_i - v_e) = \frac{1}{2}\cancel{\rho A_t} (v_i - v_e)(v_i + v_e)$$

$$\boxed{v_t = \frac{v_i + v_e}{2}} \quad \text{(3)}$$

$a = \dfrac{v_i - v_t}{v_i}$ = Axial induction factor.

$v_t = v_i - a v_i = (1-a) v_i$

$v_e = (1-2a) v_i$ (using eqn ③).

By eqn (B) —

$$F_A = \frac{1}{2}\rho A_t\left(v_i^2 - (1-2a)^2 v_i^2\right)$$

$$= \frac{1}{2}\rho A_t v_i^2\left(1 - (1+4a^2-4a)\right)$$

$$= \frac{1}{2}\rho A_t v_i^2\left(4a - 4a^2\right)$$

$$= \frac{1}{2}\rho A_t v_i^2\, 4a(1-a)$$

$$\boxed{F_A = (4a)(1-a)\ \frac{1}{2}\rho A_t v_i^2}$$

By eqn (B)

$v_e = 0$ then $F_A = F_{A_{max}}$.

$$F_{A_{max}} = \frac{1}{2}\rho A_t(v_i^2 - 0)$$

$$\Rightarrow \boxed{F_A = 4a(1-a)\,(F_A)_{max}.}$$

$$\text{Power } (P) = (F_A)\,v_t.$$

$$= (4a)(1-a)(1-a)\,v_i \times \frac{1}{2}\rho A_t v_i^2$$

$$P = (4a)(1-a)^2\left(\frac{1}{2}\rho A_t v_i^3\right)$$

$$\boxed{P = (C_p)\left(\frac{1}{2}\rho(A_t)v_i^3\right)}$$

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

For maximum power —

$$\frac{d C_p}{da} = 0$$

$$4\left[a\,2(1-a)(-1) + (1-a)^2(1)\right] = 0$$

$$2(1-a)(a) = (1-a)^2$$

$$2a = 1-a$$

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

$$C_{p_{max}} = 4 \times \frac{1}{3}\left(1-\frac{1}{3}\right)^2 = \frac{16}{27}$$

$\boxed{C_{p_{max}} = \frac{16}{27}}$ → Betz limit.

$$C_f = 4a(1-a)$$

$$C_f = \frac{4}{3}\left(1-\frac{1}{3}\right) = \frac{4}{3} \times \frac{2}{3} = \frac{8}{9}$$

$\boxed{C_f = \frac{8}{9}}$

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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]

On the Basis of electrolyte type –

1) PEMFC (Polymer electrolyte Membrane fuel cell)
2) PAFC (Phosphoric acid fuel cell) (H_3PO_4 is used as electrolyte)
3) AFC (Alkaline fuel cell). (KOH is used as electr.)
4) MCFC (Molten carbonate fuel cell) (Carbonates of alkali metals like, Na, K, Li)
5) SOFC (Solid oxide fuel cell) (ZrO is used as solid electr.)
6) DMFC (Direct Methanol fuel cell) (CH_3OH is used in place of fuel H_2)

On the Basis of chemical nature

1.) Acidic
2.) Neutral
3.) Alkaline.

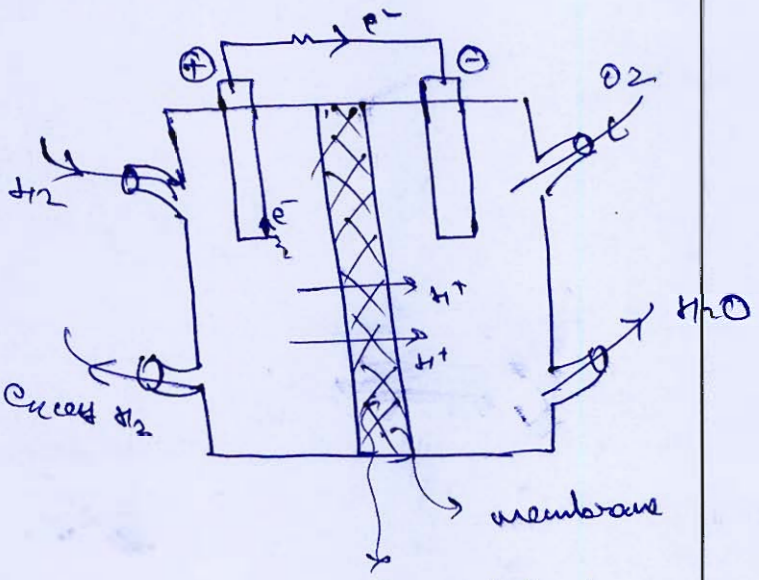
On the Basis Temperature –

1.) High temp → (SOFC & MCFC) (500°C – 800°C)
2.) Medium temp. → (PAFC) (100° – 500°C)
3.) Low temp. → (PEMFC, AFC) (50° – 80°)

PEMFC

Components —

1.) 2 electrodes cathode & Anode.
2.) semi permeable membrane. (allows ions to pass & restrict e^-)
3.) fuel H_2 and Oxidant O_2.
4.) Container & resistance wire.



Principle -

→ It is based on the principle of reverse of electrolysis.

Anode.

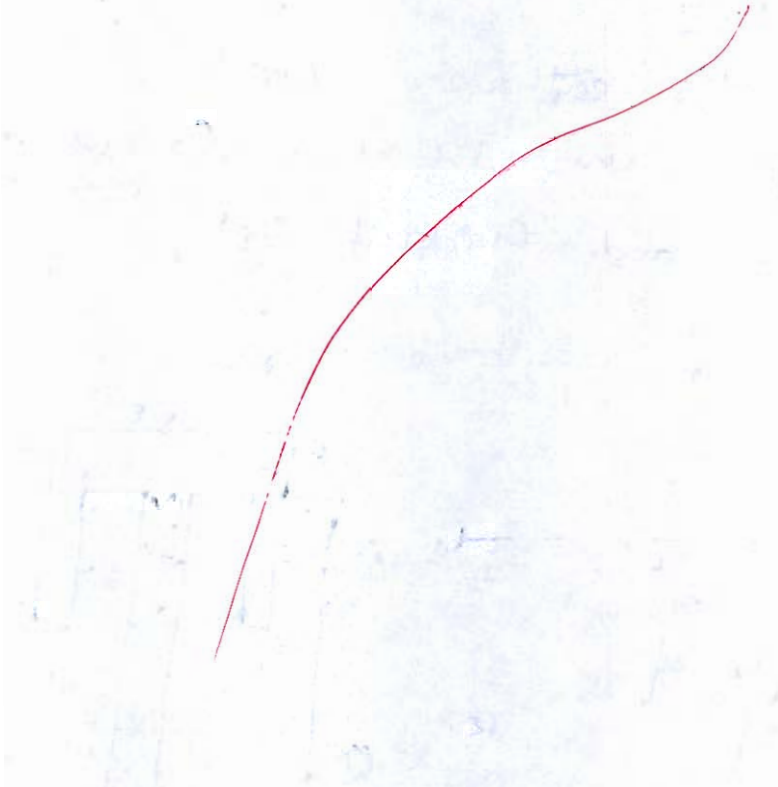
$$H_2 \rightarrow 2H^+ + 2e^-$$

Cathode

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

16

e^- produced is passed through anode. to cathode and the electricity is generated due to the movement of e^-s. in the opposite direction of movement of e^-s.



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]

(i)

$\lambda = 0.00034 \frac{\text{failure}}{\text{hr}}$ (assume 24 hrs → 1 day)

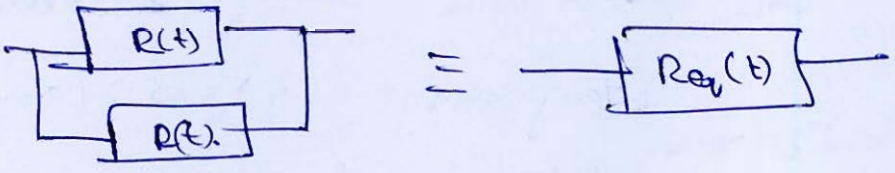
$R(t) = e^{-0.00034\,t}$ (t is in hrs)

$R(t = 30\text{ day}) = e^{-0.00034 \times 30 \times 24}$

$= 30 \times 24\text{ hrs}$

$R = 0.782$ → Ans (i)

(20)



$$R_{eq}(t) = \left[1 - (1 - R(t))^2\right]$$

$$= 1 - (1 - e^{-\lambda t})^2$$

Reliability funcn $= 1 - (1 + e^{-2\lambda t} - 2e^{-\lambda t})$

$$R_{eq}(t) = 2e^{-\lambda t} - e^{-2\lambda t}$$ Ans $\rightarrow (\lambda = 0.00034)$

$= e^{-\lambda t}(2 - e^{-\lambda t})$

$$F(t) = 1 - R(t) = 1 - 2e^{-\lambda t} + e^{-2\lambda t}$$ Ans

↳ Hazard Rate funcn.

$$R_{eq}(30) = 2e^{-0.00034(30\times24)} - e^{-2\times0.00034(30\times24)}$$

$R_{eq}(30) = 0.9528$ Ans

↳ Reliability for 30 days.

(6)

(ii)

3 eggs/week ← Old hens → ~~2 ₹/each~~ 2 ₹/each ✓

5 eggs/week ← Young hens → 5 ₹/each ✓

1 egg = $\frac{30}{100} = 0.3$ ₹ ✓

Total hens $\leq$ 20 hens ✓

Total hens ₹ spent $\leq$ 80 ₹ ✓

1 Hen food = 1 ₹/week ✓

Profit $\geq$ 5.8 ₹/week.

Let x old hens & y young hens are purchased.

$$Z = x \text{ old hens} \times \frac{3(\text{eggs} \times 0.3)\ ₹}{\text{week} \quad \text{hen.}} + y \times 5 \times 0.3$$

Calculate Per week

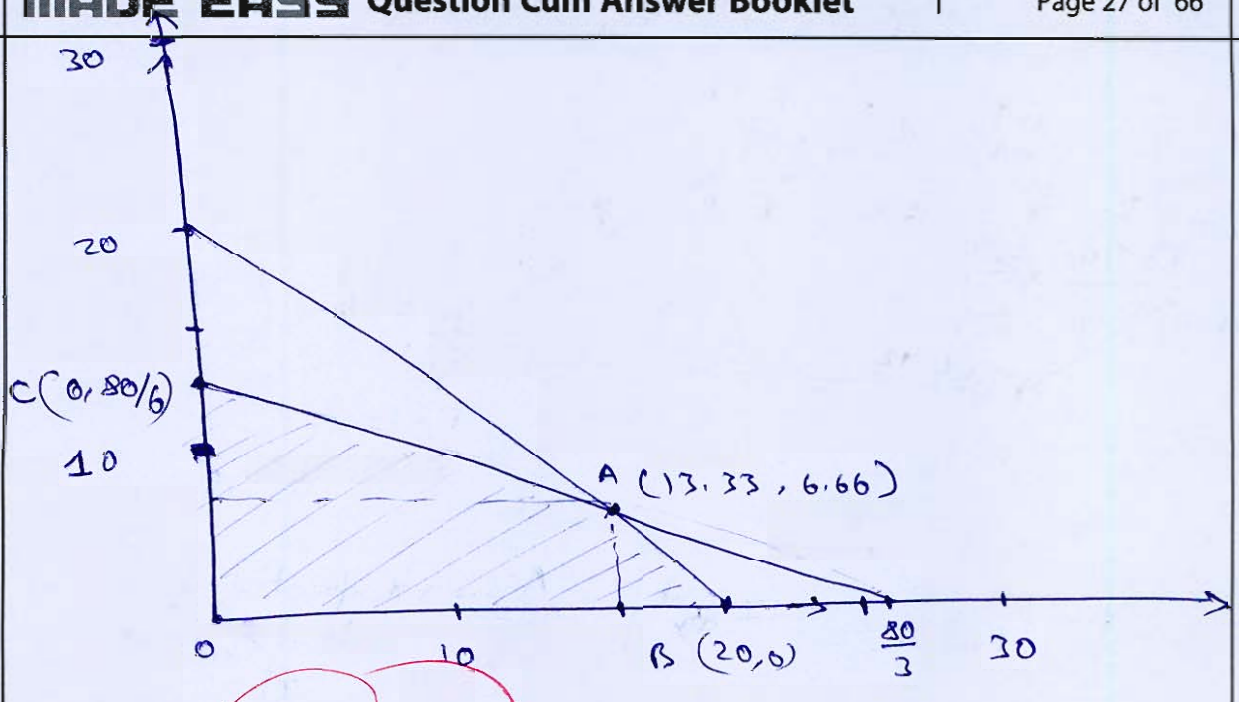
$$Z = 0.9x + 1.5y \rightarrow T.$$

$$x + y \leq 20 \rightarrow \frac{x}{20} + \frac{y}{20} \leq 1$$

3

$$y + x + 2x + 5y \leq 80$$

$$3x + 6y \leq 80 \rightarrow \frac{x}{\frac{80}{3}} + \frac{y}{\frac{80}{6}} \leq 1$$



Z_A = 21.987 ₹

Z_C = 20 ₹

Z_B = 18 ₹

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

$t_E = \frac{t_0 + t_p + 4t_m}{6}$

Activity	t_0	t_m	t_p	t_E	$\sigma = \frac{t_p - t_0}{6}$
1 - 2	1	1	7	2	1
1 - 3	1	4	7	4	1
1 - 4	2	2	8	3	1
2 - 5	1	1	1	1	0
3 - 5	2	5	14	6	2
4 - 6	2	5	8	5	1
5 - 6	3	6	15	7	2

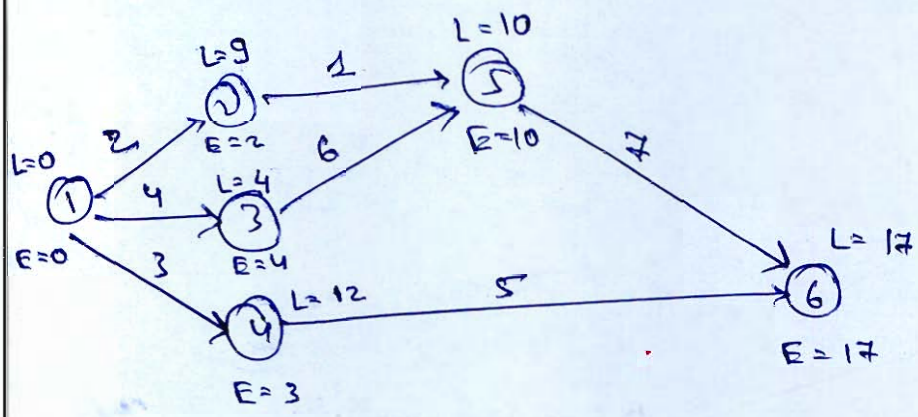
(i) Draw the project network and identify all the paths through it.

(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]



$T_{Project} = 17$ weeks

Ans ⇒ Expected Proj length

Variance Proj $= \sigma^2_{Project} = \left(\Sigma \sigma_{i\to j}\right)^2$

$= 1^2 + 1^2 + 1^2 + 0^2 + 2^2 + 1^2 + 2^2$

$= 3 + 4 + 1 + 4$

Variance Project $= 12$ Ans.

12

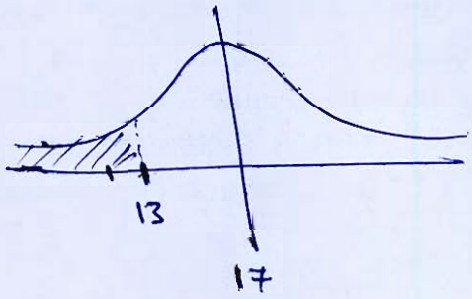
$\sigma_{proj} = \sqrt{12} = 3.464$ Ans

(iii)

(1) $T_S = T_E + z\,\sigma_{pr}$

$13 = 17 + z\,\sigma_{pr}$

$z = \dfrac{-4}{3.464}$

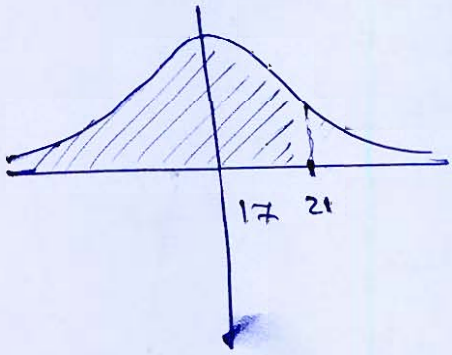


Prob = 12.41 %

(2)

$T_S = 21 = 17 + z\,\sigma_{pr}$

$z = +1.547$



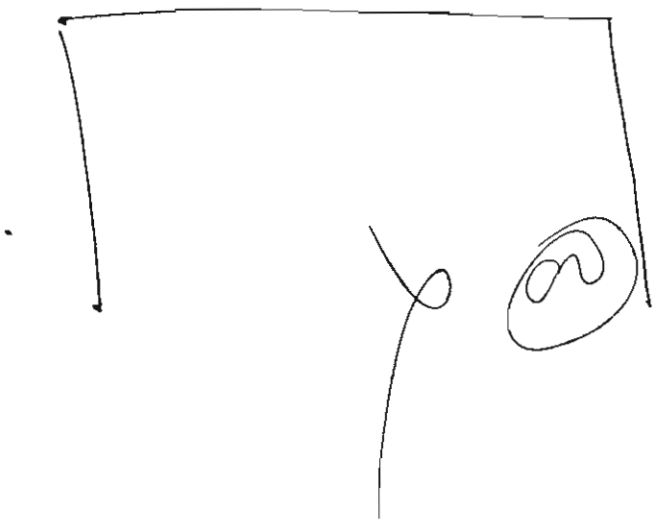
Prob = 87.589 %

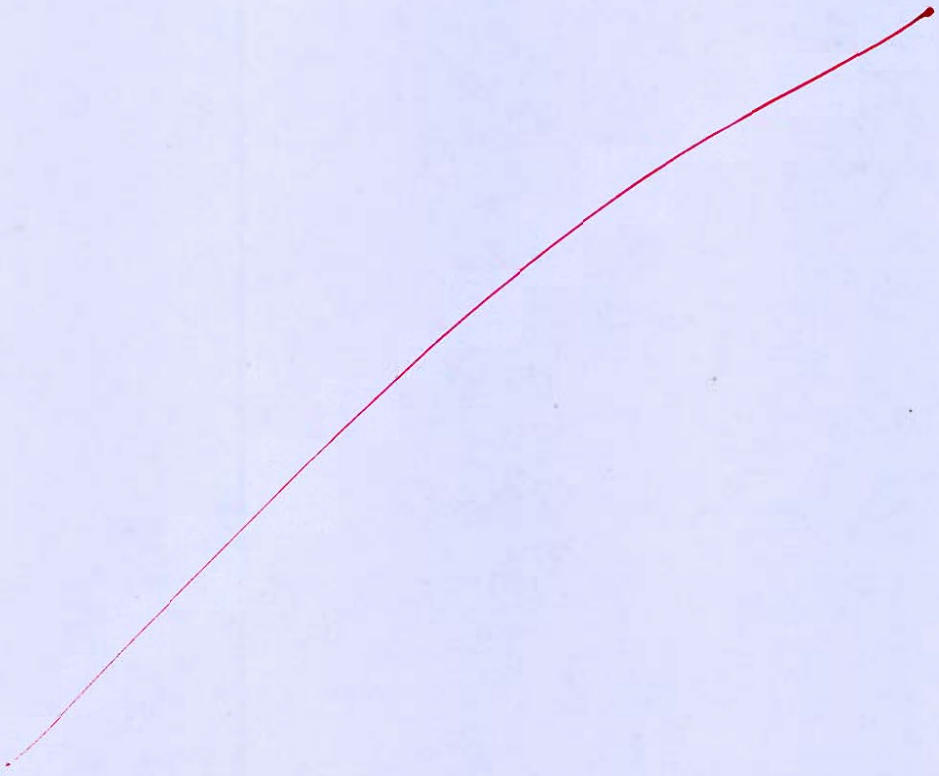
Q.4 (b) A manufacturer of complex electronic equipment has just received a sizable contract and plans to subcontract part of the job. He has solicited bids for 6 subcontracts from 3 firms. Each job is sufficiently large and any firm can take only one job. The table below shows the bids as well as the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

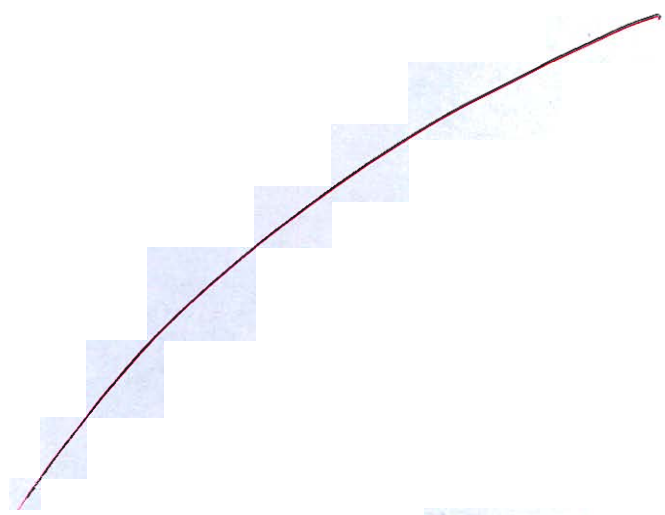
Firm \ Job	1	2	3	4	5	6
1	44	67	41	53	48	64
2	46	69	40	45	45	68
3	43	73	37	51	44	62
Internal	50	65	35	50	46	63

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

[20 marks]







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]

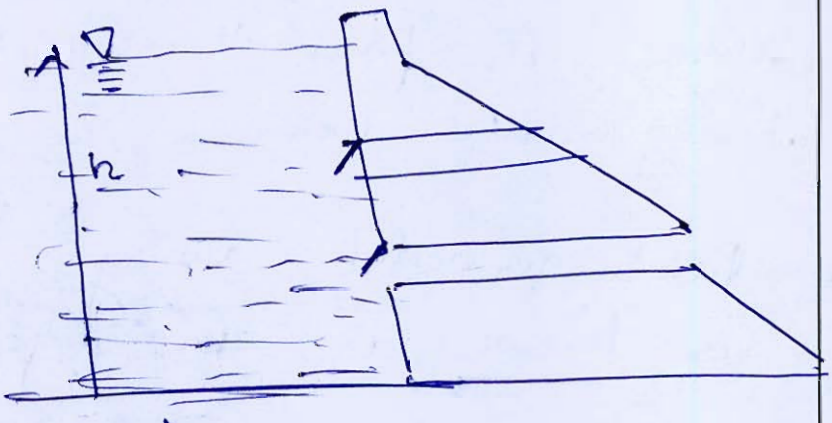
Tidal Plants on the Basis of Basin & their mode

1.) Single Basin – Single effect scheme.
(Power produced either in ebb or in flood cycle.)

2.) Single Basin – Double effect scheme.
(Power is produced in both ebb as well as flood cycle.)

3. Double Basin.

Components of Tidal powerplant



1.) dam
(for storing water)

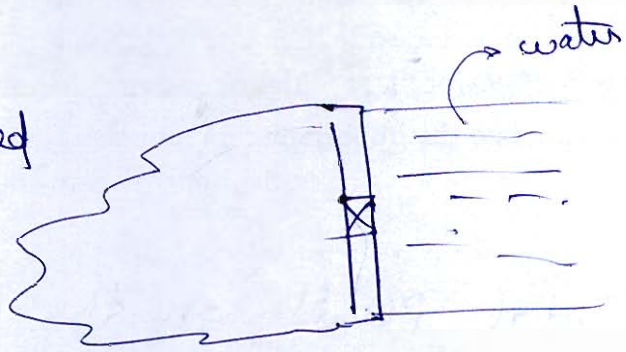
2.) sluice ways.
& wicket gates.

3.) Turbine – Generator Sets

* Turbines used can be both way operated. i.e multi way turbine.
* Turbines used can be single way.

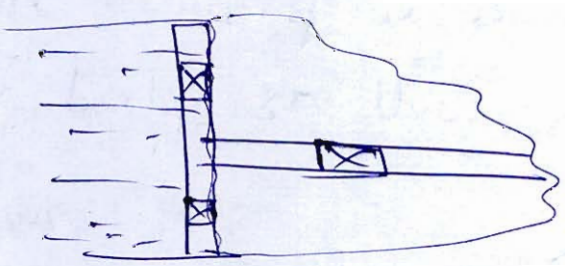
Single Basin

→ Here power developed is intermittent.



Double Basin

→ The main advantage of double basin is that this generates continous power.

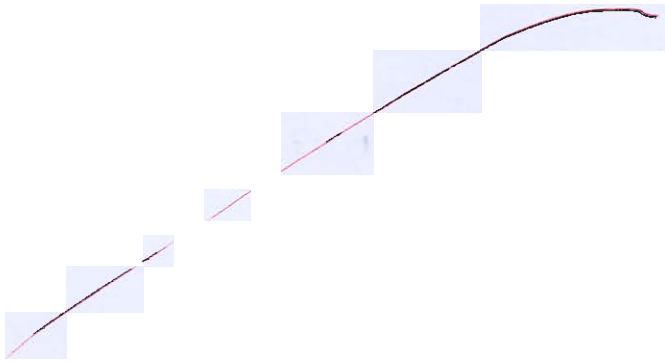


→ That is during High Tide as well as low tide water is stored in the respective basin and can be allowed to pass through the turbine to generate power.

12

→ Power generated during low tide is known as Ebb generation cycle.

→ Power generated during high tide is known as flood generation cycle.



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]

$a = 0.8 \quad b = 1.5 \quad K = 800 \text{ MPa} \quad n = 0.17$

$\sigma = 800 \epsilon^{0.17}$

$\sigma = (a + b \ln R)\sigma_0$ (R = Extrusion Ratio)

$$R = \frac{A_0}{A_f} = \frac{d_0^2}{d_f^2} = \frac{40^2}{15^2} = 7.1111 \rightarrow \text{Ans}$$

$\epsilon = \frac{V_{i_0} - V_f}{V_{i_0}}$

$d_i^2 l_i = d_f^2 l_f$

$40^2 (110) = 15^2 l_f$

$l_f = 782.222 \text{ mm}$

$$\epsilon = \ln\left(\frac{A_0}{A_f}\right)$$

$$= \ln(7.1111)$$

$$\epsilon = 1.9616$$

Ans ⇒ Extrusion strain

$$\bar{\sigma}_0 = \frac{K\epsilon^n}{n+1} = \frac{(800)(1.9616)^{0.17}}{1.17}$$

$$\bar{\sigma}_0 = 766.739 \text{ MPa}$$

$$\bar{\sigma} = \bar{\sigma}_0(0.8 + 1.5(1.9616))$$

$$\bar{\sigma} = 2869.446 \text{ MPa}$$

$$F_{ram} = \bar{\sigma} \times A$$

$$= (2869.446) \times \frac{\pi}{4} \times (40^2 - 15^2) \times \frac{1}{10^6}$$

$$= 3.09877 \text{ MN}$$

(12)

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]

$A_{sprue} : A_{runner} : A_{gate}$

1 : 2 : 3.

Choke area $= C.A = \dfrac{m}{\rho\, t_f\, C_D \sqrt{2gh}}$

$h = 12\times10^{-3}$ m.

$m = w = 30$ kg.

assuming $t_f = k\sqrt{w}$ is in second

$t_f = k\sqrt{w} = 2.3\sqrt{w} = 2.3\sqrt{30}$ sec.

$C_D = 0.9$

$\rho = 7900$ kg/m3

$$C.A = \frac{30}{(7900)(2.3\sqrt{30})(0.9)\sqrt{2\times9.81\times12\times10^{-3}}}$$

$= 6.90276\times10^{-4}$ m^2

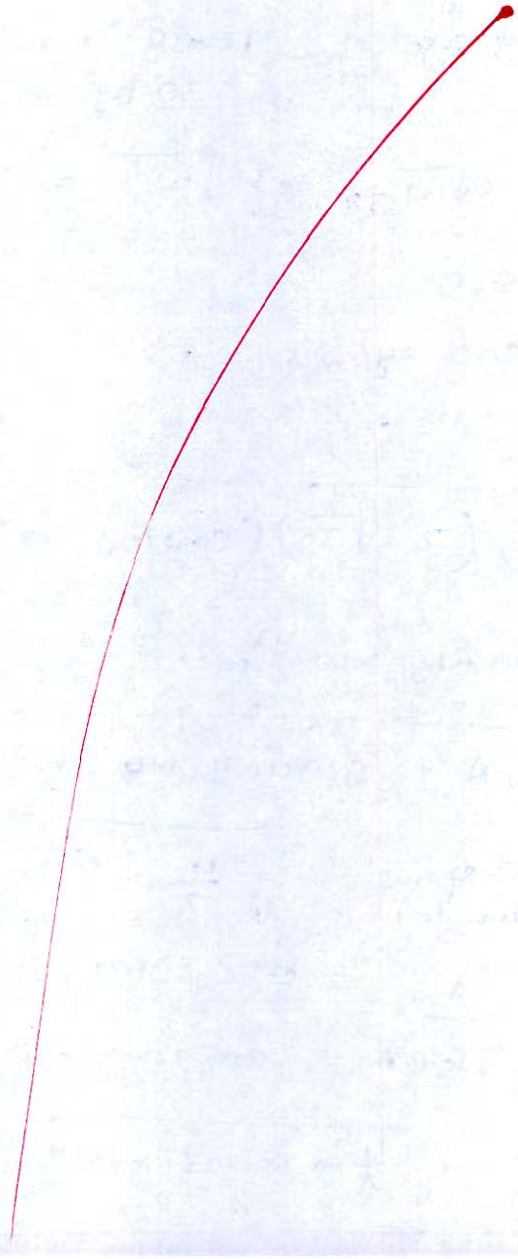
$A_{sprue} = C.A = 6.9027\times10^{-4}$ m^2

d_{sprue} (diameter) $= \sqrt{\frac{4}{\pi}\times 6.9027\times10^{-4}}$

$= 0.02964$ m

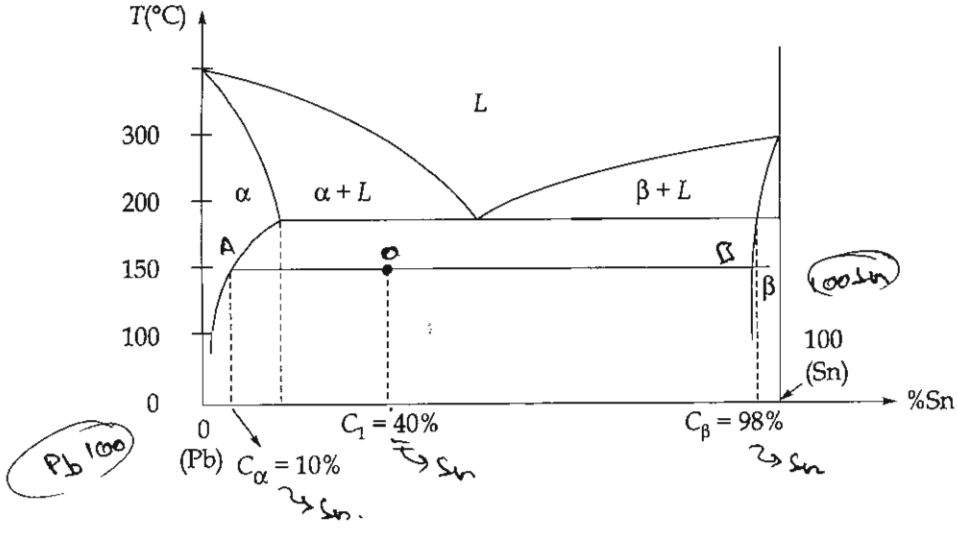
$A_{gate} = 3\times C.A = 20.7081\times10^{-4}$ m^2

d_{gate} (diameter) $= \sqrt{\frac{4}{\pi}\times 20.7081\times10^{-4}} = 0.05134$ m



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

$\% \alpha = \frac{OB}{AB} \times 100$

$= \frac{(98-40)}{(98-10)} = \frac{58}{88} \times 100 = 65.909\%$

mass.

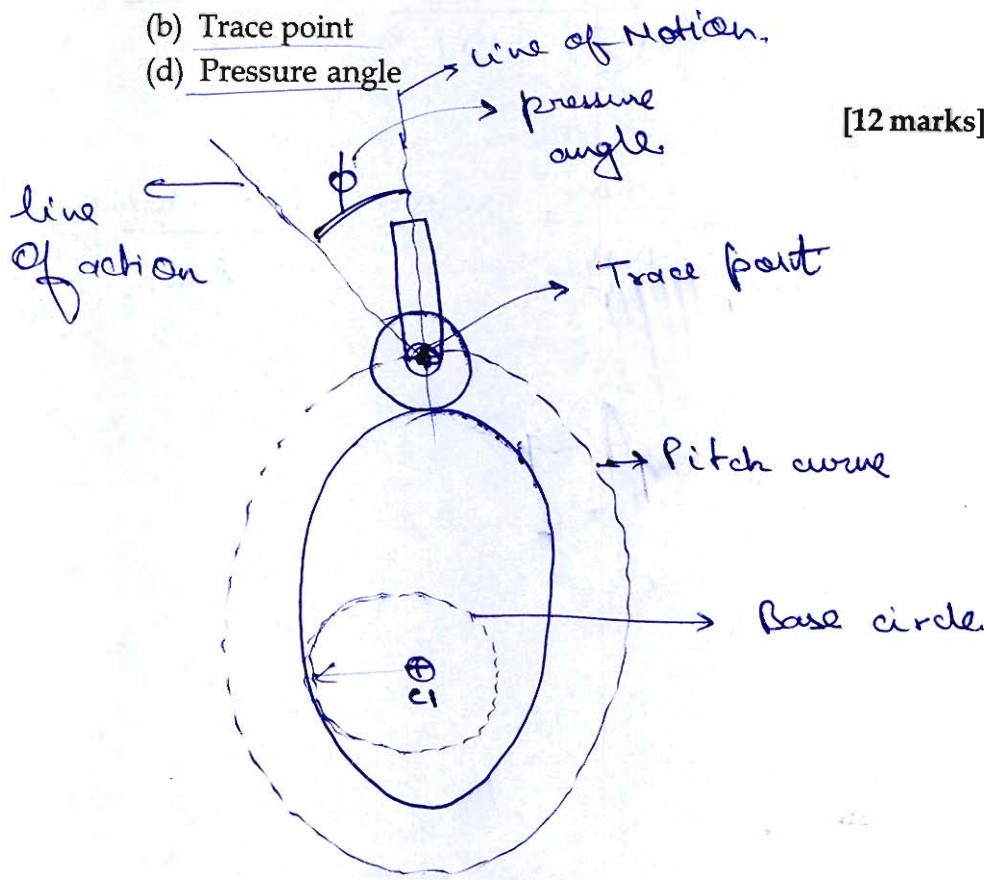
$\% \beta = \frac{OA}{AB} \times 100 = \frac{(40-10)}{88} \times 100 = 34.0909\%$

3

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]



Base circle = It is the smallest circle drawn with centre at the cam's centre and radius equal to minimum distance b/w cam & its centre.

Trace point = It is a point on the follower.

Pitch curve = It is a curve traced by Trace point over the cam.

6

Pressure angle = It is the angle b/w line of motion of follower and the line of action.

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.

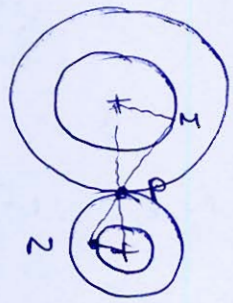
[12 marks]

$\phi = 20°$ $N_p = 300$ rpm $R = \frac{mT}{2} = 192$ mm $r = 80$ mm

$G_r = 2.4$ $t = 20$ $m = 8$ mm.

$2.4 = \frac{T}{t} \Rightarrow T = 2.4 \times 20 = 48$ teeth.

$$T_{min} = \frac{2 \times A G_r}{\left\{\sqrt{1 + \frac{1}{G_r}\left(\frac{1}{G_r} + 2\right)\sin^2\phi} - 1\right\}}$$



$$48 = \frac{2 \times A G_r}{\left\{\sqrt{1 + \frac{1}{2.4}\left(\frac{1}{2.4} + 2\right)\sin^2 20°} - 1\right\}}$$

$A G_r = 1.3741$

addenda of wheel = $m A G_r = 10.993$ mm

Ans (i)

$R_{out} = R + 10.993 = 202.993$ mm

$$t_{min} = \frac{2 \times A_p}{\left\{\sqrt{1 + G(G+2)\sin^2\phi} - 1\right\}}$$

$A_p = 4.9508$

addenda of Pinion $= m A_p$
$= 39.606$ mm

Ans (ii)

$\hookrightarrow r_a = 80 + 39.606$
$= 119.606$ mm

$POC = KP + PL.$

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

(Path of App.)

$= 27.3613$ mm

$PL = \sqrt{r_a^2 - r^2\cos^2\phi} - r\sin\phi$

$= 65.666$ mm

Path of contact (POC) $= 93.0273$ mm

Ans (ii)

12

V_{max} (Sliding) $= (\omega_P + \omega_G) \times (PL)$.

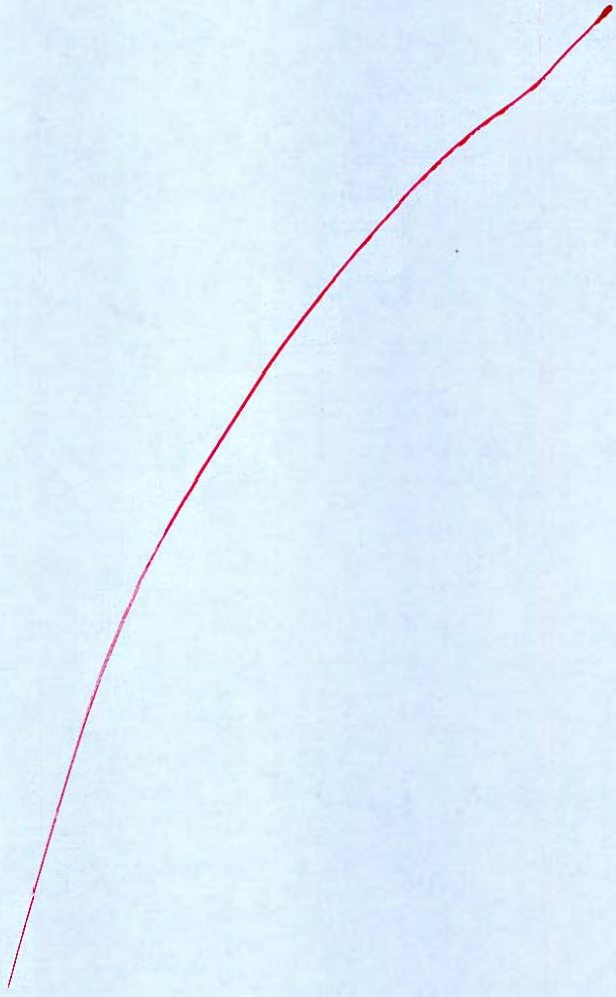
$= \frac{2\pi}{60}\left(300 + \frac{300}{2.4}\right) \times \frac{65.666}{1000}$

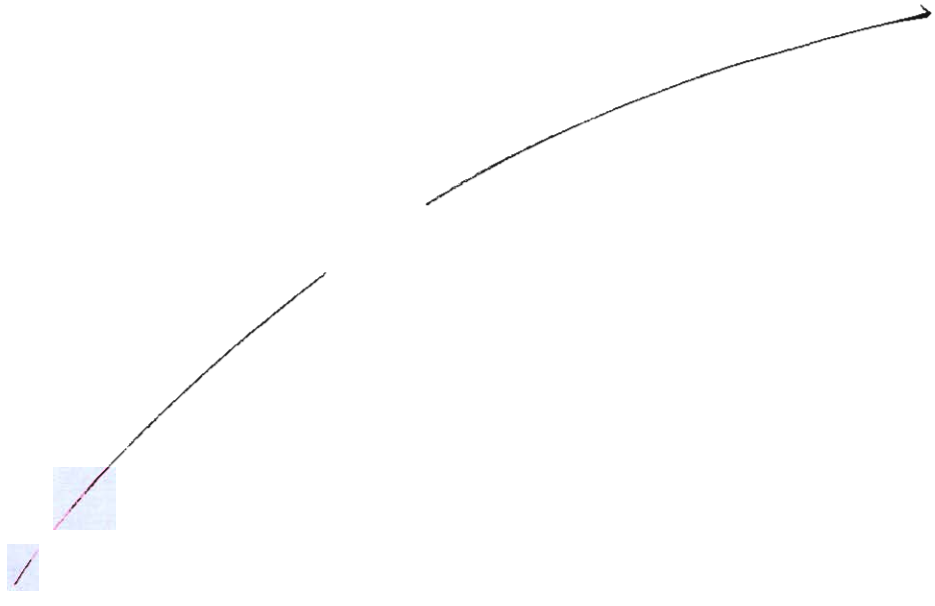
$= 2.9225$ m/s.

Ans (iii)

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]

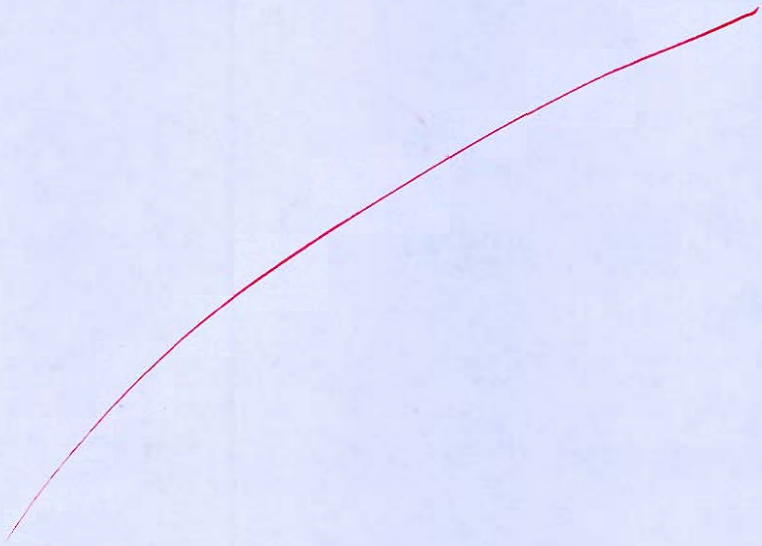


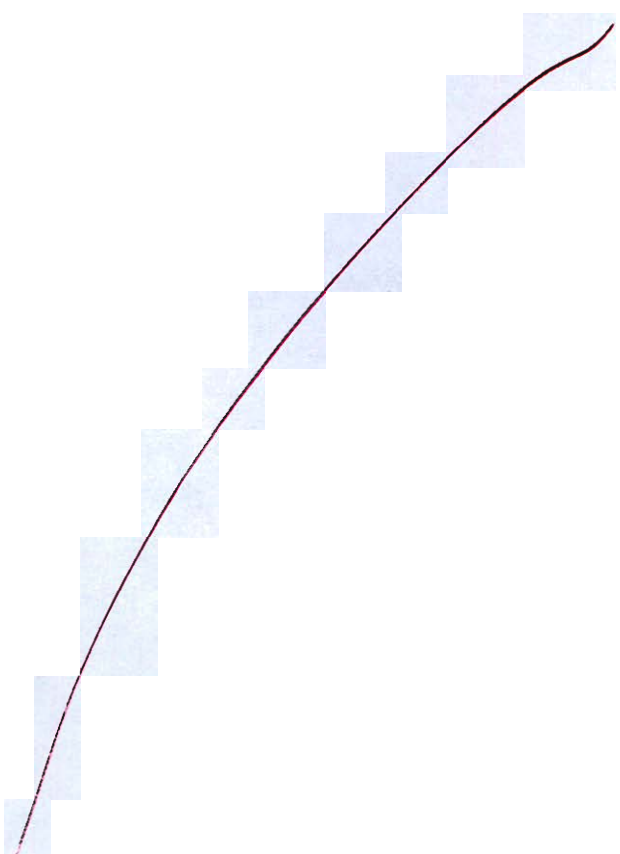


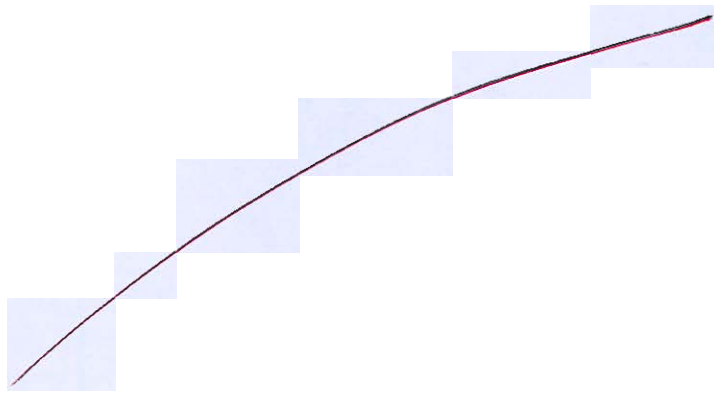
Q.6 (b) (i) Write the various characteristics of miller indices of plane as well as direction.

(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]

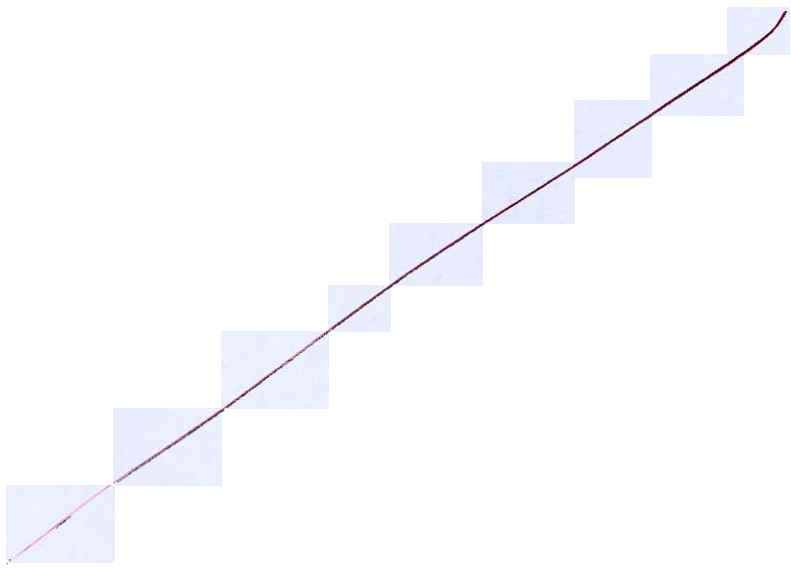


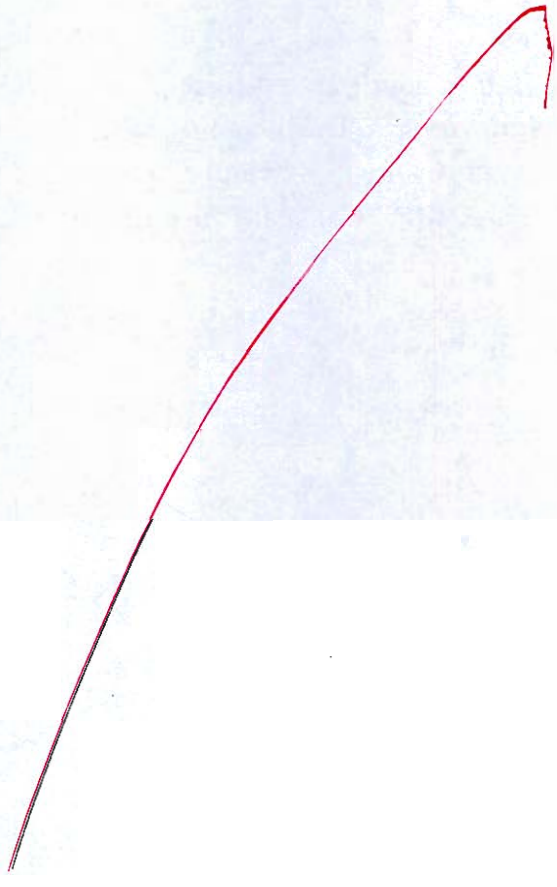


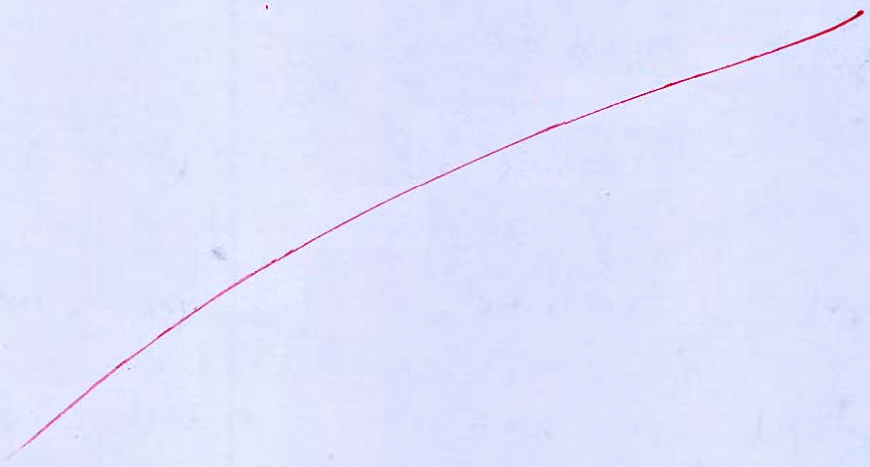


Q.6 (c) In a wire drawing operation after passing through a conical portion, the wire passes through a die land of 4 mm length. The incoming wire diameter is 8 mm and outgoing diameter is 6 mm. The semi-die angle is 8° and co-efficient of friction is 0.05. If nominal strength of the material is 30 MPa.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

[20 marks]







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]

(4)

14 stable Bravais lattice system.

(2)

~~7 Bravais lattice crystals~~

7 crystals —

Triclinic.	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma$
Monoclinic	$a \neq b \neq c$	$\alpha = \beta \neq \gamma$
Orthorhombic	$a \neq b \neq c$.	~~$\alpha = \beta = \gamma = 90^\circ$~~ ?
Tetragonal.	$a = b \neq c$.	
Cubic.	$a = b = c$.	$\alpha = \beta = \gamma = 90^\circ$
Hexagonal.	$a = b \neq c$	$\alpha = \beta$ $\gamma = 90^\circ$
Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$

(6)

Diff unit cell

Scc.	(Simple cubic)	$z = 1$
Bcc.	(Body centered)	$z = 2$
FCC	(face centered)	$z = 4$
HCP	(Hexagonal centred).	$z = 6$
DCC	(Diamond cubic)	

(ii)

Zn → HCP.

$r = 0.133\ nm$ $\quad a = 2r$

$AMU = 65.39\ g/mol.$

$Z = 6$

$$\rho = \frac{Z \times AMU}{N_a \times a^3} = \frac{(6) \times (6.022 \times 10^{23})}{}$$

1

$$= \frac{6 \times 65.39.}{6.022 \times 10^{23} \times (2 \times 0.133 \times 10^{-9} \times 10^{2})^3}$$

$$\rho = 34.616\ g/cm^3$$

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

[20 marks]

→ Fused Deposition Modelling

→ Steriolithography

→ Selective laser sintering.

→ Lamina Object Manufacturing.

Advantages

1.) Complex shapes can be formed.

2.) Automated process less skilled labours are required.

3.) Less Noise is produced.

Disadvantages

1.) Bit slow process.

2.) Limited few materials.

3.) Corners of the products are not very strong.

Stereolithography

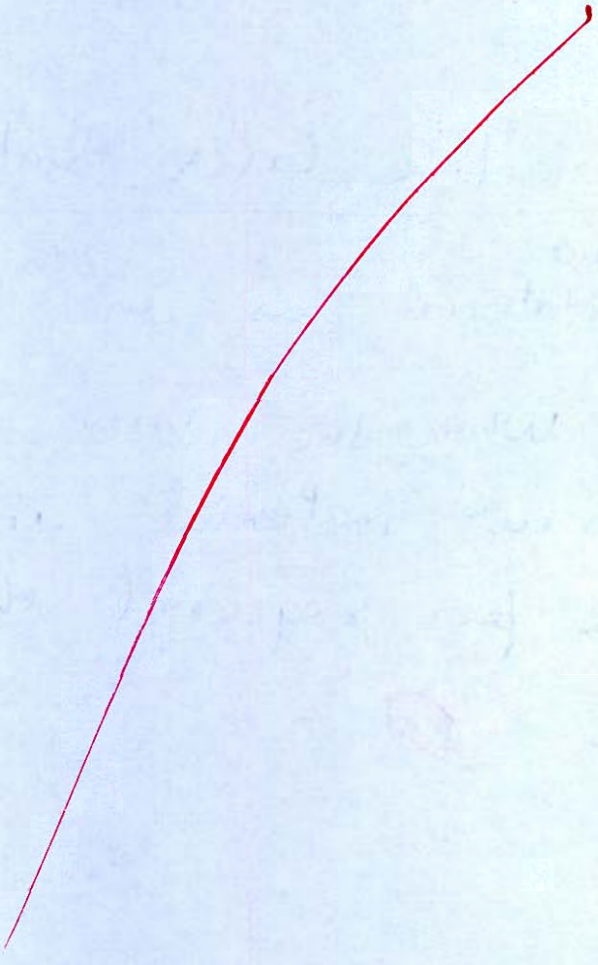
or

- It is uses light and the raw material in liquid form.
- When the light falls on the raw material it gets solidified as per required shape.

Selective Laser Sintering

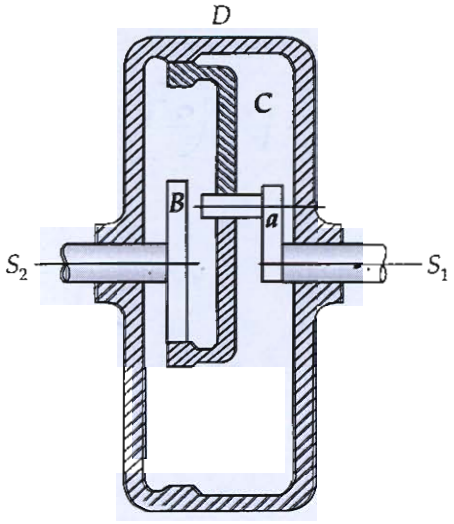
- Raw Material is in powdered form.
- When the laser falls on the raw material it gets solidified as per required shape.

8



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]

$d_W = 650$ mm

$I_W = 1.3$ kg m^2

$m = 200$ kg.

$h = 590$ mm.

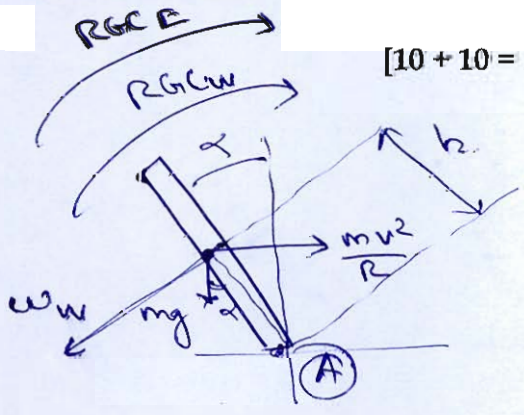
$I_E = 0.2$ kg-m^2

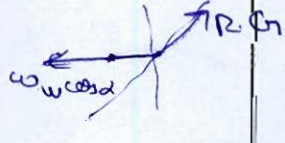
$\omega_E = 6\omega_W$

$V = 50 \times \frac{5}{18} = 13.88$ m/s.

$R_{cm} = 30$ m

$\omega_p = \frac{V}{30} = 0.4626$ rad/s





$13.88 = \frac{650}{2000} \times \omega_W$

$\omega_W = 42.735$ rad/s

$\omega_E = 256.410$ rad/s

$$\Sigma M_A = 0$$

$$(mg)\, h \sin\alpha = \frac{mv^2}{R} h\cos\alpha + \left(R.G.C_W + R.G.C_E\right)$$

$$R.G.C_W = I_W \omega_W \omega_p \cos\alpha.$$

$$R.G.C_E = I_E \omega_E \omega_p \cos\alpha.$$

$$\tan\alpha = \frac{\frac{mv^2}{R} h + \left(2 I_W \omega_W \omega_p + I_E \omega_E \omega_p\right)}{mgh}$$

$$= 0.7195$$

$$\alpha = 35.7356^\circ \quad \text{Ans} \quad (10)$$

(i)

	C (30) 8(36)	B (24)	D (44)
0	$-x \times \frac{44}{36}$	$-x \times \frac{44}{36} \times \frac{30}{24}$	$+x$
y	y	y	y

$N_C = y - \frac{44x}{36}$

$y - \frac{44 \times 30 \times x}{36 \times 24} = N_B$

$N_D = x + y$

(1) D is find.

(2) $x + y = 0$

$x = -y$

(2) S_2 is find.

$N_B = 0$

$y = \frac{44 \times 30}{36 \times 24} x$

$y = 1.5277x$

$\frac{N_{S1}}{N_D} = \frac{y}{x+y}$

$= \frac{1}{\left(\frac{x}{y}+1\right)}$

$\frac{N_{S1}}{N_D} = 0.60439$ Ans (2)

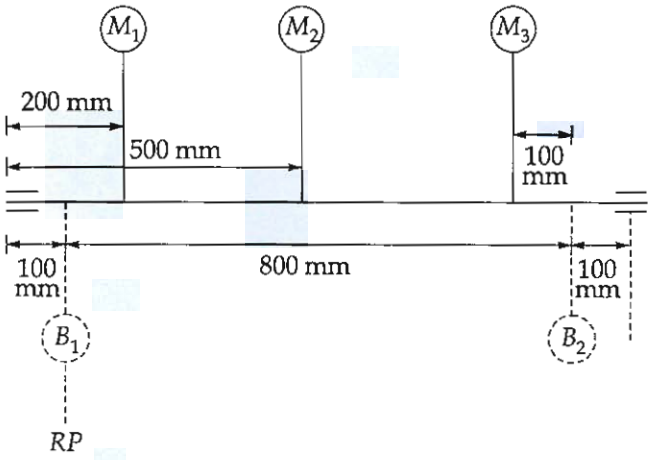
$N_{S_2} = N_B = -x\left(1 + \frac{44 \times 30}{36 \times 24}\right)$

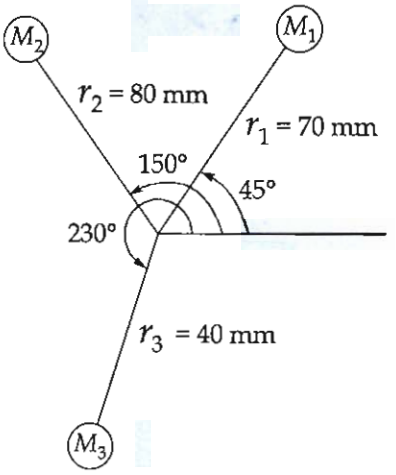
$N_{S_1} = y.$

$\frac{N_{S1}}{N_{S2}} = \frac{y}{-x(1+1.5277)}$

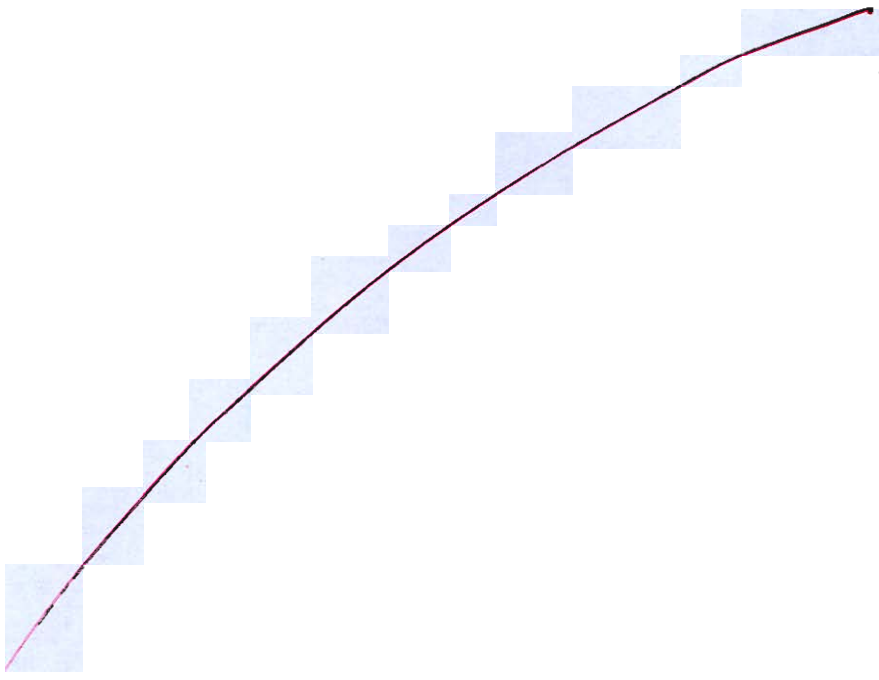
$\frac{N_{S1}}{N_{S2}} = 0.3956$ Ans (1)

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.



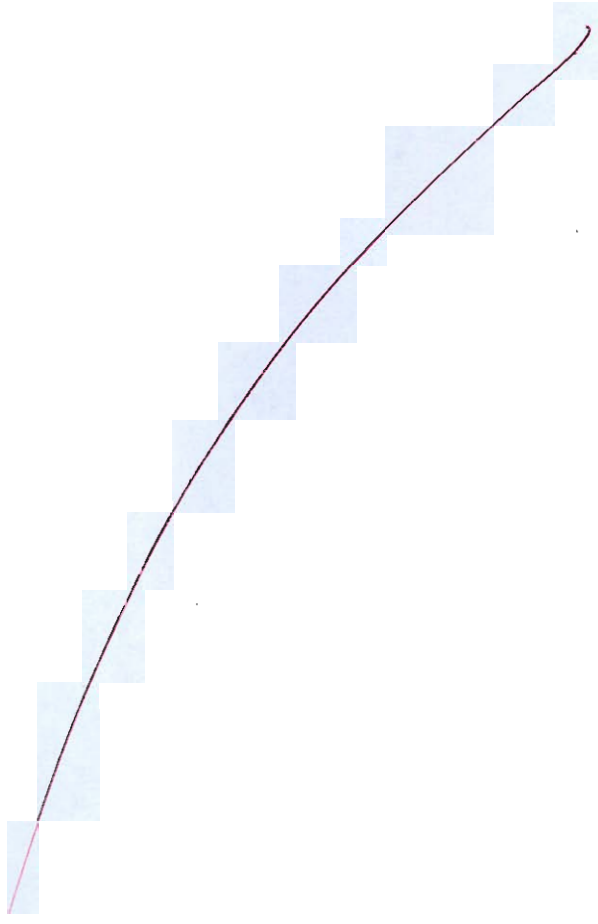


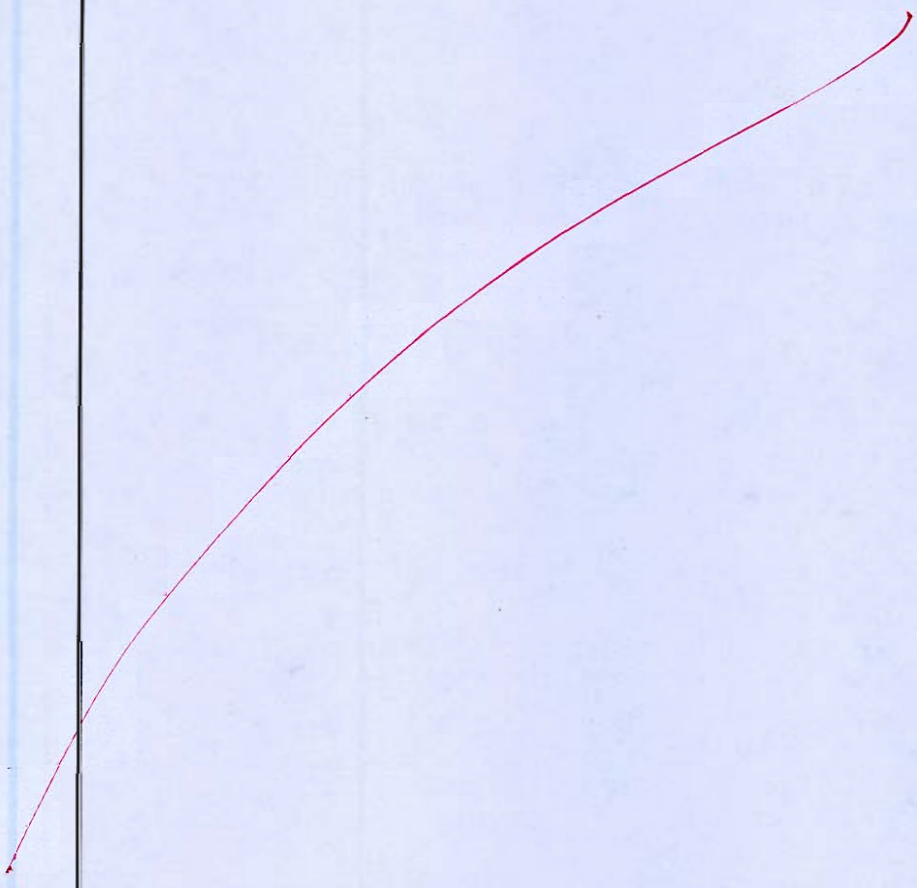
[20 marks]



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.

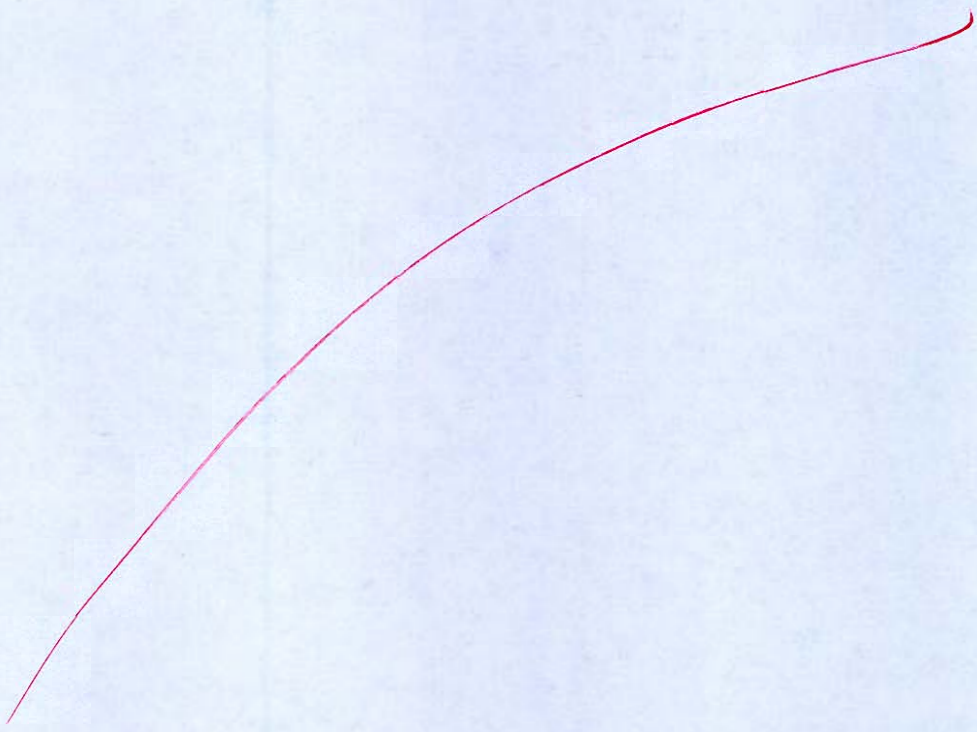
[20 marks]

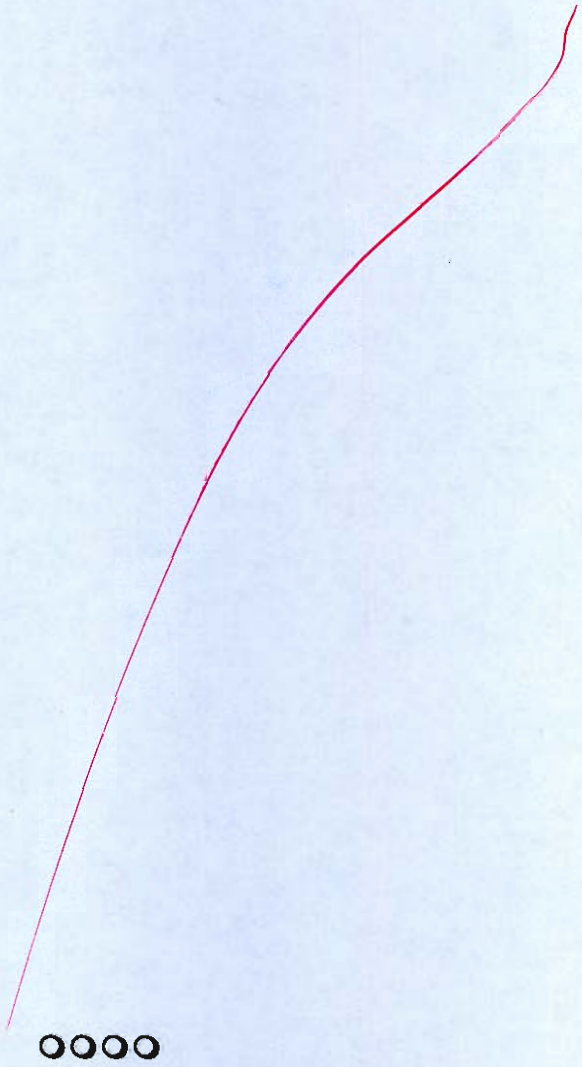




Q.8 (c) Why are Non-Ferrous Materials Important in engineering applications? Briefly discuss Aluminium, Copper, Zinc and Magnesium.

[20 marks]





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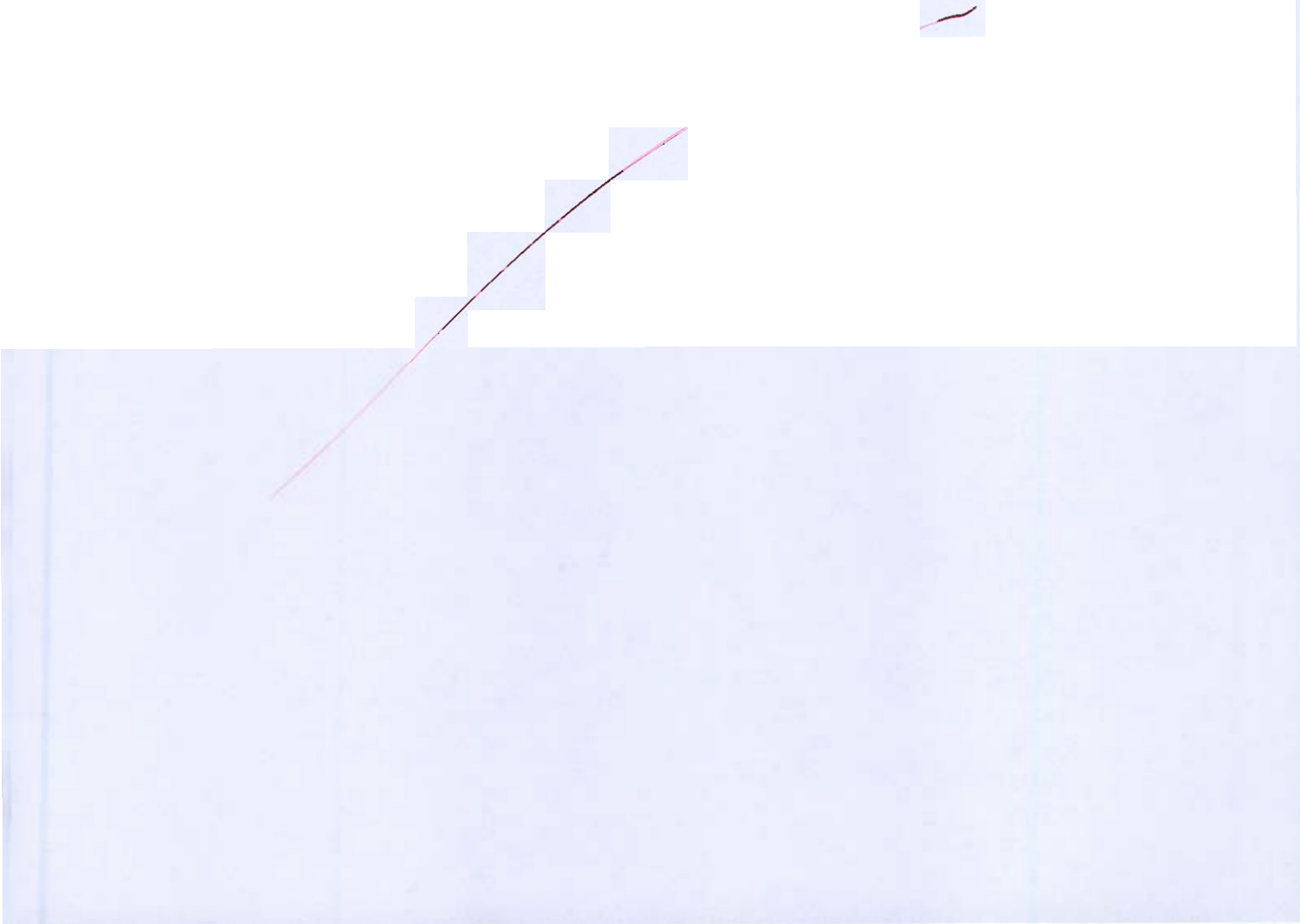

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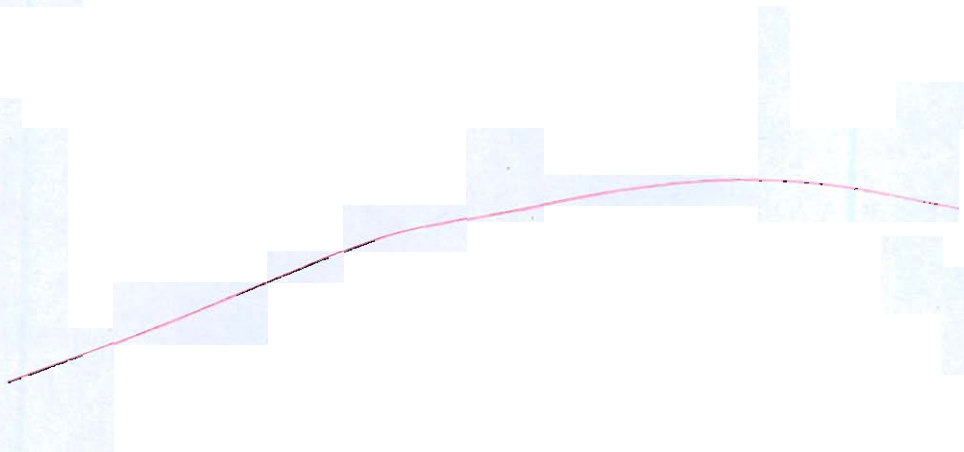

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