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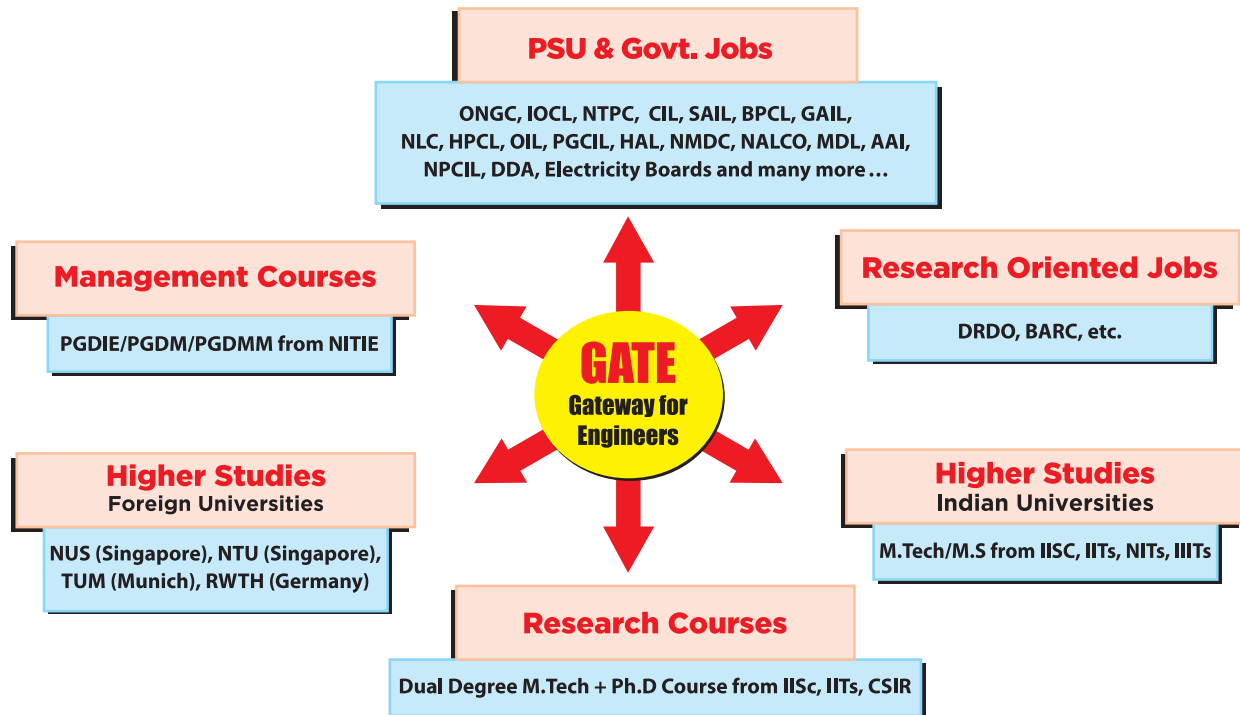
Revision through Questions for GATE 2020

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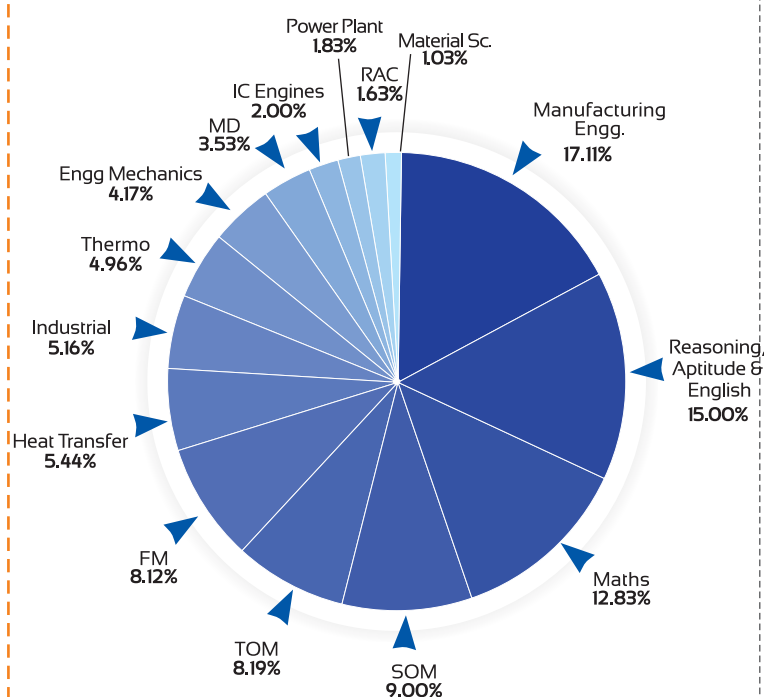
MECHANICAL ENGG.

Q.1 - Q.25
out of 200 Questions

Day 1 of 8



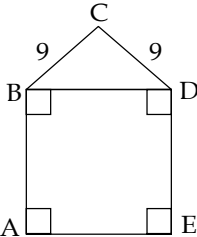
SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 1 : Q.1 to Q. 25 : General Aptitude

- Q.1** Choose the correct set of words to complete the sentence:
Politicians must be _____ for the people, but they should never be _____ for public welfare.
(a) disinterested, uninterested (b) disinterested, disinterested
(c) uninterested, uninterested (d) uninterested, disinterested
- Q.2** How many numbers between 1 to 300 are divisible by only 11 or only 13 but not by both?
(a) 45 (b) 46
(c) 48 (d) 50
- Q.3** Triangles ABC and CDE have a common vertex C with side AB of triangle ABC being parallel to side DE of triangle CDE . If length of side $AB = 4$ cm and length of side $DE = 10$ cm and perpendicular distance between sides AB and DE is 9.8 cm, then the sum of areas of triangle ABC and triangle CDE is _____ cm^2 .
- Q.4** A and B will participate in a sack race (In a sack race, people hop to reach the finish line). In the time that A takes 3 hops, B takes 4 hops but the distance covered by A in 4 hops is equal to distance covered by B in 5 hops. What is the ratio of A's speed: B's speed?
(a) 3 : 5 (b) 12 : 20
(c) 15 : 16 (d) 1 : 1
- Q.5** In the sentence given below, a part of sentence is underlined, choose the correct alternative of the phrasing of the underlined part:
While their ostrich like attitude is aggravating, what is very serious is loss of wealth and loss of business.
(a) their refusal to face facts (b) their heavy handedness
(c) their annoying behaviour (d) their big ego
- Q.6** What is the sum of all possible solutions to $|x - 3|^2 + |x - 3| = 20$?
(a) -1 (b) 6
(c) 7 (d) 12
- Q.7** A lizard is crawling up a minaret to reach the top. The top of the minaret is 1800 cm from its position. After every minute of crawling it halts for half a minute. In every halt it slides down by 30 cm from its position. Time the lizard will take to reach the top of the minaret if it can crawl 150 cm per minute is
(a) 21 minutes 48 seconds (b) 25 minutes
(c) 20 minutes (d) 32 minutes 40 seconds
- Q.8** How many 5 letter words (with or without meaning) can be formed using all the following 5 letters A, B, C, D and E so that letter A is to the left of letter B?
(a) 120 (b) 60
(c) 48 (d) 24

- Q.9** Choose the option that best substitutes the underlined part of the sentence :
TCS is edging closer to become the country's first 100 bn \$ company. The company is fortunate to have excellent relationships among its employees : they each have a relationship of respect for all the others.
- (a) they each have a relationship of respect for all the others.
(b) they have respect for one another.
(c) each one has respect for one another.
(d) they each have a relationship of respect for each other.
- Q.10** What is the remainder when $1! + 2! + 3! \dots 100!$ is divided by 18?
(a) 0 (b) 1
(c) 5 (d) 9
- Q.11** The percentage profit earned by selling an article for ₹1920 is equal in the percentage loss incurred by selling the same article for ₹1280. At what price (in ₹) should the article be sold to make 25% profit?
- Q.12** A faulty wall clock is known to gain 15 minutes every 24 hours. It is synchronized to the correct time at 9 AM on 14th August. What will be the correct time to the nearest minute when the clock shows 2 PM on 18th August of the same year?
(a) 12:45 PM (b) 12:58 PM
(c) 1:00 PM (d) 2:00 PM
- Q.13** As shown in the figure below, two sides of triangle BCD are each 9 feet long. Triangle BCD shares side BD with square ABDE, and angle CBD measures 45° . What is the total area of figure ABCDE in square feet? (Note: Figure not drawn to scale.)
- 
- (a) 121.5 (b) $40.5 + 81\sqrt{2}$
(c) 202.5 (d) 221
- Q.14** A farmer can plow his wheat field in 12 days. After working for 5 days, his daughter joins him and together they finish plowing the field in 4 days. How many days would it take the daughter to plow the wheat field alone?
- Q.15** A series of numbers are written using digits 1, 2, 3, 4 and 5 in the following pattern:
1, 2, 2, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5, 5, 1, 1, 1, 1, 1, 1, (six 1's) and so on. Which of the following digits will come at the 100th position in this sequence?
(a) 1 (b) 2
(c) 3 (d) 4

Q.16 A part has been omitted from the sentence given below and it is to be filled with idiom(s), to make the sentences grammatically meaningfully correct. Mark the answer accordingly.

Although Mr. Naipaul was _____, he never boasted about anything or try to use the resources available to him in an unethical way.

1. An armchair traveller
2. Born with a silver spoon
3. A big fish in a small pond

- (a) Only 2 (b) Both 2 and 3
(c) Both 1 and 3 (d) None of these

Q.17 In the given question, a set of conclusions is given. There are four options comprising of three or more statements. You need to choose the option that contains the set of statements from which the given conclusions logically follow.

All horses cannot be cottages. No glance is a cottage.

- (a) Some glances are horses. Some horses are blemishes. No blemish is a cottage.
(b) No horse is a blemish. All cottages are blemishes. All glances are horses.
(c) Some horses are blemishes. All glances are blemishes. Some cottages are not blemishes.
(d) All horses are blemishes. Some blemishes are not cottages. No blemish is a glance.

Q.18 Vessel A contains six green and four red balls and vessel B contains four green and six red balls. One ball is drawn at random from vessel A and placed in vessel B. Then one ball is transferred at random from vessel B to vessel A. If one ball is now drawn at random from vessel A, the probability that it is green is

- (a) $\frac{23}{55}$ (b) $\frac{32}{65}$
(c) $\frac{33}{65}$ (d) $\frac{32}{55}$

Q.19 Four runners started running the race in the same direction along a circular path of 7 km. Their speed are 4, 3, 9, 3.5 km/hr. individually. If they started their race at 6 AM then at what time they all will be at the starting point?

- (a) 2 PM (b) 8 PM
(c) 8 AM (d) 6 PM

Q.20 The average number of goals scored per match by Sunil Chhetri in matches where he was in the team of starting 11 is 1.5 and the average number of goals scored by him in matches where he came on as a substitute is 0.5. He scored 390 goals more in matches where he was in the team of starting 11 than in matches in which he came on as a substitute. If he played 388 matches in total, the average number of goals scored by him per match is

Q.21 In a family of 4 members, the eldest member expires after 5 years at the age of 88 and 10 years after that a baby is born in the family such that the difference of family's eldest to youngest member alive after 20 years from present is 57. At present, the age of youngest member is 14 years and the average age of remaining member is 54. The age of the two eldest members alive after 5 years would be

- (a) 88, 47 (b) 42, 19
(c) 47, 42 (d) 37, 42

Q.22 Which of phrases given below should replace the phrase printed in **bold** type to make the sentence grammatically correct?

The **crime has growth rapidly** in Russia since the disintegration of the communist system.

- (a) rapid crime has grown
- (b) crime has grown rapidly
- (c) crimes grow rapidly
- (d) crimes have been rapidly grown

Q.23 A sphere is inscribed in a cube with an edge of 10 units. What is the shortest possible distance in units from one of the vertices of the cube to the surface of the sphere?

- (a) $10(\sqrt{3} - 1)$
- (b) 5
- (c) $10(\sqrt{2} - 1)$
- (d) $5(\sqrt{3} - 1)$

Q.24 Based on the given statements, select the most appropriate option to solve the question.

Sheetal wants to sell her bicycle at either a profit of $K\%$ or a loss of $K\%$. What is the value of K ?

Statement 1: Difference between the amount Sheetal gets in the 2 cases is ₹2560.

Statement 2: If Sheetal's profit is ₹ K , her profit in percentage is 7.5%.

- (a) Statement 1 alone is sufficient, but statement 2 alone is NOT sufficient.
- (b) Statement 2 alone is sufficient, but statement 1 alone is NOT sufficient.
- (c) Both statements together are sufficient, but neither statement alone is sufficient.
- (d) Statement 1 and 2 together are NOT sufficient.

Q.25 Select the pair which has the same relationship as the two words

IMPLAUSIBLE : ABSURD :: ?

- (a) shadowy : illuminated
- (b) flamboyant : public
- (c) surprising : shocking
- (d) superfluous : truncated

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Detailed Explanations

1. (a)

'Disinterested' means 'free from bias, free from personal/selfish motives'.

'Uninterested' means 'lacking interest'.

2. (b)

Between 1 to 300:

There are 27 multiples of 11.

There are 23 multiples of 13.

There are 2 multiples of 143 (of both 11 and 13).

So, there are $27 - 2 = 25$ numbers divisible by 11 only.

And, there are $23 - 2 = 21$ numbers divisible by 13 only.

In all, there are $25 + 21 = 46$ numbers divisible by 11 or 13 but not by both.

3. 40.6 (40 to 41)

Given

$$AB \parallel DE$$

$\Rightarrow$

$$\angle B = \angle D \quad (\text{Alternate angles})$$

and

$$\angle A = \angle E \quad (\text{Alternate angles})$$

$\therefore$

$$\Delta ABC \sim \Delta EDC \quad (\text{AAA similarity})$$

$\Rightarrow$

$$\frac{h_1}{h_2} = \frac{AB}{DE} = \frac{4}{10} = \frac{2}{5}$$

and

$$h_1 + h_2 = 9.8 \text{ cm} \quad (\text{given})$$

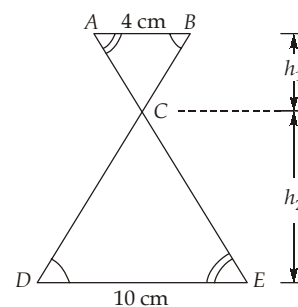
$\therefore$

$$h_1 = 2.8 \text{ cm and } h_2 = 7 \text{ cm}$$

$$\text{Area of } \Delta ABC = \frac{1}{2} \times 4 \times 2.8 = 5.6 \text{ cm}^2$$

$$\text{Area of } \Delta EDC = \frac{1}{2} \times 10 \times 7 = 35 \text{ cm}^2$$

$$\therefore \text{Sum of areas of } \Delta ABC \text{ and } \Delta EDC = 40.6 \text{ cm}^2$$



4. (c)

Let time taken by A and B to complete 3 and 4 hops respectively be 't'

Therefore time taken by A and B to do 1 hop is $\frac{t}{3}$ and $\frac{t}{4}$ respectively

Let distance covered in A and B's 4 and 5 hops respectively be 'd'

Therefore distance covered by A and B in 1 hop is $\frac{d}{4}$ and $\frac{d}{5}$ respectively

$$\text{A's speed: B's speed} = \frac{\left(\frac{d}{4}\right)}{\left(\frac{t}{3}\right)} : \frac{\left(\frac{d}{5}\right)}{\left(\frac{t}{4}\right)} = \left(\frac{3}{4}\right) \times \left(\frac{d}{t}\right) : \left(\frac{4}{5}\right) \times \left(\frac{d}{t}\right) = 15 : 16$$

5. (a)

'Ostrich like attitude' means 'when you overlook or ignore a problem'.

6. (b)

First of all $|x - 3|^2 = (x - 3)^2$, so we have: $(x - 3)^2 + |x - 3| = 20$.

when $x < 3$, $x - 3$ is negative, thus $|x - 3| = -(x - 3)$. In this case we will have $(x - 3)^2 - (x - 3) = 20$

$$\Rightarrow x = -1 \text{ or } x = 8.$$

Discard $x = 8$ because it's not in the range we consider (< 3).

when $x \geq 3$, $x - 3$ is non-negative, thus $|x - 3| = x - 3$. In this case we will have $(x - 3)^2 + (x - 3) = 20$

$$\Rightarrow x = -2 \text{ or } x = 7.$$

Discard $x = -2$ because it's not in the range we consider (≥ 3).

Thus there the two solutions: $x = -1$ and $x = 7$

$$\Rightarrow \text{The sum} = 6.$$

7. (a)

$$\text{Number of trials} = \frac{1800}{150 - 30} = \frac{1800}{120} = 15$$

Let us take 14 trials of sliding up

For every trial of these 14 trials, its effective upward movement is $(150 - 30) = 120$ cm

$$\text{The time taken for this} = \left(14 \times 1 + 14 \times \frac{1}{2} \right) = 21 \text{ minutes}$$

$$\text{Total distance} = (14 \times 120) = 1680 \text{ cm}$$

$$\text{Remaining} = 1800 - 1680 = 120 \text{ cm}$$

$$\text{Remaining 120 cm it can reach in } \frac{(60 \times 120)}{150} = 48 \text{ seconds}$$

$$\text{Total time} = 21 \text{ minutes } 48 \text{ seconds}$$

8. (b)

Total ways of arranging 5 letters in any possible order $= 5 \times 4 \times 3 \times 2 \times 1 = 5! = 120$

In half of the cases A will be to the left of B and in other half A will be to the right of B

Hence, desired outcome

9. (b)

This is a situation in which there is the same relationship, respect, between any possible pair of people in the group. This is a saturation that calls for the structure "each other" or "one another".

Choice (a) doesn't use this, and what is used is very wordy and awkward, so it is incorrect.

These structures, "each other" and "one another", demand a plural subject. Choices (c) and (d) make the mistake of using a singular subject, so these are incorrect.

Option (b) is the right answer.

10. (d)

Factorial of the positive integers greater than 5 is divisible by 18.

So, we have to find out the remainder when $1!+2!+3!+4!+5! (= 153)$ is divided by 18. (All other terms yield zero remainder)

So, Remainder = 9.

11. (2000)

Let Percentage Profit/Loss = x and Cost Price = C

Now, $C + xC = 1920$

$C - xC = 1280$

Solving for $C \Rightarrow 2C = 3200 \Rightarrow C = 1600$

Sale Price with 25% profit $\Rightarrow 1.25 \times 1600 = 2000$.

12. (b)

9 AM of 14th August to 2 PM on 18th August = 101 hours

$\left(24 + \frac{15}{60}\right)$ hours of incorrect clock = 24 hours of correct clock

1 hour of incorrect clock = $\frac{96}{97}$ hours of correct clock

101 hours of incorrect clock = $\frac{96}{97} \times 101$ hours of correct clock

= 99 hours and approx 58 minutes

So, correct time will be

2 PM, 14th August + (99 hours and 58 minutes) = 12:58 PM on 18th August

13. (c)

The length of the hypotenuse of the triangle is the length of one of the sides multiplied by $\sqrt{2}$,

i.e. $9\sqrt{2}$ feet. Therefore the area of the square is $9\sqrt{2} \times 9\sqrt{2} = 81 \times 2 = 162$ sq. feet.

The area of the triangle must be exactly one quarter of the area of the square. If you don't see that directly, imagine the triangle being flipped down into the square. Therefore, the total

area is $\left(162 + \frac{162}{4}\right)$ sq. feet = 202.5 sq feet.

14. (16)

Farmer works for $5 + 4 = 9$ days

If he completes entire work in 12 days, he will finish $\frac{9}{12}$ or $\frac{3}{4}$ th work in 9 days.

Remaining work, $1 - \frac{3}{4} = \frac{1}{4}$, is done by daughter in 4 days..

So if daughter does $\frac{1}{4}$ work in 4 days, she will complete the whole work in $4 \times 4 = 16$ days.

15. (d)

We will be required to get the value of n such that $\frac{n(n+1)}{2} = 100$. If $n = 13$, $\frac{n(n+1)}{2} = 91$ which

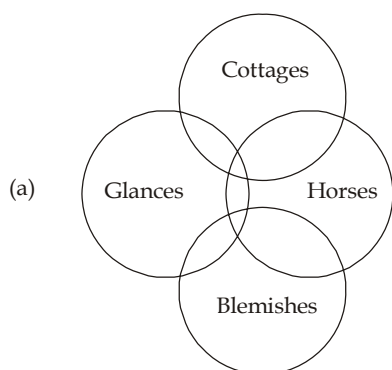
means that 100th digit will be occupied by 14th set of digits or it will be equal to 4.

16. (b)

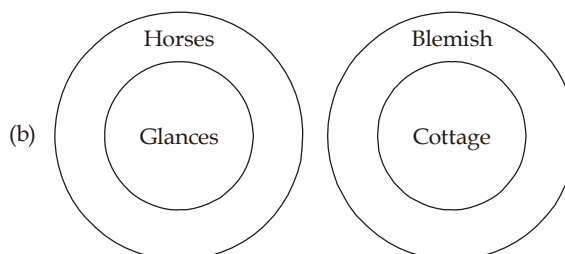
'Armchair traveller' = Someone who reads books or watches TV programmes about other places and countries, but doesn't actually travel anywhere. "Born with a silver spoon" = born into a very rich family. "A big fish in a small pond" = an important or highly-ranked person in a small group or organisation. Since, the sentence does not contain any reference about travelling, (1) cannot be true here.

17. (b)

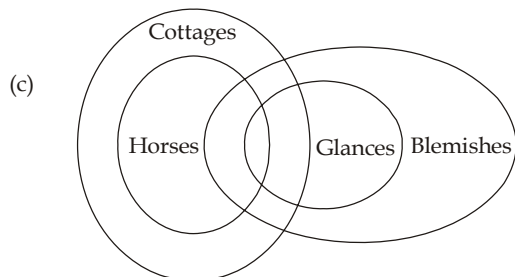
The statements given in option (b) lead to the required conclusions.



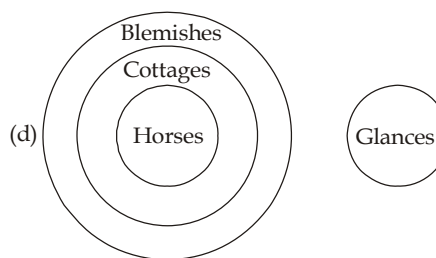
In this scenario conclusion II does not follow



In this scenario both the conclusions are true



In this case we see that neither of the conclusions is true



In this scenario conclusion I does not follow

18. (d)

The probability that a green ball is transferred from A to B and a green ball is transferred from

vessel B to vessel A, $P_{\text{green, green}} = \left(\frac{6}{10}\right) \times \left(\frac{5}{11}\right) = \frac{30}{110}$.

Similarly other cases, $P_{\text{green, red}} = \left(\frac{6}{10}\right) \times \left(\frac{6}{11}\right) = \frac{36}{110}$.

$$P_{\text{red, green}} = \left(\frac{4}{10}\right) \times \left(\frac{4}{11}\right) = \frac{16}{110}$$

$$P_{\text{red, red}} = \left(\frac{4}{10}\right) \times \left(\frac{7}{11}\right) = \frac{28}{110}$$

Probability of drawing a green ball from vessel A after the transfers in these four cases are

$\frac{6}{10}, \frac{5}{10}, \frac{7}{10}, \frac{6}{10}$ respectively.

Therefore the required probability

$$= \left(\frac{30}{110}\right) \times \left(\frac{6}{10}\right) + \left(\frac{5}{10}\right) \times \left(\frac{36}{110}\right) + \left(\frac{7}{10}\right) \times \left(\frac{16}{110}\right) + \left(\frac{6}{10}\right) \times \left(\frac{28}{110}\right) = \frac{32}{55}$$

19. (b)

The time required by individual to complete one revolution is

$\frac{7}{4}, \frac{7}{3}, \frac{7}{9}, \frac{7}{3.5}$ hours

To reach at starting point, the time required is LCM of $\frac{7}{4}, \frac{7}{3}, \frac{7}{9}$ and $\frac{2}{1}$ hours.

$$= \frac{\text{LCM}(7, 7, 7, 2)}{\text{HCF}(4, 3, 9, 1)} = 14 \text{ hours}$$

After 14 hours, all 4 will be at starting point.

or, $6 + 14 = 20 = 8 \text{ PM}$

all will be at starting point.

20. 1.253 (1.2 to 1.3)

Let the number of matches in which he was in the team of starting 11 be x and the matches in which he came on as a substitute be y .

Thus, $x + y = 388$... (i)

Number of goals scored in matches in which he was in the team of starting 11 = Average $\times$ number of matches = $1.5x$

Number of goals scored in matches in which he came on as a substitute = $0.5y$

Thus, $1.5x = 0.5y + 390$... (ii)

Solving both equations for x and y , we have $x = 292$ and $y = 96$

So, the total number of goals scored by him = $1.5 \times 292 + 0.5 \times 96 = 486$ goals

Therefore, average number of goals scored per match = $486 \div 388 = 1.253$

21. (c)

At present,

Let the members be M, N, O and P

Where age of $P > O > N > M$

Since P died after 5 years at the age of 88. So, present age of P = $88 - 5 = 83$

Youngest member = M = 14 years

$$N + O + P = 54 \times 3$$

$$N + O = 162 - 83 = 79 \quad \dots (i) \quad (O > N)$$

10 years after the death of P means 15 years hence from present, let Q be born.

20 years from present means at that time Q = 5 years and is youngest.

Eldest member at that time = O (age = $O + 20$)

$$(O + 20) - 5 = 57$$

$$O = 57 - 15 = 42 \text{ years}$$

So, $N = 79 - 42 = 37 \text{ years}$

After 5 years, members alive are = M, N, O

$$M = 14 + 5 = 19 \text{ years}$$

$$N = 37 + 5 = 42 \text{ years}$$

$$O = 42 + 5 = 47 \text{ years}$$

Required ages of N and O are 42 and 47.

22. (b)

23. (d)

It would be easier if we visualize this problem. As sphere is inscribed in cube then the edges of the cube equal to the diameter of sphere,

$$\text{Diameter} = 10 \text{ units}$$

Next, Diagonal of a cube = $\sqrt{10^2 + 10^2 + 10^2} = 10\sqrt{3}$.

Now, half of (Diagonal minus Diameter) is the gap between the vertex of cube and surface of the sphere, which will be the shortest distance:

$$x = \frac{\text{Diagonal} - \text{Diameter}}{2} = \frac{10\sqrt{3} - 10}{2} = 5(\sqrt{3} - 1)$$

24. (c)

Let us assume $k = \frac{K}{100}$ and the cost price = C

Based on S1, we can write $C \times \left(1 + \frac{K}{100}\right) - C \times \left(1 - \frac{K}{100}\right) = 2560$

i.e. $\frac{2CK}{100} = 2560$ or $Ck = 1280$ which does not give the value of k or K . Hence Statement 1 is NOT sufficient.

Based on S2, $C \times 0.075 = K$ which gives $C = 40K/3 = 4000k/3$ which will NOT give the value of k or K .

When we combine the information given in both the statements, we will be able to find C as well as k or K . Hence option (c) is the correct option.

25. (c)

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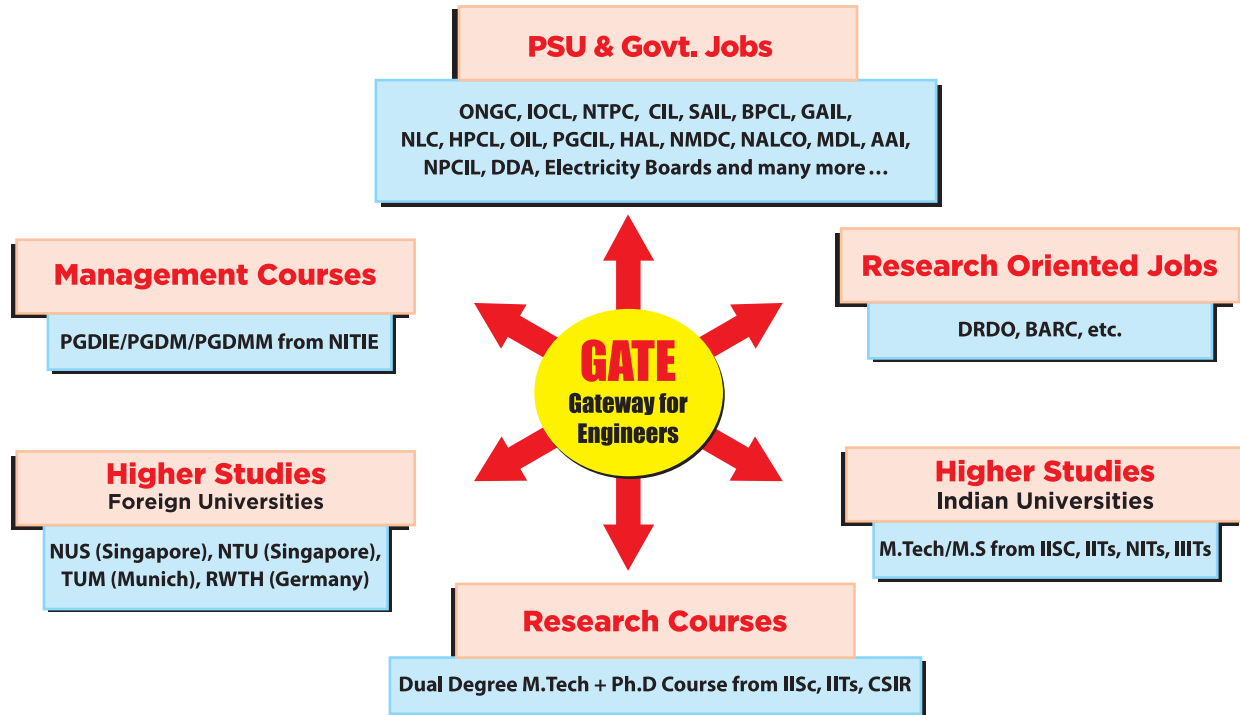
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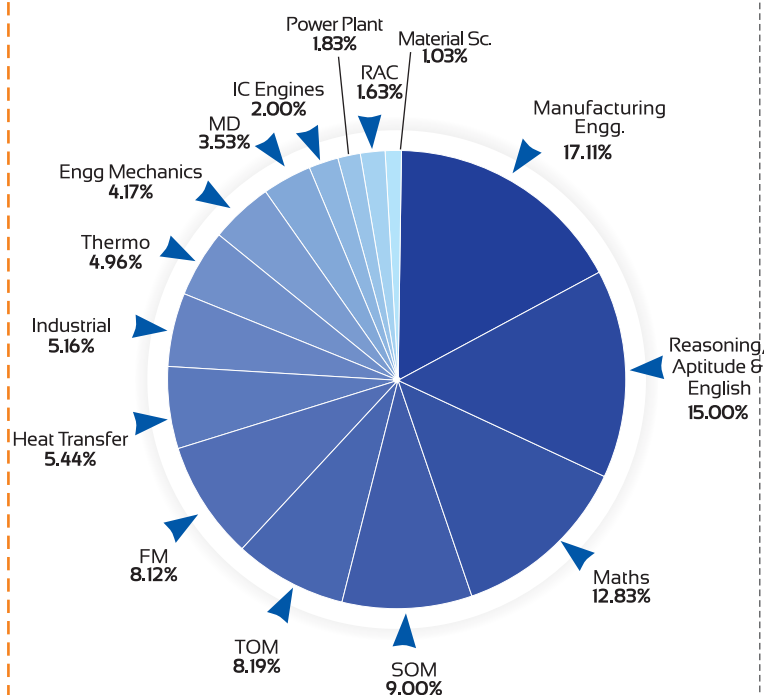
MECHANICAL ENGG.

Q.26 - Q.50
out of 200 Questions

Day 2 of 8



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Day 2 : Q.26 to Q. 50 : Mechanical Engineering

- Q.26** Two reversible refrigerators are arranged in series and their COPs are 3 and 4 respectively. The COP of composite refrigeration system would be _____.
- Q.27** A mixture of dry air and water vapour is at a temperature of 21°C and under a total pressure of 736 mm Hg. Specific humidity of given sample of air is 0.011 kg water vapour/kg dry air. Specific volume of air per kg of dry air is _____ m³/kg dry air. [Take $R = 0.287$ kJ/kgK]
- Q.28** An R134a simple saturation cycle refrigerator operates at 40°C condenser and -16°C evaporator temperature. COP of refrigerator is
Given data:
At $t_k = 40^\circ\text{C}$; $P_k = 1.0166$ bar; $c_p = 1.145$ kJ/kgK; $h_f = 256.41$ kJ/kg; $s_g = 1.711$ kJ/kgK;
 $h_g = 419.43$ kJ/kg;
At $t_0 = -16^\circ\text{C}$; $P_0 = 0.1573$ MPa; $c_p = 0.831$ kJ/kgK; $h_g = 389.02$ kJ/kg; $s_g = 1.7379$ kJ/kgK
(a) 3.41 (b) 4.78
(c) 2.92 (d) 4.41
- Q.29** Air enters the compressor of an ideal Brayton refrigeration cycle at 1 atm and 270 K with a volumetric flow rate of 1.5 m³/s. If the compressor pressure ratio is 3 and turbine inlet temperature is 300 K. The net power input required for the cycle is:
Turbine and compressor be 100% efficient.
Assume $c_p = 1.005$ kJ/kgK, Compression index = 1.4; $R = 0.287$ kJ/kgK
(a) 196.98 kW (b) 158.86 kW
(c) 36.91 kW (d) 29.18 kW
- Q.30** Moist air at standard atmospheric pressure is passed over a cooling coil. The inlet and exit states are

State	DBT	Relative humidity
Inlet	30°C	50 %
Outlet	15°C	80 %

Take: $[P_{\text{sat}}]_{30^\circ\text{C}} = 4.246$ kPa

$[P_{\text{sat}}]_{15^\circ\text{C}} = 1.7051$ kPa

$P_{\text{atm}} = 101.325$ kPa

Then the amount of moisture removed per kg of dry air is

- (a) 4.82 gm/kg da (b) 13.31 gm/kg da
(c) 8.49 gm/kg da (d) 10.92 gm/kg da

Q.31 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

- A. Earring
- B. Spatter
- C. Alligatoring
- D. Fish tailing

List-II

- 1. Extrusion
- 2. Rolling
- 3. Welding
- 4. Deep-drawing

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	4	3	2	1
(c)	2	1	4	3
(d)	2	1	3	4

Q.32 A 400 mm wide 25 mm thick strip is fed through a rolling mill with two powered rolls each of radius = 250 mm. The work thickness is to be reduced to 22 mm in one pass. The work material has average flow stress as 175 MPa. The torque required to drive each roll is _____ kNm.

Q.33 Match **List-I** (NC Code) with **List-II** (Definition) and select the correct answer using the codes given below in the lists:

List-I

- A. M 06
- B. M 03
- C. G 90
- D. G 00

List-II

- 1. Dwell
- 2. Tool selection
- 3. Absolute coordinate system
- 4. Spindle start
- 5. Spindle stop
- 6. Positioning

Codes:

	A	B	C	D
(a)	2	4	3	6
(b)	2	5	4	1
(c)	4	2	3	1
(d)	5	2	3	6

Q.34 A cylindrical side riser is used for a sand-casting mold. The casting itself is a rectangular plate with dimensions $7.5 \times 12.5 \times 2$ cm. The solidification time for this casting is 1.6 min. The cylinder for the riser have a diameter to height ratio equal to 1. If the riser and casting are in the same mold, then for a riser solidification time of 2 min, its dimension is _____ cm.

- Q.35** 2000 cc of air takes 90 seconds to pass through a standard specimen of sand (5.08 cm high and 5.08 cm diameter). The manometer indicates pressure as 5 g/cm². In this case the permeability number is
(a) 30 (b) 42
(c) 51 (d) 67
- Q.36** Consider the following parameters in a steady state gas metal arc welding with DC positive electrode polarity:
Welding speed : 8 m/min
Welding voltage : 40V
Electrode diameter : 1.5 mm
Electrode feed rate : 14 m/min
Density of electrode : 8000 kg/m³
Specific heat of electrode : 600 J/kg-K
Melting temperature of electrode : 1580°C
Latent heat of electrode : 265.6 kJ/kg
Ambient temperature : 30°C
Electrical efficiency : 65 %
Melting efficiency : 40%
The required welding current is
(a) 620 Amp (b) 295 Amp
(c) 482 Amp (d) 380 Amp
- Q.37** During orthogonal metal cutting process, the following data is obtained :
Rake angle = 12°
Chip thickness ratio = 0.5
Undeformed thickness = 0.7 mm
Cutting speed = 2.4 m/s
If the mean thickness of primary shear zone is 25 microns, then shear strain rate (in s⁻¹) during the process is
(a) 4.9×10^4 (b) 0.98×10^4
(c) 9.8×10^4 (d) 0.49×10^4
- Q.38** For a cutting tool, the value of rake angle is 0°. The minimum value of shear strain is
(a) 0 (b) 1
(c) 2 (d) 3
- Q.39** A 20 mm diameter drill is used to drill a hole in a 50 mm thick plate. The cutting speed and feed are 30 m/min and 0.6 mm/rev. If the point angle of drill is 118° then time to drill a hole is _____ sec.

Q.40 During an orthogonal machining operation on mild steel, the following results are obtained :
Uncut chip thickness = 0.3 mm

Chip thickness = 0.9 mm

Rake angle = 0°

Cutting force = 900 N

Thrust force = 400 N

Ultimate shear stress of the work materials = 380 N/mm^2

The minimum shear plane area is

- (a) 1.914 mm^2 (b) 2.628 mm^2
(c) 3.828 mm^2 (d) 4.029 mm^2

Q.41 During a turning operation, the following equation is given for tool life

$$VT^{0.13} f^{0.77} d^{0.37} = C$$

A 60 minutes tool life was obtained while cutting at $V = 30 \text{ m/min}$, $f = 0.3 \text{ mm/rev}$ and $d = 2.5 \text{ mm}$. If the cutting speed, feed and depth of cut are increased together by 20%, then the new tool life is

- (a) 14.75 min (b) 8.26 min
(c) 2.98 min (d) 5.22 min

Q.42 In a metal machining process, the tool change time and tool re-grind time are 10 mins and 8 mins respectively. If the machine running cost is Rs. 6 per hour and the tool depreciation per re-grind is 30 paise, then the optimum cutting speed is _____ m/sec. (Take $n = 0.25$ and $C = 180$)

Q.43 Consider a cube and a sphere. Both made up of same material and have the same volume. They are being cast. If the side length of cube is 100 mm, then the ratio of solidification time of the sphere to that of cube is _____.

Q.44 What is the smallest punch diameter that can be designed for piercing sheet metal strip with the following data?

Crushing strength of the punch material is 1500 MPa. Thickness of the sheet is 2 mm, factor of safety is 3, shear strength of the sheet material 500 MPa is

- (a) 2 mm (b) 6 mm
(c) 8 mm (d) 24 mm

Q.45 Composition of a Nickel super-alloy is as follow:

$$\text{Ni} = 70\%, \text{Cr} = 20\%, \text{Fe} = 5\%, \text{Ti} = 5\%$$

If the area of the tool is 1500 mm^2 and a current of 1000 A is being passed through the solution, then the rate of dissolution is _____ mm/min. (Use $F = 96500$)

$A_{\text{Ni}} = 58.71$	$\rho_{\text{Ni}} = 8.9 \text{ g/cm}^3$	$V_{\text{Ni}} = 2$
$A_{\text{Cr}} = 51.99$	$\rho_{\text{Cr}} = 7.19 \text{ g/cm}^3$	$V_{\text{Cr}} = 2$
$A_{\text{Fe}} = 55.85$	$\rho_{\text{Fe}} = 7.86 \text{ g/cm}^3$	$V_{\text{Fe}} = 2$
$A_{\text{Ti}} = 47.9$	$\rho_{\text{Ti}} = 4.51 \text{ g/cm}^3$	$V_{\text{Ti}} = 3$

Q.46 Two tools A and B have signatures

$$5^\circ - 5^\circ - 6^\circ - 6^\circ - 10^\circ - 45^\circ - 0 \text{ and}$$

$$5^\circ - 6^\circ - 7^\circ - 8^\circ - 12^\circ - 15^\circ - 0 \text{ (both ASA)}$$

respectively. They are used to turn components with feed of tool A as twice of feed of tool B . If h_A and h_B denote the peak-to-valley heights of surfaces produced by the tools A and B , then the ratio of h_A/h_B will be _____.

Q.47 A hole is specified as $30^{+0.012}_{-0.000}$ mm. The mating shaft has a clearance fit with minimum clearance of 0.02 mm. The hole tolerance is to be 1.5 times the shaft tolerance. The maximum clearance between the hole and the shaft is _____ mm.

Q.48 The voltage length characteristic of a direct current (dc) arc is given by: $V = (30 + 60\ell)$ volts, where ℓ is the length of the arc in cm. The power source characteristic is approximated by a straight line with an open circuit voltage = 80 V and a short circuit current = 1000 amp. Then the optimum arc length is

- (a) 0.5 cm (b) 0.267 cm
(c) 0.167 cm (d) 0.34 cm

Q.49 A steel wire is drawn from an initial diameter of 15 mm to a final diameter of 13.4 mm. The mean flow stress of steel is 400 MPa. The ideal force required for drawing is

- (a) 15.94 kN (b) 12.72 kN
(c) 14.28 kN (d) 56.41 kN

Q.50 Match **List-I** (process) with **List-II** (product/material) and select the correct answer using the codes given below the lists:

List-I

- A. Die casting
B. Shell molding
C. CO₂ molding
D. Centrifugal casting

List-II

1. Phenol formaldehyde
2. C.I. Pipes
3. Non ferrous alloys
4. Sodium silicate

Codes:

- | | A | B | C | D |
|-----|---|---|---|---|
| (a) | 1 | 3 | 4 | 2 |
| (b) | 3 | 1 | 4 | 2 |
| (c) | 3 | 1 | 2 | 4 |
| (d) | 1 | 3 | 2 | 4 |

■■■■

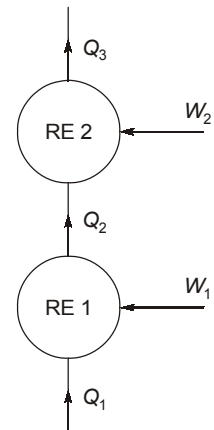
Detailed Explanations

26. (1.5)

$$\text{COP}_1 = \frac{Q_1}{W_1} = 3$$

$$\text{COP}_2 = \frac{Q_2}{W_2} = 4$$

$$\begin{aligned} \text{COP of composite system} &= \frac{Q_1}{W_1 + W_2} = \frac{Q_1}{\frac{Q_1}{3} + \frac{Q_2}{4}} = \frac{Q_1}{\frac{Q_1}{3} + \frac{(Q_1 + W_1)}{4}} \\ &= \frac{Q_1}{\frac{Q_1}{3} + \frac{Q_1 + \frac{Q_1}{3}}{4}} = \frac{1}{\frac{1}{3} + \frac{1}{4} + \frac{1}{3 \times 4}} = 1.5 \end{aligned}$$



27. (0.875)(0.87 to 0.88)

Given:

$$\omega = 0.011 \text{ kg w.v./kg d.a.}$$

$$P = 736 \text{ mm}$$

$$\text{Now, } \omega = 0.622 \frac{P_v}{(P - P_v)}$$

where, P_v = Partial pressure of water vapour

$$\Rightarrow 0.011 = 0.622 \frac{P_v}{(736 - P_v)}$$

$$\Rightarrow P_v = 12.79 \text{ mm Hg}$$

Now, partial pressure of given air sample

$$P_a = P - P_v = 736 - 12.79 = 723.21 \text{ mm Hg}$$

Specific volume of air is equal to the volume of 1 kg of dry air

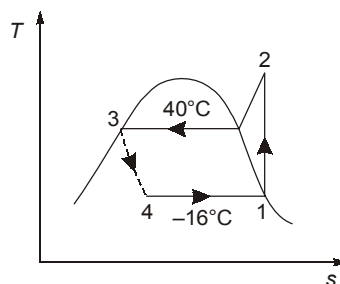
$$\Rightarrow v = v_a = \frac{R_a T}{P_a} = \frac{287 \times (273 + 21)}{\frac{723.21}{1000} \times 13.6 \times 1000 \times 9.81}$$

$$\Rightarrow v_a = 0.875 \text{ m}^3/\text{kg da}$$

28. (a)

Given data:

$$h_1 = 389.02 \text{ kJ/kg}$$



$$h_3 = 256.41 \text{ kJ/kg} = h_4$$

$$s_1 = 1.7379 \text{ kJ/kgK} = s_2$$

To calculate discharge temperature of compressor,

$$\Rightarrow s_2 = s_{g40^\circ\text{C}} + c_p \ln \frac{T_2}{T_g} = s_1$$

$$\Rightarrow 1.711 + 1.145 \ln \frac{T_2}{313} = 1.7379$$

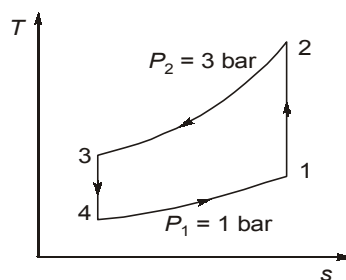
On solving,

$$\Rightarrow T_2 = 320.5 \text{ K}$$

$$\begin{aligned} \text{Now, } h_2 &= h_{g40^\circ\text{C}} + C_p [T_2 - T_3] \\ &= 419.43 + 1.145 [320.5 - 313] = 427.92 \text{ kJ/kg} \end{aligned}$$

$$\text{Now, COP} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{389.04 - 256.41}{427.92 - 389.04} = 3.41$$

29. (c)



$$T_1 = 270 \text{ K}; P_1 = 1 \text{ atm}; P_2 = 3 \text{ atm}$$

$$\Rightarrow T_2 = T_1 \times \left[\frac{P_2}{P_1} \right]^{\frac{\gamma-1}{\gamma}} = 270 \times (3)^{0.4/1.4} = 369.56 \text{ K}$$

$$\Rightarrow T_3 = 300 \text{ K}$$

$$\Rightarrow T_4 = \frac{T_3}{\left[\frac{P_2}{P_1} \right]^{\frac{\gamma-1}{\gamma}}} = 300 / (3)^{0.4/1.4} = 219.18 \text{ K}$$

$$\text{Specific volume, } v_1 = \frac{RT_1}{P_1} = \frac{287 \times 270}{1.01 \times 10^5} = 0.765 \text{ m}^3/\text{kg}$$

$$\text{Mass flow rate, } \dot{m} = \frac{\dot{V}}{v_1} = \frac{1.5}{0.765} = 1.96 \text{ kg/s}$$

$$\begin{aligned} \text{Net power input} &= \dot{m} c_p [(T_2 - T_1) - (T_3 - T_4)] \\ &= 1.96 \times 1.005 [(369.56 - 270) - (300 - 219.18)] = 36.91 \text{ kW} \end{aligned}$$

30. (a)

Inlet conditions denoted by subscript 1.

Outlet conditions denoted by subscript 2.

$$P_{s1} = 4.246 \text{ kPa}$$

$$\phi_1 = 0.5$$

$$P_{v1} = \phi_1 P_{s1} \\ = 0.5 \times 4.246 = 2.123 \text{ kPa}$$

$$P_{s2} = 1.7051 \text{ kPa}$$

$$\phi_2 = 0.8$$

$$P_{v2} = \phi_2 P_{s2} \\ = 0.8 \times 1.7051 = 1.3641 \text{ kPa}$$

Specific humidities are:

$$\omega_1 = 0.622 \times \frac{P_{v1}}{P - P_{v1}} \\ = 0.622 \times \frac{2.123}{101.325 - 2.123} = 0.01331 \text{ kg/kg da}$$

$$\omega_2 = 0.622 \times \frac{P_{v2}}{P - P_{v2}} \\ = 0.622 \times \frac{1.3641}{101.325 - 1.3641} = 0.00849 \text{ kg/kg da}$$

$$\text{Moisture removed} = \omega_1 - \omega_2 \\ = 0.01331 - 0.00849 = 0.00482 \text{ kg/kg da}$$

31. (b)

32. (26.26)(25.90 to 26.60)

Given:

$$H_1 = 25 \text{ mm}; H_2 = 22 \text{ mm}$$

$$R = 250 \text{ mm}; \bar{\sigma}_f = 175 \text{ MPa},$$

$$n = 0.15; w = 400 \text{ mm}$$

The contact length is given by,

$$L = \sqrt{R\Delta H} = \sqrt{250 \times (25 - 22)} = 27.39 \text{ mm}$$

$$\text{Now, rolling force (F), } F = \bar{\sigma}_f \times L \times w = 175 \times 27.39 \times 400 = 1917300 \text{ N}$$

$$\therefore \text{ Torque (each roll) } = F \times a = 1917300 \times 0.5 \times 27.39 \\ = 26257423.5 \text{ Nmm} = 26.26 \text{ kNm}$$

33. (a)

34. (4.699)(4.6 to 4.9)

$$\text{Volume of plate} = 7.5 \times 12.5 \times 2 = 187.5 \text{ cm}^3$$

$$\text{Surface area of plate} = 2(7.5 \times 12.5 + 7.5 \times 2 + 12.5 \times 2) = 267.5 \text{ cm}^2$$

For the casting,

$$t = C_m \left(\frac{V}{SA} \right)^2$$

$$\therefore C_m = \frac{1.6}{\left(\frac{187.5}{267.5} \right)^2} = 3.26 \text{ min/cm}^2$$

Now, we design the riser so that its solidification time is 2 min, using the same value of mold constant (C_m) as they both are in the same mold.

$$\text{Volume of riser} = \frac{\pi D^2}{4} \times H = \frac{\pi D^3}{4}$$

$$\begin{aligned} \text{Surface area of riser} &= \pi DH + \frac{2 \times \pi D^2}{4} \\ &= \pi D^2 + \frac{\pi D^2}{2} = \frac{3\pi D^2}{2} \end{aligned}$$

$$\text{Thus, } \left(\frac{V}{SA} \right)_{\text{riser}} = \frac{D}{6}$$

$$\text{Now, } t_{\text{riser}} = 2 \text{ min (Given)}$$

$$\text{So, } t_{\text{riser}} = c_m \left(\frac{V}{SA} \right)^2$$

$$\Rightarrow 2 = 3.26 \times \frac{D^2}{36}$$

$$\Rightarrow D = 4.699 \text{ cm}$$

35. (d)

$$\text{Permeability number, } P = \frac{Vh}{pAt}$$

$$\text{where, Volume of air, } V = 2000 \text{ cm}^3$$

$$\text{Time (in minutes) } t = 90 \text{ sec or } 1.5 \text{ minutes}$$

$$\text{Height, } h = 5.08 \text{ cm}$$

$$\text{Area, } A = \frac{\pi}{4} d^2 = \frac{\pi}{4} (5.08)^2$$

$$\text{and Pressure, } p = 5 \text{ g/cm}^2$$

$$\text{So, Permeability number, } P = \frac{2000 \times 5.08}{5 \times \frac{\pi}{4} \times (5.08)^2 \times 1.5} = 66.84 \text{ or } 67$$

36. (d)

Let welding current = I

So, Heat generated = $VI = 40I \text{ J/s}$

$$\begin{aligned}\text{Heat required for welding} &= \frac{\pi d^2}{4} \times R \times \rho \times (L + c_p \times \Delta T) \\ &= \frac{\pi}{4} \times 1.5^2 \times 10^{-6} \times \frac{14}{60} \times 8000 (265.6 \times 10^3 + 600 \times (1580 - 30)) \\ &= 3943.89 \text{ J/s}\end{aligned}$$

Now, heat available for melting = $\eta_{\text{electric}} \times \text{Heat generated}$
 $= 0.65 \times 40 \times I = 26I \text{ J/s}$

$$\begin{aligned}\text{Heat required for welding} &= \eta_{\text{melting}} \times \text{Heat available for melting} \\ 3943.89 &= 0.4 \times 26I \\ I &= \frac{3943.89}{10.4} = 379.22 \text{ Amp.} \approx 380 \text{ Amp.}\end{aligned}$$

37. (c)

$r = 0.5$; $\alpha = 12^\circ$; $v = 2.4 \text{ m/s}$

$$\text{Now, } \tan \phi = \frac{r \cos \alpha}{1 - r \sin \alpha} = \frac{0.5 \cos 12^\circ}{1 - 0.5 \sin 12^\circ}$$

$$\phi = \tan^{-1}(0.5458) = 28.63^\circ$$

Also, shear velocity is,

$$v_s = \frac{v \cos \alpha}{\cos(\phi - \alpha)} = \frac{2.4 \cos 12^\circ}{\cos(28.63 - 12)} = 2.45 \text{ m/s}$$

$$\therefore \text{Shear strain rate} = \frac{v_s}{t_s} = \frac{2.45}{25 \times 10^{-6}} = 9.8 \times 10^4 \text{ s}^{-1}$$

38. (c)

Shear strain, $\epsilon = \cot \phi + \tan(\phi - \alpha)$

$\Rightarrow$ For zero rake angle shear strain, $\epsilon = \cot \phi + \tan \phi$

For minimum shear strain, $\frac{d\epsilon}{d\phi} = -\text{cosec}^2 \phi + \sec^2 \phi = 0$

$$\Rightarrow \sec^2 \phi = \text{cosec}^2 \phi$$

$$\Rightarrow \frac{1}{\cos^2 \phi} = \frac{1}{\sin^2 \phi}$$

$$\therefore \tan^2 \phi = 1$$

$$\Rightarrow \tan \phi = \pm 1$$

Discarding negative value, $\phi = 45^\circ$

So, minimum value of shear strain is given by

$$\epsilon_{\min} = \cot 45^\circ + \tan 45^\circ = 2$$

39. (11.729)(11 to 12)

$$N = \frac{30 \times 1000}{\pi \times 20} = 477.45 \text{ rpm}$$

Cone height :

$$X = \frac{D/2}{\tan \alpha/2} = \frac{10}{\tan 59^\circ} = 6 \text{ mm}$$

$$\text{Time required} = \frac{50 + 6}{0.6 \times 477.45} \times 60 = 11.729 \text{ sec}$$

40. (a)

$$t = 0.3 \text{ mm}; t_c = 0.9 \text{ mm}; \alpha = 0^\circ; F_c = 900 \text{ N}, F_T = 400 \text{ N}; \tau_s = 380 \text{ N/mm}^2$$

$$\text{Now, } \tan \phi = \frac{r \cos \alpha}{1 - r \sin \alpha} = r = \frac{t}{t_c} = \frac{1}{3}$$

$$\Rightarrow \phi = \tan^{-1}\left(\frac{1}{3}\right) = 18.43^\circ$$

Now, the shear force (F_s) is given by

$$F_s = F_c \cos \phi - F_T \sin \phi = 900 \cos(18.43^\circ) - 400 \sin(18.43^\circ)$$

$$F_s = 727.38 \text{ N}$$

$\therefore$ Area of shear plane is,

$$A_s = \frac{F_s}{\tau_s} = \frac{727.38}{380} = 1.914 \text{ mm}^2$$

41. (c)

$$V' = 30 \times 1.2 = 36 \text{ m/min}$$

$$f' = 0.3 \times 1.2 = 0.36 \text{ mm/rev.}$$

$$d' = 2.5 \times 1.2 = 3 \text{ mm}$$

$$\text{So, } VT^{0.13} f^{0.77} d^{0.37} = V'(T')^{0.13} (f')^{0.77} (d')^{0.37}$$

$$\Rightarrow \left(\frac{T'}{T}\right)^{0.13} = \frac{V}{V'} \times \left(\frac{f}{f'}\right)^{0.77} \times \left(\frac{d}{d'}\right)^{0.37} = 0.6769$$

$$\therefore T' = (0.6769)^{1/0.13} \times T = 2.98 \text{ min}$$

42. (1.06)(1.03 to 1.10)

$$\text{Tooling cost, } C_t = (\text{Tool re-grind cost}) + (\text{Tool depreciation})$$

$$= \frac{6}{60} \times 8 + 0.3 = 0.8 + 0.3 = \text{Rs. 1.1/re-grind}$$

Machining cost, $C_m = \text{Rs. } \frac{6}{60} \text{ per min} = \text{Rs. } 0.1/\text{min}$

$$T_0 = \left(T_c + \frac{C_t}{C_m} \right) \left(\frac{1-n}{n} \right) = \left(10 + \frac{1.1}{0.1} \right) \left(\frac{1-0.25}{0.25} \right) = 63 \text{ min}$$

$$V_0 T_0^n = C,$$

$$V_0 = \frac{C}{T_0^n} = \frac{180}{63^{0.25}} = 63.89 \text{ m/min} = 1.06 \text{ m/s}$$

43. (1.539)(1.52 to 1.55)

Given: $l = 100 \text{ mm}$

Now, $\frac{4}{3}\pi r^3 = l^3$

$$\Rightarrow r = \left(\frac{3}{4\pi} \right)^{1/3} \times l = 62.035 \text{ mm}$$

$$t \propto \left(\frac{V}{SA} \right)^2$$

Now, $\frac{t_s}{t_c} = \left(\frac{6}{4\pi} \right)^2 \left(\frac{l}{r} \right)^4 = 1.539$

44. (c)

Punching force = $\pi d t \tau$

$$= \pi \times d \times 2 \times 500$$

...(i)

Considering crushing strength, we have

$$\text{Force} = \frac{1500}{3} \times \frac{\pi d^2}{4}$$

...(ii)

Equating Eqs. (i) and (ii), we get

$$1000 \pi d = \frac{500}{4} \times \pi d^2 \quad \text{or} \quad d = 8 \text{ mm}$$

45. (1.409)(1.39 to 1.45)

$$\frac{100}{\rho_{eq}} = \sum \left(\frac{x_i}{\rho_i} \right) = \frac{70}{8.9} + \frac{20}{7.19} + \frac{5}{7.86} + \frac{5}{4.51}$$

$$\Rightarrow \rho_{eq} = 8.069 \text{ g/cm}^3$$

Also $\frac{100}{E_{eq}} = \sum \left(\frac{x_i v_i}{A_i} \right) = \frac{70 \times 2}{58.71} + \frac{20 \times 2}{51.99} + \frac{5 \times 2}{55.85} + \frac{5 \times 3}{47.9}$

$$\Rightarrow E_{eq} = 27.426$$

$$\begin{aligned}\text{Now, Rate of dissolution} &= \frac{E_{eq} \Gamma}{\rho_{eq} F(\text{Area})} = \left(\frac{27.426 \times 1000}{8.069 \times 96500 \times 1500} \right) \times 1000 \\ &= 0.023 \text{ mm/sec} = 1.409 \text{ mm/min}\end{aligned}$$

46. (1.491)(1.485 to 1.495)

$$h_A = \frac{f_A}{\tan 45^\circ + \cot 10^\circ}$$

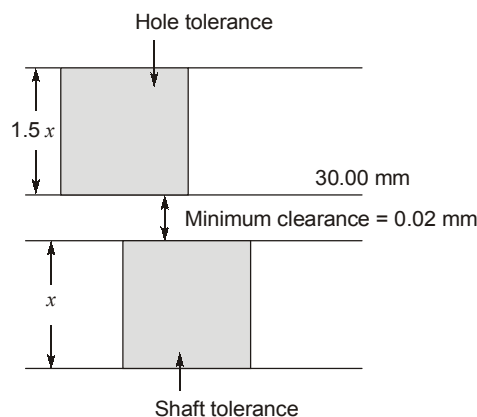
and

$$h_B = \frac{f_B}{\tan 15^\circ + \cot 12^\circ}$$

$$\therefore \frac{h_A}{h_B} = \frac{f_A}{f_B} \times \left(\frac{\tan 15^\circ + \cot 12^\circ}{\tan 45^\circ + \cot 10^\circ} \right)$$

$$\Rightarrow \frac{h_A}{h_B} = 2 \times \left(\frac{4.9726}{6.6713} \right) = 1.491$$

47. (0.04)



Let shaft tolerance be x

$$\text{Hole tolerance} = 1.5x = 0.012 \text{ mm}$$

$$x = 0.008 \text{ mm}$$

$$\begin{aligned}\text{Maximum clearance} &= x + 1.5x + 0.02 \\ &= 0.008 + 0.012 + 0.02 = 0.04 \text{ mm}\end{aligned}$$

48. (c)

$$V = \left(80 - \frac{80}{1000} I \right) \text{ volts}$$

we have, $V = (30 + 60I) \text{ volts}$, substituting we get,

$$80 - \frac{80}{1000} I = 30 + 60I$$

or
$$I = (50 - 60l) \frac{1000}{80} \text{ amp.}$$

Now,
$$P = VI = (30 + 60l)(50 - 60l) \frac{1000}{80}$$

For maximum power, $\frac{dP}{dl} = 0$

$$-60(30 + 60l) + 60(50 - 60l) = 0$$

$$\therefore l_{\text{opt}} = \frac{20}{120} = 0.167 \text{ cm}$$

49. (b)

Given: $D_i = 15 \text{ mm}$; $D_f = 13.4 \text{ mm}$; $\sigma_0 = 400 \text{ MPa}$

$$\sigma_0 = \sigma_0 \ln \left(\frac{A_i}{A_f} \right) = 2 \times \sigma_0 \ln \left(\frac{D_i}{D_f} \right)$$

$$= 2 \times 400 \times \ln \left(\frac{15}{13.4} \right) = 90.23 \text{ MPa}$$

$$\text{Ideal drawing force} = \sigma_d \times A_f$$

$$= 90.23 \times \frac{\pi}{4} \times d_f^2 = 90.23 \times \frac{\pi}{4} \times (13.4)^2 = 12.724 \text{ kN}$$

50. (b)

A - 3, B - 1, C - 4, D - 2.

■■■■



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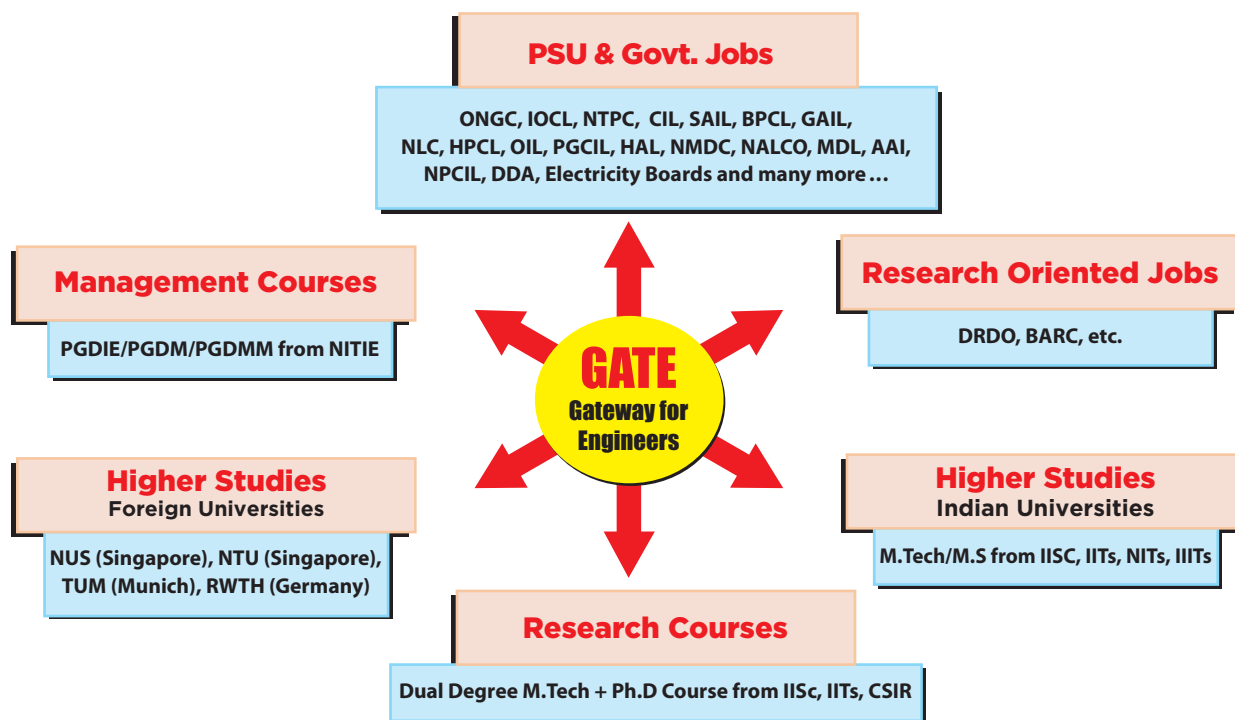
Revision through Questions for GATE 2020

ME

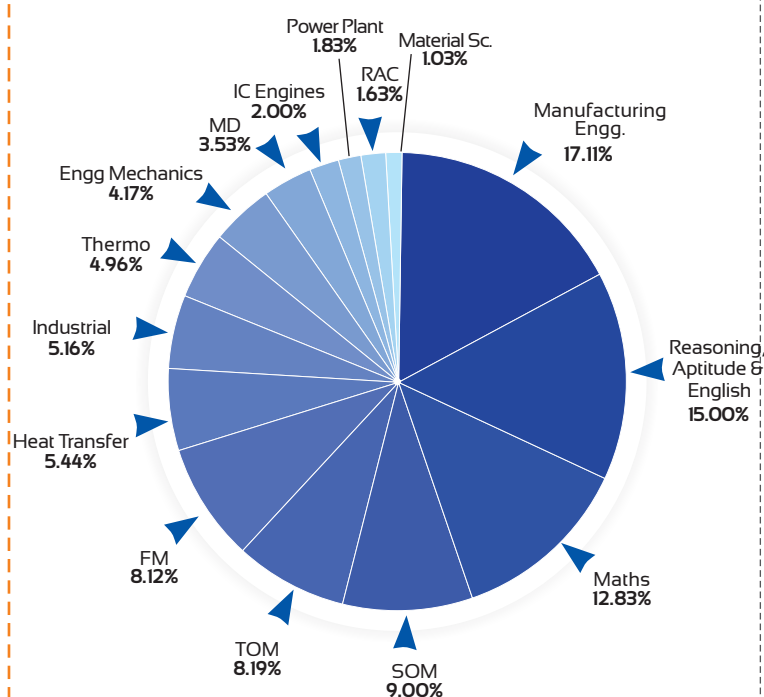
MECHANICAL ENGG.

Q.51 - Q.75
out of 200 Questions

Day 3 of 8



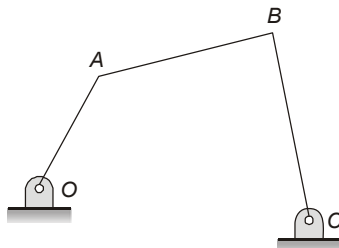
SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 3 : Q.51 to Q.75 : Mechanical Engineering

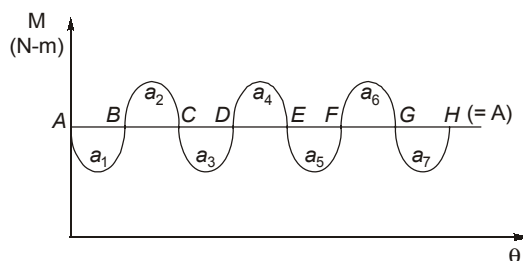
Q.51 The four bar mechanism shown in the figure (Given: $OA = 4$ cm; $AB = 5$ cm; $BC = 6$ cm; $OC = 8$ cm) is a



- (a) Double crank mechanism (b) Crank rocker mechanism
(c) Double rocker mechanism (d) Single slider mechanism

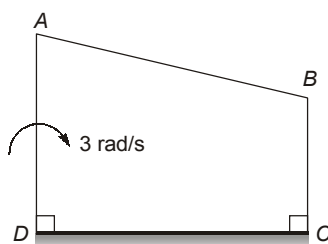
Q.52 A turning moment diagram for a multi-cylinder engine is shown in the figure. The areas (in cm^2) of the turning moment diagram above and below the mean torque line are given in the table. The engine speed is 94 rad/s and it is desired that the fluctuation from minimum to maximum speed should not be more than $\pm 3\%$ of average speed. The moment of inertia of the flywheel is _____ kgm^2 .

(Vertical scale : 1 cm = 7000 Nm; Horizontal scale : 1 cm = 30° crank rotation)



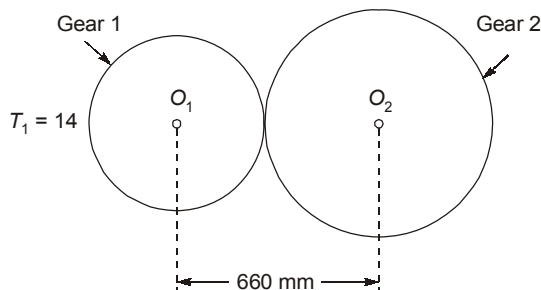
Name	Area (cm^2)
a_1	0.5
a_2	1.2
a_3	0.95
a_4	1.45
a_5	0.85
a_6	0.71
a_7	1.06

Q.53 At an instant, a four bar mechanism is shown below. The angular velocity of link BC at this instant. ($AD = 10$ m, $BC = 5$ m)

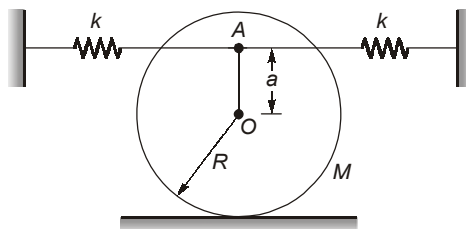


- (a) 3 rad/s (b) 4 rad/s
(c) 5 rad/s (d) 6 rad/s

- Q.54** A gear train is shown in the figure. If the pinion transmits 250 kW at 1800 rpm and the tangential load on the gear tooth is 22.1048 kN, then the gear ratio (to the closest integer) is



- (a) 5 (b) 10
(c) 15 (d) 20
- Q.55** A disc of radius R and mass M is connected to two springs (spring constant = k) as shown in figure. If the disc rolls without slipping, then the natural frequency of vibration of the disc is



- (a) $\frac{R+a}{a} \sqrt{\frac{4k}{3M}}$ (b) $\frac{R}{a} \sqrt{\frac{4k}{M}}$
(c) $\frac{R+a}{R} \sqrt{\frac{2k}{3M}}$ (d) $\frac{R+a}{R} \sqrt{\frac{4k}{3M}}$
- Q.56** The turbine rotor of a ship has a mass of 8 tonnes and a radius of gyration 0.6 m. It rotates at 1800 rpm clockwise, when looking from the stern. The gyroscopic couple, if the ship travels at 100 km/hr and steer to the left in a curve of radius 75 m, is
- (a) 200.86 kNm (b) 180.42 kNm
(c) 210.1 kNm (d) 280.62 kNm
- Q.57** A uniform disc of diameter 300 mm and mass of 5 kg is mounted on one end of an arm of length 600 mm. The other end of the arm is free to rotate in a universal bearing. If the disc rotates about the arm with a speed of 300 rpm clockwise, looking from the front, with what speed will it precess about the vertical axis?
- (a) 159.7 rpm (b) 169.5 rpm
(c) 179.5 rpm (d) 189.8 rpm

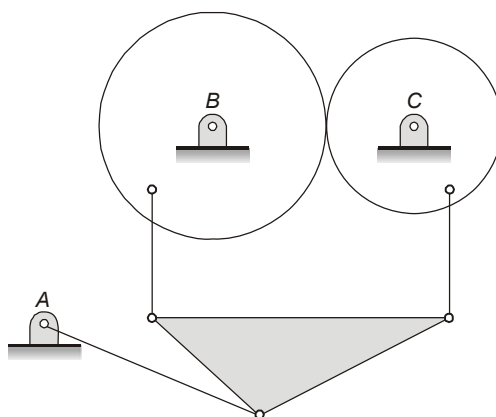
Q.58 A machine weights 18 kg and is supported on springs and dashpots. The equivalent stiffness of the springs is 12 N/mm and the damping factor is 0.215. The system is initially at rest and a velocity of 120 mm/s is imported to the mass. Displacement of the machine as a function of time is given by equation.

$$x = Xe^{-at} \sin(bt + \phi) \text{ mm}$$

Value of X in the above equation will be

- (a) 5.55 mm (b) 8.37 mm
(c) 3.83 mm (d) 4.76 mm

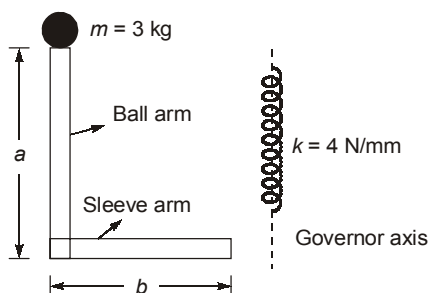
Q.59 The mobility of the mechanism shown in the figure is



- (a) -1 (b) 0
(c) 1 (d) 2

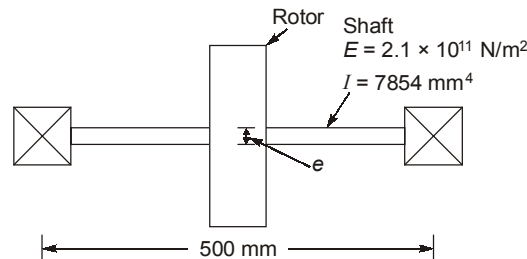
Q.60 A Hartnell governor as shown in the figure, the maximum and minimum speed of rotation are 23 rad/s and 22 rad/s respectively. If the maximum radius of rotation is twice the minimum

radius, then the ratio $\left(\frac{b}{a}\right)$ is

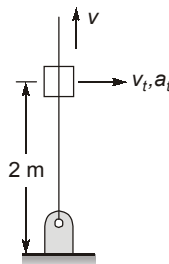


- (a) 1.16 (b) 0.86
(c) 1.08 (d) 0.93

- Q.61** The rotor of a turbine 15 kg in mass, is supported at the midspan of a shaft as shown in figure. The shaft rotates at 500 rpm and the rotor displaces by an additional of 0.01 mm. The eccentricity (e) of the rotor is
(Assume simply supported shaft)



- (a) 144 μm (b) 0.69 μm
(c) 14.4 μm (d) 6.9 μm
- Q.62** A link with a slider is rotating as shown in figure. At this instant the sliding velocity of slider is 3 m/s. The tangential acceleration and tangential velocity of the slider are 4 m/s² and 8 m/s respectively. At this instant, the total acceleration of slider is

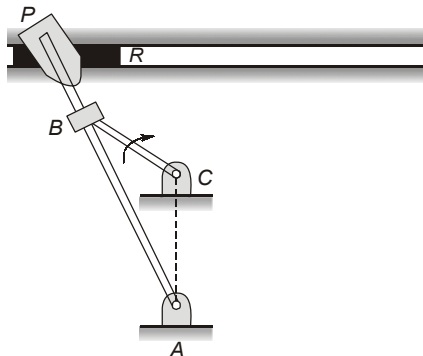


- (a) 32.61 m/s² (b) 38.22 m/s²
(c) 42.52 m/s² (d) 50.88 m/s²
- Q.63** In an epicyclic gear train, an arm carries two gears A and B having 36 and 45 teeth respectively. If the arm rotates at 150 rpm in the anticlockwise direction about the centre of gear A which is fixed, the speed of gear B is
(a) 510 rpm CCW (b) 270 rpm CW
(c) 510 rpm CW (d) 270 rpm CCW

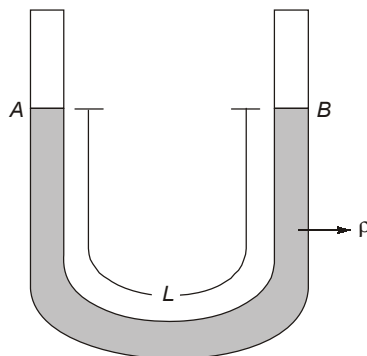
- Q.64** The turning moment curve of an engine is given by
 $T = 20000 + 9500 \sin 2\theta - 5700 \cos 2\theta$ Nm,
where, θ is the angle moved by crank from inner dead centre. If the moment of inertia of flywheel is 3121 kgm², then the angular acceleration of the flywheel, when the crank has turned 45° from inner dead centre is _____ rad/s².

- Q.65** A machine requires a torque of $(5000 + 500 \sin \theta)$ Nm to drive it, where θ is the angle of rotation. The machine is directly coupled to any engine which produces a torque of $(5000 + 600 \sin 2\theta)$ Nm. The flywheel has a mass of 500 kg at a radius of gyration of 0.4 m. If the mean speed is 15 rad/s, then the total percentage fluctuation of speed is _____. (Maximum fluctuation of energy occurs between 180° and 300° angular position approximately)

- Q.66** Figure shows the layout of a quick return mechanism of the oscillating link type. The driving crank BC is 30 mm long and the time ratio of the working stroke to the return stroke is 1.7. If the length of working stroke of R is 120 mm, then the ratio of dimensions of AC and AP is _____.



- Q.67** A U-tube as shown in figure contains a liquid of density ρ . The liquid is set into motion by applying a force. The natural frequency of oscillation is given by



- (a) $\sqrt{\frac{g}{L}}$ (b) $\sqrt{\frac{g}{2L}}$
(c) $\sqrt{\frac{2g}{L}}$ (d) $\sqrt{\frac{3g}{2L}}$

- Q.68** In a cam design, the rise motion is given by a Simple Harmonic Motion (SHM)

$$s = \frac{h}{2} \left(1 - \cos \frac{\pi\theta}{\beta} \right) \text{ where } h \text{ is total rise, } \theta \text{ is camshaft angle, } \beta \text{ is the total angle of the rise}$$

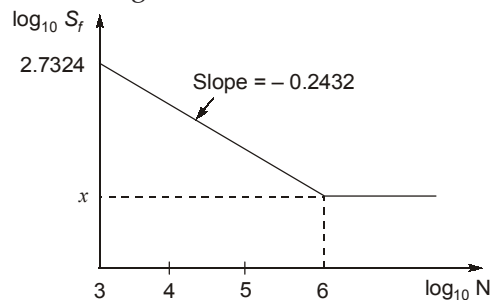
interval. The jerk is given by

- (a) $\frac{h}{2} \left(1 - \cos \frac{\pi\theta}{\beta} \right)$ (b) $\frac{\pi h}{\beta^2} \sin \left(\frac{\pi\theta}{\beta} \right)$
(c) $\frac{\pi^2 h}{\beta^2} \cos \left(\frac{\pi\theta}{\beta} \right)$ (d) $-\frac{\pi^3 h}{\beta^3} \sin \left(\frac{\pi\theta}{\beta} \right)$

- Q.69** A spur gear has module of 3 mm, number of teeth 16, a face width of 36 mm and a pressure angle of 20° . It is transmitting a power of 3 kW at 20 rev/s. Taking a velocity factor of 1.5 and a form factor of 0.3, the stress in the gear tooth is _____ MPa.

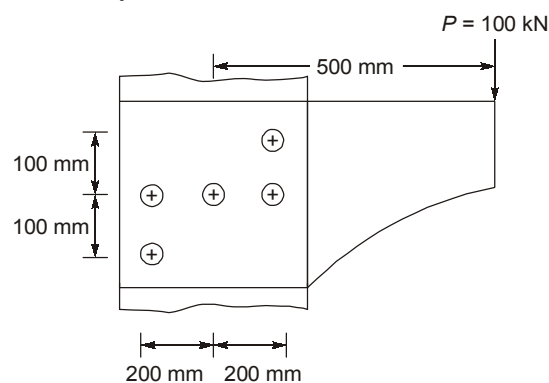
Q.70 A machine component is subjected to fluctuating stress that varies from 40 to 100 N/mm². The corrected endurance limit stress for the machine component is 270 N/mm². The ultimate tensile strength and yield strength of the material are 600 and 450 N/mm² respectively. The factor of safety using Goodman line is _____.

Q.71 A S-N curve for steel is shown in the figure below. The corrected endurance limit will be (in MPa)

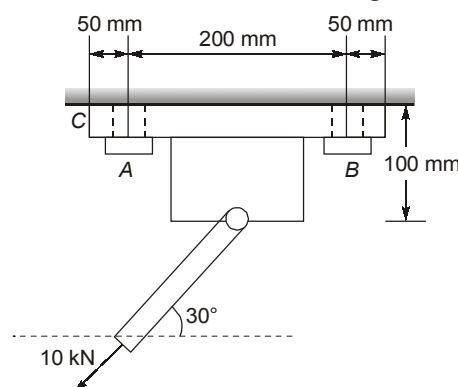


- (a) 2.0028
(b) 100.65
(c) 7.409
(d) 50.32

Q.72 Shown in the figure is a bracket attached to a channel by means of 5 identical rivet. The maximum load on most heavily stressed rivet is _____ kN.



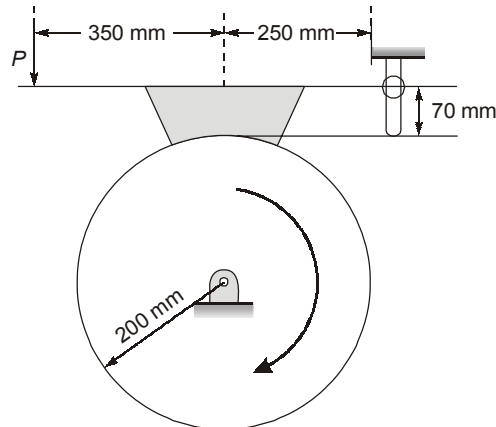
Q.73 Shown below is a bracket fastened by means of four identical bolts, two at A and two at B. Maximum shear stress introduced in the bolts due to given loading is



(Take bolt of nominal diameter 10 mm)

- (a) 21.02 N/mm²
(b) 27.56 N/mm²
(c) 48.77 N/mm²
(d) 33.23 N/mm²

- Q.74** Shown in the figure is a single block brake. The intensity of pressure between the block and brake drum is 1.5 N/mm^2 . The dimensions of block is $40 \text{ mm} \times 80 \text{ mm}$. The coefficient of friction is 0.25. What is the value of hinge pin reaction for clockwise rotation of the drum?



- (a) 1860 N
(b) 3175.5 N
(c) 2940 N
(d) cannot be calculated from given data
- Q.75** A deep groove ball bearing has a dynamic load capacity of 40000 N. Work cycle consists of 5000 N at 1440 rpm for 20% time, 3000 N at 2880 rpm for 50% time and 6000 N at 720 rpm for 30% time. The life of bearing is _____. (in million rev.)



Detailed Explanations

51. (c)

Sum of shortest and largest link length = $4 + 8 = 12$ cm

Sum of other two links length = $5 + 6 = 11$ cm

If the sum of shortest and longest links is greater than sum of other two then always, double rocker mechanism is obtained.

52. (11.75)(11.3 to 12.3)

Let the energy at A $E_A = E$

So, $E_B = E - 0.5$

$$E_C = E - 0.5 + 1.2 = E + 0.7$$

$$E_D = E - 0.5 + 1.2 - 0.95 = E - 0.25$$

$$E_E = E - 0.5 + 1.2 - 0.95 + 1.45 = E + 1.2$$

$$E_F = E - 0.5 + 1.2 - 0.95 + 1.45 - 0.85 = E + 0.35$$

$$E_G = E - 0.5 + 1.2 - 0.95 + 1.45 - 0.85 + 0.71 = E + 1.06$$

$$E_H = E_A = E$$

$$\text{So, } \Delta E = E_{\max} - E_{\min} = E_E - E_B = (E + 1.2) - (E - 0.5)$$

$$= 1.7 \text{ cm}^2 = 1.7 \times 7000 \times \frac{30\pi}{180} = 6230.83 \text{ Nm}$$

$$\text{Also, } \Delta E = I\omega^2 c$$

$$\therefore I = \frac{6230.83}{(94)^2 \times 0.06} = 11.75 \text{ kgm}^2$$

53. (d)

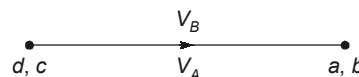
Given: $\omega_{AD} = 3 \text{ rad/s}$

$$AD = 10 \text{ m}$$

$$BC = 5 \text{ m}$$

$$\text{So, } V_A = \omega_{AD} \times AD = 3 \times 10 = 30 \text{ m/s}$$

Velocity diagram at this instant will be,



$$\text{So, } V_A = V_B = 30 \text{ m/s}$$

$$\text{Now, } \omega_{BC} = \frac{V_B}{BC} = \frac{30}{5} = 6 \text{ rad/s}$$

54. (b)

Given: $P = 250 \text{ kW}$, $N_1 = 1800 \text{ rpm}$, $F = 22.1048 \text{ kN}$, $T_1 = 14$

$$\text{So, } P = T\omega_1 = T \times \left(\frac{2\pi N_1}{60} \right) = T \times \left(\frac{2\pi \times 1800}{60} \right)$$

$$\Rightarrow T = \frac{250 \times 60}{2\pi \times 1800} = 1.326 \text{ kNm}$$

$$\text{Also, } T = \frac{F \times D_1}{2}$$

$$\therefore D_1 = \frac{2T}{F} = \frac{2 \times 1.326}{22.1048} = 0.11997 \text{ m} = 119.974 \text{ mm}$$

Now, $\frac{D_1}{2} + \frac{D_2}{2} = 660$

$$\Rightarrow D_2 = 1200.026 \text{ mm}$$

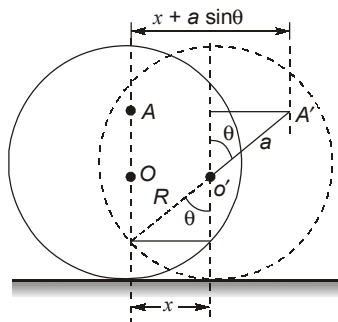
Also, by equal module of gear 1 and 2,

$$\frac{D_1}{T_1} = \frac{D_2}{T_2}$$

$$\therefore \frac{T_2}{T_1} = \frac{D_2}{D_1} = \frac{1200.026}{119.974} = 10$$

55. (d)

Let the disc rotate by a small angle θ



Displacement, $AA' = x + a \sin \theta = x + a \theta$

(For small angle, $\sin \theta = \theta$)

So, $AA' = (R + a) \theta$

The total energy of the system,

$$U = \frac{1}{2} M \dot{x}^2 + \frac{1}{2} I \omega^2 + 2 \times \frac{1}{2} k y^2$$

where, $y = AA' = (R + a) \theta$ and $I = \frac{MR^2}{2}$

So, $U = \frac{1}{2} M \dot{\theta}^2 R^2 + \frac{1}{2} \times \frac{MR^2}{2} \times \dot{\theta}^2 + k(R + a)^2 \theta^2$

$$U = \frac{3}{4} MR^2 \dot{\theta}^2 + k(R + a)^2 \theta^2$$

Now, $\frac{dU}{dt} = 0$

$$\frac{3}{2} MR^2 \ddot{\theta} + 2k(R + a)^2 \theta = 0$$

$$\Rightarrow \ddot{\theta} + \frac{4k(R + a)^2}{3M R^2} \theta = 0$$

$$\therefore \omega_n = \sqrt{\frac{4k(R + a)^2}{3M R^2}} = \frac{R + a}{R} \sqrt{\frac{4k}{3M}}$$

56. (a)

Given: $m = 8000 \text{ kg}$, $k = 0.6 \text{ m}$, $N = 1800 \text{ rpm}$, $\omega = \frac{2\pi N}{60} = 188.5 \text{ rad/s}$, $V = 100 \text{ km/hr} = 27.8 \text{ m/s}$,

$$R = 75 \text{ m}$$

Now, moment of inertia of rotor

$$I = mk^2 = 8000 \times (0.6)^2 = 2880 \text{ kg m}^2$$

Angular velocity of precession (ω_p),

$$\omega_p = \frac{V}{R} = \frac{27.8}{75} = 0.37 \text{ rad/s}$$

So, gyroscopic couple is,

$$C = I\omega\omega_p = 2880 \times 188.5 \times 0.37 \\ = 200.86 \text{ kNm}$$

57. (a)

Given: $d = 300 \text{ mm} = 0.3 \text{ m}$; $m = 5 \text{ kg}$; $l = 0.6 \text{ m}$; $N = 300 \text{ rpm}$

$$\omega = \frac{2\pi N}{60} = 31.42 \text{ rad/s}$$

Now, moment of inertia of the disc about the axis passing through its centre and perpendicular to plane of disc is,

$$I = \frac{mr^2}{2} = 0.056 \text{ kg m}^2$$

Couple due to mass of disc is,

$$= mgl = 5 \times 0.6 \times 9.81 = 29.43 \text{ Nm}$$

This couple will be equal to the gyroscopic couple

$$\text{So, } 29.43 = I\omega\omega_p$$

$$\text{so, } \omega_p = \frac{29.43}{0.056 \times 31.42} = 16.73 \text{ rad/s}$$

$$N_p = \frac{60\omega_p}{2\pi} = 159.73 \text{ rpm}$$

58. (d)

Displacement equation of damped vibrations is given by

$$x = Xe^{-\xi\omega_n t} \sin(\omega_d t + \phi) \text{ mm}$$

Comparing it with given equation we get,

$$b = \omega_d$$

$$\therefore \omega_n = \sqrt{\frac{s}{m}} = \sqrt{\frac{12000}{18}} = 25.82 \text{ rad/s}$$

$$\omega_d = (\sqrt{1 - \xi^2})\omega_n = \sqrt{1 - 0.215^2} \times 25.82 = 25.2 \text{ rad/s}$$

$$x = Xe^{-at} \sin(bt + \phi)$$

$$x = 0 \quad \text{at } t = 0$$

$$\begin{aligned} \Rightarrow X \sin \phi &= 0 \\ \text{or } \sin \phi &= 0 & (X \text{ cannot be zero}) \\ \text{or } \phi &= 0 \\ \Rightarrow x &= X e^{-at} \sin \omega_d t \\ \dot{x} &= X e^{-at} \cos \omega_d t \times \omega_d + X e^{-at} (-a) \sin \omega_d t \\ \therefore \dot{x} &= 120 \text{ mm/s at } t = 0 \\ \Rightarrow 120 &= X \times \omega_d \\ \Rightarrow X &= \frac{120}{25.2} = 4.76 \text{ mm} \end{aligned}$$

59. (c)

Number of links, $l = 7$

Number of lower pairs, $j = 8$

Number of higher pair, $h = 1$

$$\text{So, } F = 3(l - 1) - 2j - h = 3 \times 6 - 2 \times 8 - 1 = 1$$

60. (d)

$$F_1 = m r_1 \omega_1^2 = 3 r_1 \times (22)^2 = 1452 r_1 \text{ N}$$

$$F_2 = m r_2 \omega_2^2 = 3 r_2 \times (23)^2 = 1587 r_2 \text{ N}$$

$$\text{Now, } k = 2 \left(\frac{a}{b} \right)^2 \left(\frac{F_2 - F_1}{r_2 - r_1} \right)$$

$$4000 = 2 \left(\frac{a}{b} \right)^2 \left(\frac{1587 r_2 - 1452 r_1}{r_2 - r_1} \right)$$

$$\text{Now, } r_2 = 2 r_1$$

$$\therefore 4000 = 2 \left(\frac{a}{b} \right)^2 \left(\frac{3174 r_1 - 1452 r_1}{r_1} \right)$$

$$\Rightarrow 2000 = \left(\frac{a}{b} \right)^2 (1722)$$

$$\therefore \frac{b}{a} = \sqrt{\frac{1722}{2000}} = 0.9279$$

61. (a)

For a simply supported shaft, the stiffness (k) is given by

$$k = \frac{48EI}{L^3} = \frac{48 \times 2.1 \times 10^{11} \times 7854}{(0.5)^3 \times (1000)^4}$$

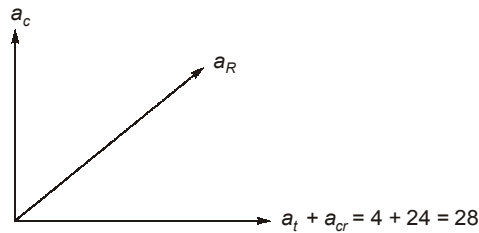
$$k = 633346.56 \text{ N/m}$$

$$\Rightarrow \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{633346.56}{15}} = 205.48 \text{ rad/s} \simeq 1962.21 \text{ rpm}$$

$$\text{Now, } \frac{y}{e} = \frac{1}{\left(\frac{\omega_n}{\omega} \right)^2 - 1}$$

$$\therefore e = y \left[\left(\frac{1962.21}{500} \right)^2 - 1 \right] = 0.01 \times 14.401 = 0.144 \text{ mm}$$

62. (c)



The slider will have 3 acceleration components:

1. Tangential acceleration (a_t)
2. Coriolis acceleration (a_{cr})
3. Centripetal acceleration (a_c)

Now a_t and a_{cr} are in the same direction.

$$a_{cr} = 2v\omega$$

$$v = \text{sliding velocity} = 3 \text{ m/s}$$

$$\omega = \text{angular velocity} = \frac{v_t}{R}$$

$$v_t = \text{Tangential velocity} = 8 \text{ m/s}$$

$$R = 2 \text{ m}$$

So, $\omega = \frac{8}{2} = 4 \text{ rad/s}$

So, $a_{cr} = 2 \times v \times \omega = 2 \times 3 \times 4 = 24 \text{ m/s}^2$

And, $a_c = \frac{v_t^2}{R} = \frac{8 \times 8}{2} = 32 \text{ m/s}^2$

$$a_R = \text{Resultant acceleration}$$

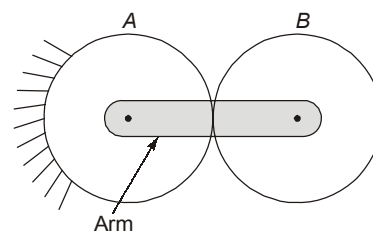
$$a_R = \sqrt{a_c^2 + (a_t + a_{cr})^2} = \sqrt{32^2 + 28^2}$$

$$\Rightarrow a_R = 42.52 \text{ m/s}^2$$

63. (d)

From the table of motions,

Arm	A (36 teeth)	B (45 teeth)
0	x	$-\frac{36x}{45}$
y	$x + y$	$y - \frac{36x}{45}$



Since, gear A is fixed,

So, $x + y = 0$

Also, arm rotates 150 rpm CCW

(Taking CCW direction as positive)

So, $y = 150$

$\Rightarrow x = -150$

Now, $N_B = y - \frac{36x}{45} = 150 + \frac{36 \times 150}{45}$

So, $N_B = 270 \text{ rpm (CCW)}$

64. (3.044)(3.03 to 3.05)

Given:

$$T = 20000 + 9500 \sin 2\theta - 5700 \cos 2\theta$$

$$\omega = \frac{2\pi N}{60} = 18.85 \text{ rad/s}$$

$$\begin{aligned} \text{Workdone per revolution, } W &= \int_0^{2\pi} T d\theta = \int_0^{2\pi} (20000 + 9500 \sin 2\theta - 5700 \cos 2\theta) d\theta \\ &= 40000 \pi \text{ N-m} \end{aligned}$$

$$\text{So, Mean torque, } T_m = \frac{W}{2\pi} = \frac{40000\pi}{2\pi} = 20000 \text{ Nm}$$

Angular acceleration in the flywheel is produced by the excess torque over the mean torque.

$$\begin{aligned} T_{\text{excess}} &= T - T_{\text{mean}} \\ &= 9500 \sin 2\theta - 5700 \cos 2\theta \end{aligned}$$

$$\text{Now, } T_{\text{excess}} \text{ at } \theta = 45^\circ = 9500 \text{ N-m}$$

$$\text{Now, } T_{\text{excess}} = I\alpha$$

$$\text{So, } \alpha = \frac{9500}{3121} = 3.044 \text{ rad/s}^2$$

65. (6.7)(6.6 to 6.8)

Given: $m = 500 \text{ kg}$; $r = 0.4 \text{ m}$; $\omega = 15 \text{ rad/s}$

$$T_1 = 5000 + 500 \sin \theta \text{ Nm}$$

$$T_2 = 5000 + 600 \sin 2\theta \text{ Nm}$$

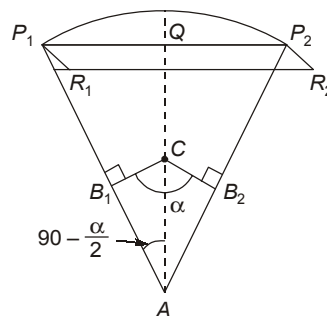
Maximum fluctuation of energy is between 180° and 300°

$$\begin{aligned} \text{So, } \Delta E_{\text{max}} &= \int_{180}^{300} (T_2 - T_1) d\theta = \int_{180}^{300} 600 \sin 2\theta d\theta - \int_{180}^{300} 500 \sin \theta d\theta \\ &= -300 [\cos 2\theta]_{180}^{300} + 500 [\cos \theta]_{180}^{300} = 1200 \text{ N-m} \end{aligned}$$

$$\text{Now, we know, } (\Delta E)_{\text{max}} = I\omega^2 C_s$$

$$\begin{aligned} \text{So, } C_s &= \frac{1200}{500 \times (0.4)^2 \times (15)^2} = 0.067 \quad [I = mk^2] \\ &= 6.7\% \end{aligned}$$

66. (0.5)(0.45 to 0.55)



We know that,

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{360 - \alpha}{\alpha} = 1.7$$

So, $\alpha = 133.3^\circ$

Now, $\sin\left(90 - \frac{\alpha}{2}\right) = \frac{B_1C}{AC}$

So, $AC = \sin\left(90 - \frac{\alpha}{2}\right) = \frac{B_1C}{\cos\frac{\alpha}{2}} = \frac{30}{\cos 66.65} = 75.7 \text{ mm}$

We know that,

$$R_1R_2 = P_1P_2 = 2P_1Q = 2AP_1 \cos\frac{\alpha}{2}$$

Length of working stroke,

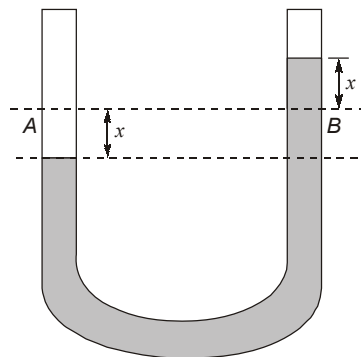
$$R_1R_1 = 120 \text{ mm}$$

So, $AP_1 = AP = 151.4 \text{ mm}$

So, $\frac{AC}{AP} = \frac{75.7}{151.4} = 0.5$

67. (c)

Let the liquid is displaced by x and the cross-section area of tube be A .



The column of liquid of length $2x$ on the right side exerts a restoring force on the remaining liquid.

Total mass of liquid, $m = AL\rho$

So, $m\ddot{x} = -2xA\rho g$

$\Rightarrow \rho AL\ddot{x} + 2xA\rho g = 0$

$\Rightarrow \ddot{x} + \frac{2g}{L}x = 0$

$\therefore \omega = \sqrt{\frac{2g}{L}}$

68. (d)

The jerk is given by $\frac{d^3s}{dt^3}$

if
$$S = \frac{h}{2} \left(1 - \cos \frac{\pi\theta}{\beta} \right)$$

$$\therefore \frac{d^3s}{dt^3} = -\frac{\pi^3}{\beta^3} \frac{h}{2} \sin \left(\frac{\pi\theta}{\beta} \right)$$

where $\theta = \omega t$

69. (46.05)(45.8 to 46.2)

Given:

$$P = 3 \text{ kW} = 3000 \text{ W}$$

$$N = 20 \text{ rps}$$

$$y = \text{Form factor} = 0.3$$

$$b = \text{face width} = 36 \text{ mm}$$

$$c_v = \text{velocity factor} = 1.5$$

$$m = \text{module} = 3 \text{ mm}$$

$$Z = \text{teeth} = 16$$

We know,
$$F_t = \frac{2T}{D} \quad \text{and } D = mZ$$

$$\therefore D = 3 \times 16 = 48 \text{ mm}$$

Also,
$$P = 2\pi NT$$

or
$$T = \frac{P}{2\pi N} = \frac{3000}{2\pi \times 20} = 23.8732 \times 10^3 \text{ Nmm}$$

We know,

$$\Rightarrow \begin{aligned} (F_d)_{\text{Lewis}} &\leq F_b \\ F_t \times c_v &\leq (\sigma_b ybm) \end{aligned}$$

$$\frac{2T}{D} \times c_v = (\sigma_b) ybm$$

So,
$$\sigma_b = \frac{2 \times 23.8732 \times 10^3 \times 1.5}{48 \times 0.3 \times 36 \times 3}$$

$$\therefore \sigma_b = 46.05 \text{ N/mm}^2$$

70. (4.39)(4.38 to 4.42)

Given: $S_{ut} = 600 \text{ N/mm}^2$; $S_{yt} = 450 \text{ N/mm}^2$; $S_e = 270 \text{ N/mm}^2$; $\sigma_{\max} = 100 \text{ N/mm}^2$; $\sigma_{\min} = 40 \text{ N/mm}^2$

So,
$$\sigma_a = \frac{\sigma_{\max} - \sigma_{\min}}{2} = \frac{100 - 40}{2} = 30 \text{ N/mm}^2$$

and
$$\sigma_m = \frac{\sigma_{\max} + \sigma_{\min}}{2} = \frac{100 + 40}{2} = 70 \text{ N/mm}^2$$

Using Goodman line equation,

$$\frac{\sigma_a}{\sigma_e} + \frac{\sigma_m}{\sigma_{ut}} = \frac{1}{F}$$

or $\frac{30}{270} + \frac{70}{600} = \frac{1}{F}$

$\therefore F = 4.39$

71. (b)

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{2.7324 - x}{(3 - 6)}$$

$$\Rightarrow -0.2432 = \frac{2.7324 - x}{(-3)}$$

$$\Rightarrow x = 2.0028$$

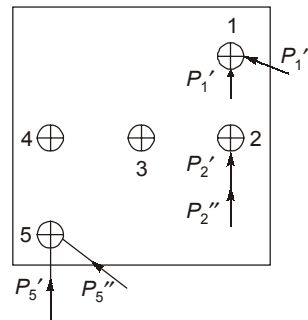
$$\Rightarrow \log_{10} S_e = 2.0028$$

$$\therefore S_e = (10)^{2.0028} = 100.6468 \text{ MPa} \approx 100.65 \text{ MPa}$$

72. (80.5)(79 to 82)

Primary shear force on each rivet.

$$P_1' = P_2' = P_5' = \frac{P}{5} = 20 \text{ kN}$$



Secondary shear force center of gravity of all rivet lie at 3.

$$r_3 = 0$$

$$r_2 = r_4 = 200$$

$$r_1 = r_5 = \sqrt{200^2 + 100^2} = 223.6$$

$$\Rightarrow C = \frac{Pe}{r_1^2 + r_2^2 + \dots + r_5^2}$$

$$= \frac{100 \times 500}{2(200)^2 + 2(223.6)^2} = 0.278 \text{ kN/mm}$$

$$\Rightarrow P_1'' = P_5'' = Cr_1 = 0.278 \times 223.6 = 62.11 \text{ kN}$$

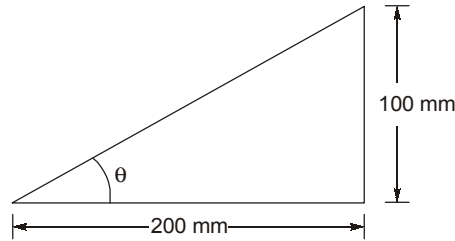
$$\Rightarrow P_2'' = P_4'' = Cr_2 = 0.278 \times 200 = 55.56 \text{ kN}$$

$$\text{Maximum load on rivet 2} = P_2' + P_2''$$

$$= 20 + 55.56 = 75.56 \text{ kN}$$

$$\text{Maximum load on rivet 1} = \sqrt{P_1'^2 + P_1''^2 + 2P_1' P_1'' \cos \theta}$$

Here



$$\begin{aligned} \cos \theta &= \frac{200}{\sqrt{200^2 + 100^2}} = \frac{200}{223.6} \\ &= \sqrt{(20)^2 + (62.11)^2 + 2 \times 62.11 \times 20 \times \frac{200}{223.6}} = 80.5 \text{ kN} \end{aligned}$$

73. (d)

The axial force in the tie rod (P) is resolved into vertical and horizontal components.

$$\text{Vertical component} = P \sin \theta = 10000 \sin 30^\circ = 5000 \text{ N}$$

$$\text{Horizontal component} = P \cos \theta = 8660.25 \text{ N}$$

Vertical component produce direct tensile force in each bolt.

$$P_1' = \frac{P}{4} = \frac{5000}{4} = 1250 \text{ N}$$

Horizontal component produce direct shear in each bolt.

$$P_1'' = \frac{8660.25}{4} = 2165.06 \text{ N}$$

Bolt B located farthest from tilting edge C, so the secondary tensile force will be maximum at B.

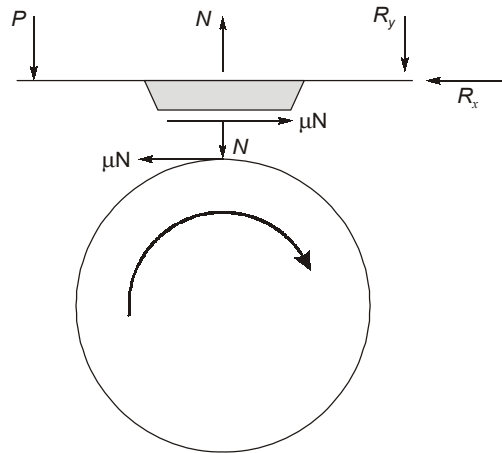
$$\Rightarrow P_1'' = \frac{P \cos \theta e l_1}{2(l_1^2 + l_2^2)} = \frac{8660.25 \times 100 \times 250}{2(50^2 + 250^2)} = 1665.4 \text{ N}$$

$$\sigma_t = \frac{P_1' + P_1''}{A} = \frac{2915.4}{A}$$

$$\tau = \frac{P_1''}{A} = \frac{2165.06}{A}$$

$$\begin{aligned} \tau_{\max} &= \sqrt{\left(\frac{\sigma_t}{2}\right)^2 + \tau^2} = \sqrt{\left(\frac{2915.4}{2A}\right)^2 + \left(\frac{2165.06}{A}\right)^2} = \frac{2610.06}{\frac{\pi}{4}(10)^2} \\ &= 33.23 \text{ N/mm}^2 \end{aligned}$$

74. (b)



$$\begin{aligned}\text{Normal reaction, } N &= p l W \\ &= 1.5 \times 40 \times 80 = 4800 \text{ N}\end{aligned}$$

Taking moments about hinge pin,

$$(\mu N) \times (70) + P \times (600) - N(250) = 0$$

$$\Rightarrow 0.25 \times 4800 \times 70 + P \times 600 - (4800) \times 250 = 0$$

$$\Rightarrow P = 1860 \text{ N}$$

$$\Rightarrow R_x = \mu N = 0.25 \times 4800 = 1200 \text{ N}$$

$$\Rightarrow R_y = N - P = 4800 - 1860 = 2940 \text{ N}$$

$$\Rightarrow R = \sqrt{R_x^2 + R_y^2} = \sqrt{1200^2 + 2940^2} = 3175.5 \text{ N}$$

75. (1023.7)(1020 to 1027)

Consider a work cycle of 1 min duration.

$$N_1 = 1440 \times 0.2 = 288 \text{ revolutions}$$

$$N_2 = 2880 \times 0.5 = 1440 \text{ revolutions}$$

$$N_3 = 720 \times 0.3 = 216 \text{ revolutions}$$

$$\begin{aligned}\text{Equivalent load, } P_e &= \sqrt[3]{\frac{N_1 P_1^3 + N_2 P_2^3 + N_3 P_3^3}{N_1 + N_2 + N_3}} \\ &= \sqrt[3]{\frac{288(5000)^3 + 1440(3000)^3 + 216(6000)^3}{288 + 1440 + 216}} = 3968.9 \text{ N}\end{aligned}$$

$$L_{10} = \left[\frac{40000}{3968.9} \right]^3 = 1023.7 \text{ million revolutions}$$

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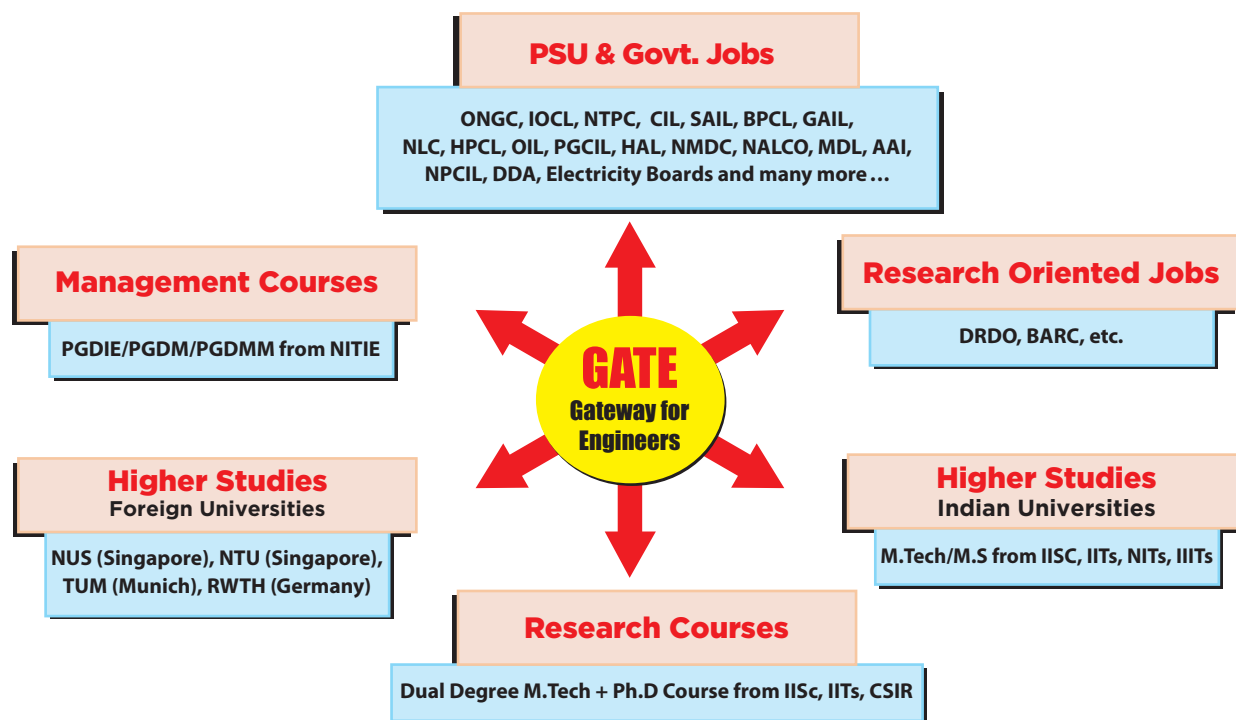
Revision through Questions for GATE 2020

ME

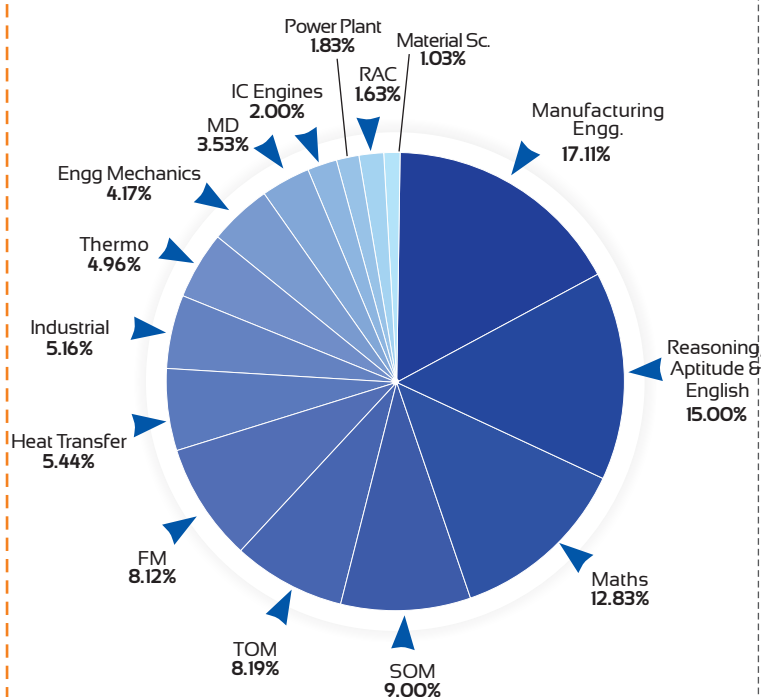
MECHANICAL ENGG.

Q.76 - Q.100
out of 200 Questions

Day 4 of 8



SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 4 : Q.76 to Q.100 : Mechanical Engineering

- Q.76** A vector $\vec{F} = (y^2 - z^2 + 3yz - 2x)\hat{i} + (3xz + 2xy)\hat{j} + (2xy - axz + 2z)\hat{k}$ is known to be solenoidal. The value of "a" is
 (a) 2 (b) -3
 (c) -2 (d) Can't be determined
- Q.77** The area bounded by the straight line $y = x - 2$ and the parabola $y^2 = 2x + 4$ is _____ unit².
- Q.78** The coordinates of a particle moving in a plane are given by, $x = 4t - \frac{t^2}{2}$ and $y = 3 + 6t - \frac{t^3}{6}$. Here t is time in seconds and x and y are in meters. The magnitude of the velocity of the particle at $t = 2$ sec is ____ m/s.
- Q.79** The value of the integral $\int_0^1 \frac{dx}{(1+x^2)^{3/2}}$ will be _____.
- Q.80** The value of $\lim_{x \rightarrow 0} \frac{e^{ax} - e^{-ax}}{\ln(1+bx)}$ is
 (a) $\frac{a}{b}$ (b) $\frac{2a}{b}$
 (c) $\frac{b}{a}$ (d) does not exist
- Q.81** A function is defined by $f(x) = 2x^3 - 3x^2 - 12x + 5$ for $-2 \leq x \leq 3$. Which one of the following statements is true about this function?
 (a) function is decreasing for $(-2, -1)$.
 (b) function has a minima for $x = -1$.
 (c) function has a maxima for $x = 2$.
 (d) function is decreasing for $(-1, 2)$.
- Q.82** Consider the 2×2 matrix $\begin{bmatrix} 1 & 2 \\ p & 5 \end{bmatrix}$. The range of possible values of p , for which both the eigen values of the matrix are real and positive, is
 (a) $-\frac{5}{2} \leq p \leq \frac{5}{2}$ (b) $2 \leq p \leq \frac{5}{2}$
 (c) $-2 \leq p \leq \frac{5}{2}$ (d) $-\frac{5}{2} \leq p \leq 2$

Q.83 Consider the system of linear equations given below:

$$-2x + y + z = l$$

$$x - 2y + z = m$$

$$x + y - 2z = n$$

If $l + m + n = 0$, then the system of equations has

- (a) no solution (b) trivial solutions
(c) unique solution (d) infinitely many solutions

Q.84 The matrix $A = \begin{bmatrix} 1 & 4 \\ 2 & 3 \end{bmatrix}$ satisfies the following polynomial: $A^5 - 4A^4 - 7A^3 + 11A^2 - 2A + kI = 0$.

The value of k is _____.

Q.85 Let $AX = B$ represents a system of equations where A is 2×3 real matrix. The system is known to be inconsistent. The highest possible rank of A is

- (a) 1 (b) 2
(c) 3 (d) can't be determined

Q.86 The Fourier cosine series for an even function $f(x)$ is given by

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos(nx)$$

The value of the coefficient a_2 for the function $f(x) = \cos^2(x)$ in $[0, \pi]$ is

- (a) -0.5 (b) 0.0
(c) 0.5 (d) 1.0

Q.87 A function $f(x)$ is given as

x	0	1	2	3	4
$f(x)$	1	0.5	0.2	0.1	0.058

The value of $\int_0^4 f(x) dx$ as evaluated by Simpson's $\frac{1}{3}$ rule is _____.

Q.88 If $y = e^{\sin^{-1} x}$ and $z = e^{-\cos^{-1} x}$, then the value of $\left. \frac{d^2 y}{dz^2} \right|_{x=1/\sqrt{2}}$ will be

- (a) 0 (b) $\frac{1}{\ln 2}$
(c) $\frac{1}{(\ln 2)^2}$ (d) $\frac{1}{2}$

Q.89 The particular integral of the differential equation $D^2(D^2 + 4)y = 96x^2$ for $x = 2$ will be

- (a) 8 (b) 5
(c) 9 (d) 2

Q.90 The rate at which a body cools is proportional to the difference between the temperature of the body and that of surrounding air. If the body cools from initial temperature of 100°C to 75°C in 1 minute, then temperature of the body after 5 minutes will be _____ $^\circ\text{C}$.
(Assume the temperature of surrounding air is 25°C)

Q.91 The solution of differential equation $(1 + xy)ydx + (1 - xy)xdy = 0$ is

- (a) $\ln\left(\frac{x}{y}\right) - \frac{1}{x+y} = C$ (b) $\ln\left(\frac{x}{y}\right) - \frac{1}{xy} = C$
(c) $\ln\left(\frac{x}{y}\right) + \frac{1}{xy} = C$ (d) $\ln\left(\frac{x}{y}\right) + \frac{1}{x+y} = C$

Q.92 An urn A contains 2 white and 4 black balls. Another urn B contains 5 white and 7 black balls. A ball is transferred from urn A to urn B, then a ball is drawn from urn B. The probability, that the drawn ball is white, is

- (a) $\frac{2}{13}$ (b) $\frac{10}{39}$
(c) $\frac{16}{39}$ (d) $\frac{12}{39}$

Q.93 The probability density function of a continuous random variable is given by,

$$f(x) = \begin{cases} x & ; 0 \leq x \leq 1 \\ 2-x & ; 1 \leq x \leq 2 \\ 0 & ; \text{Otherwise} \end{cases}$$

The mean value of the random variable is

- (a) 1 (b) 1.5
(c) 1.67 (d) 0

Q.94 The chances that doctor A will diagnose a disease X correctly is 60%. The chances that a patient will die by his treatment after correct diagnosis is 40% and the chances of death by wrong diagnosis is 70%. A patient of doctor A, who had disease X, died. The chances that his disease was diagnosed correctly is _____%.

Q.95 A and B throw alternatively a pair of dice. A wins if he throws 6 before B throws 7 and B wins if he throws 7 before A throws 6. If A starts the game, then the probability that B wins the game is

- (a) $\frac{5}{6}$ (b) $\frac{31}{61}$
(c) $\frac{30}{61}$ (d) $\frac{36}{71}$

Q.96 If the probability of a bad reaction from a certain injection is 0.001, then the probability that out of 2000 individuals more than two will get a bad reaction is

- (a) $1 - \frac{5}{e^2}$ (b) $1 - \frac{5}{e^3}$
(c) $\frac{5}{e^2}$ (d) $\frac{5}{e^3}$

Q.97 The real root of the equation $x^3 - 3x^2 + 3x - 5 = 0$ is calculated using Newton-Raphson method. The number of different values of x_0 for which the Newton-Raphson method fails for the equation is _____.

Q.98 If L defines the Laplace Transform of a function, $L[\sin(at)]$ will be equal to

- (a) $\frac{a}{s^2 - a^2}$ (b) $\frac{a}{s^2 + a^2}$
(c) $\frac{s}{s^2 + a^2}$ (d) $\frac{s}{s^2 - a^2}$

Q.99 The Laplace transform of the function " $t^2 \cos(at)$ " for $t > 0$ is

- (a) $\frac{2s(3a^2 - s^2)}{(s^2 + a^2)^3}$ (b) $\frac{2s(s^2 - 3a^2)}{(s^2 + a^2)^3}$
(c) $\frac{2a(3s^2 - a^2)}{(s^2 + a^2)^3}$ (d) $\frac{2a(a^2 - 3s^2)}{(s^2 + a^2)^3}$

Q.100 The type of the partial differential equation $\frac{\partial f}{\partial t} = \frac{\partial^2 f}{\partial x^2}$ is

- (a) Parabolic (b) Elliptic
(c) Hyperbolic (d) Non-linear

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Detailed Explanations

76. (a)

$$\nabla \cdot \vec{F} = 0 \quad [\text{For solenoidal vector}]$$

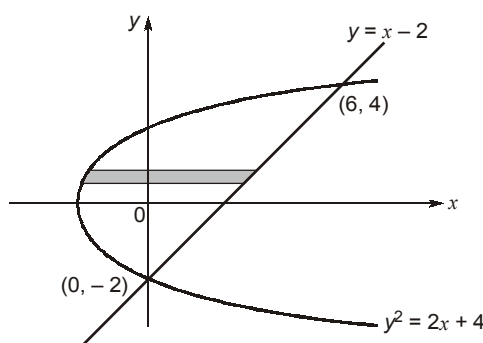
$$\frac{\partial(y^2 - z^2 + 3yz - 2x)}{\partial x} + \frac{\partial(3xz + 2xy)}{\partial y} + \frac{\partial(2xy - axz + 2z)}{\partial z} = 0$$

$$-2 + 2x - ax + 2 = 0$$

$$\text{From here,} \quad a = 2$$

77. (18)

The point of intersection of line and parabolic are (0, -2) and (6, 4).



$$\begin{aligned} \text{Area} &= \int_{-2}^4 \int_{\frac{y^2-4}{2}}^{y+2} dx dy = \int_{-2}^4 x \Big|_{\frac{y^2-4}{2}}^{y+2} dy \\ &= \int_{-2}^4 \left(y + 2 - \frac{y^2}{2} + 2 \right) dy = \left(\frac{y^2}{2} + 4y - \frac{y^3}{6} \right) \Big|_{-2}^4 = 18 \end{aligned}$$

78. 4.47 (4.35 to 4.60)

$$\vec{r} = \left(4t - \frac{t^2}{2} \right) \hat{i} + \left(3 + 6t - \frac{t^3}{6} \right) \hat{j}$$

$$\vec{v} = \frac{d\vec{r}}{dt} = (4 - t)\hat{i} + \left(6 - \frac{t^2}{2} \right) \hat{j}$$

$$\vec{v}|_{t=2} = 2\hat{i} + 4\hat{j}$$

$$|\vec{v}|_{t=2} = \sqrt{2^2 + 4^2} = 4.47 \text{ m/s}$$

79. 0.707 (0.65 to 0.75)

$$\begin{aligned} \text{Let,} \quad x &= \tan \theta \\ dx &= \sec^2 \theta d\theta \end{aligned}$$

$$\text{When } x = 0, \theta = 0 \text{ when } x = 1, \theta = \frac{\pi}{4}.$$

So,

$$\begin{aligned} I &= \int_0^{\pi/4} \frac{\sec^2 \theta d\theta}{(1 + \tan^2 \theta)^{3/2}} = \int_0^{\pi/4} \frac{\sec^2 \theta d\theta}{\sec^3 \theta} \\ &= \int_0^{\pi/4} \frac{1}{\sec \theta} d\theta = \int_0^{\pi/4} \cos \theta d\theta = +\sin \theta \Big|_0^{\pi/4} \\ I &= \frac{1}{\sqrt{2}} = 0.707 \end{aligned}$$

80. (b)

$$\begin{aligned} \lim_{x \rightarrow 0} \frac{e^{ax} - e^{-ax}}{\ln(1+bx)} &= \lim_{x \rightarrow 0} \frac{(e^{ax} - e^{-ax}) \times 2ax \times b}{2ax \times b \times \ln(1+bx)} \\ &= \lim_{x \rightarrow 0} \left(\frac{e^{ax} - e^{-ax}}{2ax} \right) \times \lim_{x \rightarrow 0} \frac{bx}{\ln(1+bx)} \left(\frac{2a}{b} \right) \\ &= \lim_{x \rightarrow 0} \left(\frac{\sinh ax}{ax} \right) \lim_{x \rightarrow 0} \frac{bx}{\ln(1+bx)} \left(\frac{2a}{b} \right) \\ &= 1 \times 1 \times \frac{2a}{b} \\ &= \frac{2a}{b} \end{aligned}$$

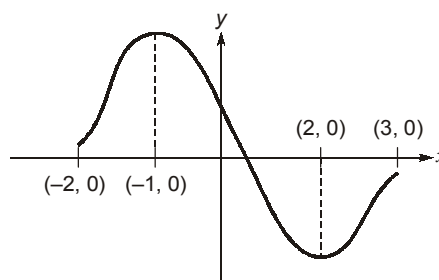
81. (d)

$$f(x) = 2x^3 - 3x^2 - 12x + 5$$

$$f'(x) = 6x^2 - 6x - 12$$

For minima/maxima, $f'(x) = 0$

$$6x^2 - 6x - 12 = 0$$



$$\begin{aligned} x^2 - x - 2 &= 0 \\ (x+1)(x-2) &= 0 \\ x &= -1, 2 \\ f''(x) &= 12x - 6 \\ f''(-1) &= -12 - 6 = -18 < 0 \Rightarrow \text{maxima} \\ f''(2) &= 24 - 6 = 18 > 0 \Rightarrow \text{minima} \end{aligned}$$

The function has maxima at $x = -1$ and minima at $x = 2$.

The function is decreasing between -1 and 2 .

82. (c)

$$\begin{vmatrix} 1-\lambda & 2 \\ p & 5-\lambda \end{vmatrix} = 0$$

$$(1-\lambda)(5-\lambda) - 2p = 0$$

$$\lambda^2 - 6\lambda + 5 - 2p = 0$$

Let the roots are λ_1 and λ_2 .

From the characteristic equation,

$$\lambda_1 + \lambda_2 = 6$$

$$\lambda_1 \lambda_2 = 5 - 2p \geq 0$$

[For roots to be positive]

$$p \leq \frac{5}{2}$$

... (i)

For roots to be real,

$$6^2 - 4(5 - 2p) \geq 0$$

$$36 - 20 + 8p \geq 0$$

$$p \geq -2$$

... (ii)

From equations (i) and (ii),

$$-2 \leq p \leq \frac{5}{2}$$

83. (d)

$$AX = B$$

$$\text{Augmented matrix, } [A : B] = \begin{bmatrix} -2 & 1 & 1 & : & l \\ 1 & -2 & 1 & : & m \\ 1 & 1 & -2 & : & n \end{bmatrix}$$

$$R_3 \rightarrow R_3 + R_2 + R_1:$$

$$[A : B] = \begin{bmatrix} -2 & 1 & 1 & : & l \\ 1 & -2 & 1 & : & m \\ 0 & 0 & 0 & : & l+m+n \end{bmatrix}$$

$$\text{Since, } l+m+n = 0$$

$$\text{Rank of } [A : B] = 2$$

$$\text{Rank of } [A] = \text{Rank of } [A : B] = 2 < 3 \text{ (Number of variables)}$$

$\Rightarrow$ Infinitely many solutions are possible.

84. (-15)

The characteristic equation of matrix A is

$$|A - \lambda I| = 0$$

$$\begin{vmatrix} 1-\lambda & 4 \\ 2 & 3-\lambda \end{vmatrix} = 0$$

$$\lambda^2 - 4\lambda - 5 = 0$$

or

$$A^2 - 4A - 5I = 0$$

Now the given polynomial can be written as,

$$A^5 - 4A^4 - 7A^3 + 11A^2 - 2A + kI = (A^3 - 2A + 3I)(A^2 - 4A - 5I) + (k + 15)I$$

Since,

$$A^2 - 4A - 5I = 0$$

For the given polynomial to be zero,

$$k + 15 = 0$$

$$k = -15$$

85. (a)

minimum (2, 3) $\Rightarrow$ highest possible rank = 2

if rank of $A = 2$, it will consistent. In order to be inconsistent, maximum rank of A is '1'.

86. (c)

$$\cos^2 x = \frac{1 + \cos 2x}{2}$$

$$f(x) = \frac{1}{2} + \frac{\cos 2x}{2}$$

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cdot \cos nx$$

$$a_0 = 1$$

$$a_1 = 0,$$

$$a_2 = \frac{1}{2}$$

87. 1.286 (1.20 to 1.35)

$$\begin{aligned} \int_0^4 f(x) dx &= \frac{h}{3} [(y_0 + y_4) + 4(y_1 + y_3) + 2y_2] \\ &= \frac{1}{3} [(1 + 0.058) + 4(0.5 + 0.1) + 2 \times 0.2] = 1.286 \end{aligned}$$

88. (a)

$$\ln y = \sin^{-1}x,$$

$$\ln z = -\cos^{-1}x$$

$$\ln y - \ln z = \sin^{-1}x + \cos^{-1}x$$

$$\ln\left(\frac{y}{z}\right) = \frac{\pi}{2}$$

$$y = ze^{\pi/2}$$

$$\frac{dy}{dz} = e^{\pi/2}$$

$$\frac{d^2y}{dz^2} = 0$$

89. (a)

For particular integral,

$$PI = \frac{96x^2}{D^2(D^2 + 4)} = 96 \frac{1}{4D^2 \left(1 + \frac{D^2}{4}\right)} x^2 = \frac{96}{4} \left[\frac{\left(1 - \frac{D^2}{4}\right)x^2}{D^2} \right]$$

$$= 24 \frac{\left(x^2 - \frac{1}{2}\right)}{D^2}$$

$$PI = 24 \left[\frac{x^4}{4 \times 3} - \frac{x^2}{4} \right] = 2x^2(x^2 - 3)$$

$$PI|_{x=2} = 2 \times 2^2(4 - 3) = 8$$

90. 34.88 (34.60 to 35.20)

$$\frac{dT}{dt} = k(T - 25)$$

T = Temperature of the body in °C and t = time in minutes.

$$\frac{dT}{T - 25} = k dt$$

$$\ln(T - 25) = kt + C_1$$

$$T - 25 = Ce^{kt}$$

At $t = 0$, $T = 100^\circ\text{C}$ and at $t = 1$ minute, $T = 75^\circ\text{C}$.

$$(100 - 25) = Ce^0$$

$\Rightarrow$

$$C = 75$$

$$50 = 75 e^k \Rightarrow e^k = \frac{2}{3}$$

At $t = 5$ minutes, $T - 25 = 75 e^{k \times 5}$

$$T = 25 + 75 \times \left(\frac{2}{3}\right)^5 \approx 34.88^\circ\text{C}$$

91. (b)

$$M = (1 + xy)y$$

and

$$N = (1 - xy)x$$

$$\frac{\partial M}{\partial y} - \frac{\partial N}{\partial x} = 4xy \neq 0$$

$$Mx - Ny = 2x^2y^2 \neq 0$$

$$\frac{1}{Mx - Ny} = \frac{1}{2x^2y^2}$$

$$\text{IF (Integrating factor)} = \frac{1}{2x^2y^2}$$

$$\left(\frac{1}{x^2y} + \frac{1}{x}\right)dx + \left(\frac{1}{xy^2} - \frac{1}{y}\right)dy = 0 \quad \dots(i)$$

equation (i) is exact

$$\frac{1}{y} \int \frac{1}{x^2} dx + \int \frac{1}{x} dx - \int \frac{1}{y} dy = C$$

$$\frac{-1}{xy} + \ln x - \ln y = C$$

or $\ln\left(\frac{x}{y}\right) - \frac{1}{xy} = C$

92. (c)

Case-I: White ball is transferred from urn A to urn B

Probability of drawing white ball from B = $\frac{2}{2+4} \times \frac{6}{13} = \frac{2}{13}$

Case-II: Black ball is transferred from A to B

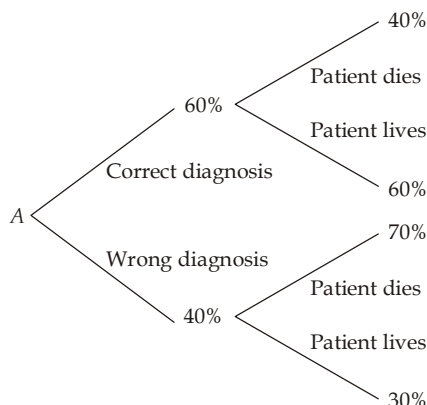
Probability of drawing black ball from B = $\frac{4}{2+4} \times \frac{5}{13} = \frac{10}{39}$

Required probability = $\frac{2}{13} + \frac{10}{39} = \frac{16}{39}$

93. (a)

$$\begin{aligned} \text{Mean} &= \int_{-\infty}^{\infty} xf(x) dx = \int_0^1 x^2 dx + \int_1^2 (2-x)x dx \\ &= \frac{x^3}{3} \Big|_0^1 + \left(x^2 - \frac{x^3}{3}\right) \Big|_1^2 = \frac{1}{3} + 4 - 1 - \frac{8-1}{3} = 1 \end{aligned}$$

94. 46.15 (46.00 to 46.25)



Probability that patient dies who had diseases X is

$$= \frac{40}{100} \times \frac{60}{100} + \frac{70}{100} \times \frac{40}{100} = \frac{52}{100}$$

Probability that he dies of correct diagnosis

$$= \frac{60 \times 40}{100 \times 100} = \frac{24}{100}$$

$$\text{Required probability} = \frac{24/100}{52/100} = \frac{6}{13}$$

$$\text{Required chances} = \frac{6}{13} \times 100 = 46.15\%$$

95. (b)

Number of ways of throwing 6 is five $\Rightarrow (1 + 5), (2 + 4), (3 + 3), (4 + 2), (5 + 1)$

Number of ways of throwing 7 is six $\Rightarrow (1 + 6), (2 + 5), (3 + 4), (4 + 3), (5 + 2), (6 + 1)$

$$\text{Probability of throwing 6, } p_1 = \frac{5}{36}$$

$$\text{Probability of failing to throw 6, } p_2 = 1 - \frac{5}{36} = \frac{31}{36}$$

$$\text{Probability of throwing 7, } q_1 = \frac{6}{36}$$

$$\text{Probability of failing to throw 7, } q_2 = 1 - \frac{6}{36} = \frac{30}{36}$$

$$\text{Probability of } B \text{ winning} = p_2 q_1 + p_2 q_2 p_2 q_1 + p_2 q_2 p_2 q_2 p_2 q_1 + \dots$$

$$= p_2 q_1 [1 + p_2 q_2 + (p_2 q_2)^2 + (p_2 q_2)^3 + \dots]$$

$$= \frac{p_2 q_1}{(1 - p_2 q_2)} = \frac{\frac{31}{36} \times \frac{6}{36}}{1 - \frac{31}{36} \times \frac{30}{36}} = \frac{31 \times 6}{366} = \frac{31}{61}$$

96. (a)

Since the probability of occurrence is very small, this follows Poisson distribution

$$\begin{aligned} \text{mean} = m &= np \\ &= 2000 \times 0.001 \\ &= 2 \end{aligned}$$

Probability that more than 2 will get a bad reaction

$$= 1 - p(0) - p(1) - p(2)$$

$$= 1 - \left[e^{-m} + \frac{e^{-m} \cdot m^1}{1!} + \frac{e^{-m} \cdot m^2}{2!} \right]$$

$$= 1 - \left[e^{-2} + \frac{e^{-2} \cdot 2}{1} + \frac{2^2 \cdot e^{-2}}{2} \right] = 1 - \left[\frac{1}{e^2} + \frac{2}{e^2} + \frac{2}{e^2} \right]$$

$$= 1 - \frac{5}{e^2}$$

97. (1)

Newton Raphson fails if $f'(x) = 0$

$$f'(x) = 3x^2 - 6x + 3 = 0$$

$$3(x^2 - 2x + 1) = 0$$

$$(x - 1)^2 = 0$$

$$x = 1$$

For only one value, Newton-Raphson method fails.

98. (b)

$$\text{Laplace transform of } \sin(at) = \frac{a}{s^2 + a^2}$$

99. (b)

$$L(\cos at) = \frac{s}{s^2 + a^2}$$

$$\begin{aligned} L(t^2 \cos at) &= (-1)^2 \frac{d^2}{ds^2} \left(\frac{s}{s^2 + a^2} \right) = \frac{d}{ds} \left[\frac{1}{s^2 + a^2} - \frac{s \times 2s}{(s^2 + a^2)^2} \right] \\ &= \frac{d}{ds} \left[\frac{s^2 + a^2 - 2s^2}{(s^2 + a^2)^2} \right] = \frac{d}{ds} \left[\frac{a^2 - s^2}{(s^2 + a^2)^2} \right] = \frac{-2s}{(s^2 + a^2)^2} - 2 \frac{(a^2 - s^2) \times 2s}{(s^2 + a^2)^3} \\ &= \frac{-2s^3 - 2a^2s - 4a^2s + 4s^3}{(s^2 + a^2)^3} = \frac{2s(s^2 - 3a^2)}{(s^2 + a^2)^3} \end{aligned}$$

100. (a)

General form of second order partial differential equation,

$$a U_{xx} + b U_{xy} + c U_{yy} = 0$$

$$\frac{\partial f}{\partial t} = \frac{\partial^2 f}{\partial x^2} \text{ has } a = 1, b = 0 \text{ and } c = 0$$

$$b^2 - 4ac = 0$$

Hence, parabolic

■■■■



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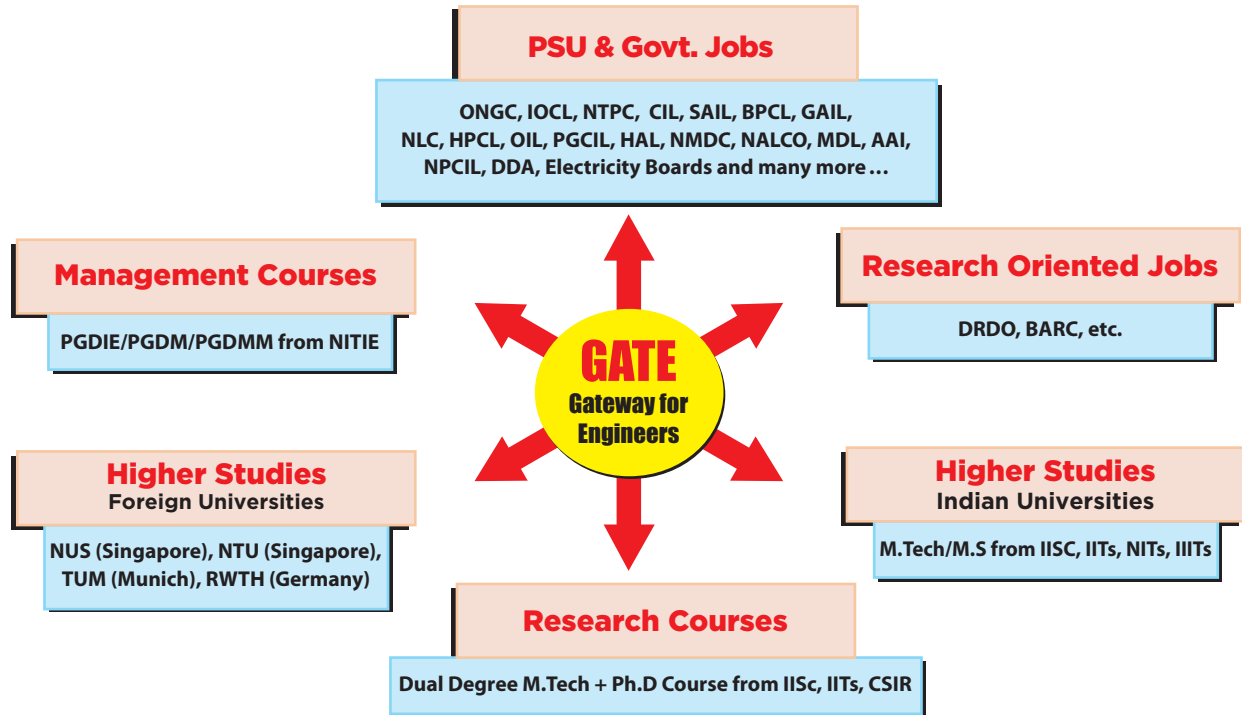
Revision through Questions for GATE 2020

ME

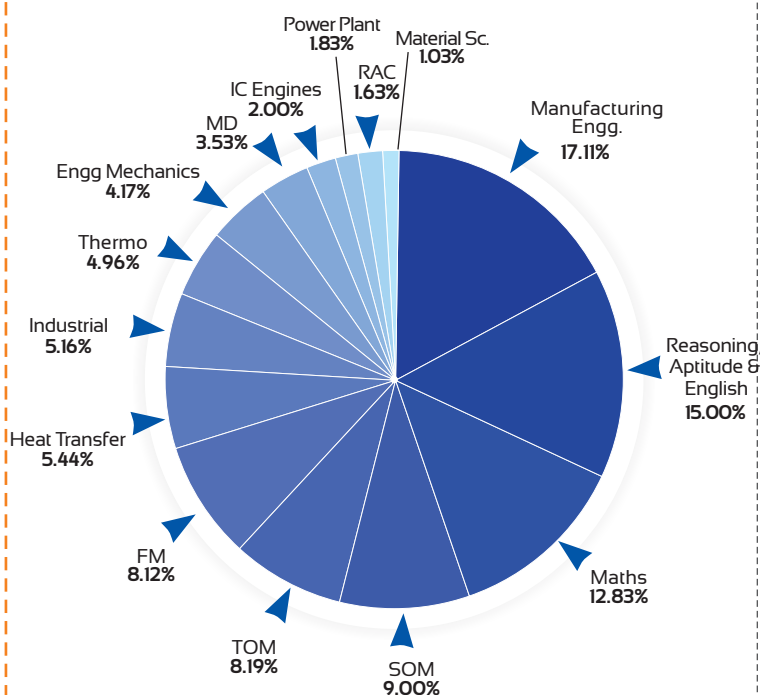
MECHANICAL ENGG.

Q.101 - Q.125
out of 200 Questions

Day 5 of 8



SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 5 : Q.101 to Q. 125 : Mechanical Engineering

Q.101 In an orthogonal machining process, for minimum power consumption, the ratio of cutting force to thrust force is 3. What is the shear angle for this process?

- (a) 38.629° (b) 35.785°
(c) 33.667° (d) 32.263°

101. (b)

Given:
$$\frac{F_C}{F_T} = 3$$

For minimum power, $2\phi + \beta - \alpha = 90^\circ$

We know that,
$$\tan(\beta - \alpha) = \frac{\text{Thrust force}}{\text{Cutting force}} = \frac{F_T}{F_C} = \frac{1}{3}$$

$$\beta - \alpha = \tan^{-1}\left(\frac{1}{3}\right) = 18.43^\circ$$

$$2\phi = 90^\circ - (\beta - \alpha) = 90^\circ - 18.43^\circ$$

$$\text{Shear angle, } \phi = 35.785^\circ$$

Q.102 One of the index plate of a milling machine dividing head has the following hole circle 15, 16, 17, 18, 19, 20. A gear wheel of 34 teeth has to be milled by simple indexing method. To machine each tooth, the index crank has to be rotated through

- (a) 17 holes is the 20-hole circle
(b) 18 holes is the 20-hole circle
(c) 1 revolution and 3 holes in 17-hole circle
(d) 1 revolution and 2 holes in 18-hole circle

102. (c)

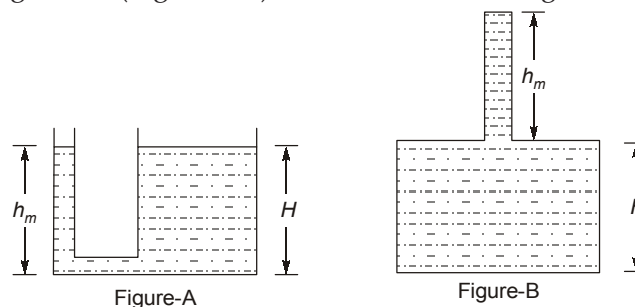
For simple indexing,

$$n = \frac{40}{N} = \frac{40}{34} = 1\frac{6}{34}$$

$$n = 1\frac{3}{17}$$

It means 1 revolution and 3 holes in 17 hole circles.

Q.103 If $h_m = H$ in both of the below case and the time required to fill the mould in bottom gate arrangement (Figure - A) is 20 min, then the time required (in minutes) to fill the mould in top gate arrangement (Figure - B) is _____. Ignore frictional effects.



103. (10)

$$\text{Bottom gate, } t_A = \frac{2A}{A_g \sqrt{2g}} [\sqrt{h_m} - \sqrt{h_m - H}] = 20 \text{ min.}$$

where, A = area of mould
 A_g = area of gate

According to question, $H = h_m$

$$\Rightarrow t_A = \frac{2A}{A_g \sqrt{2g}} \sqrt{h_m} = 20$$

For top gate, $H = h_{m'}$

$$\Rightarrow t_B = \frac{A \sqrt{h_m}}{A_g \sqrt{2g}} = \frac{t_A}{2} = 10 \text{ min}$$

Q.104 In a cutting operation, Taylor's tool life equation is $VT^{0.46} = 300$. Tooling cost is Rs.100/ regrind and machining cost is Rs.10/min. Tool change time is 2 min. Optimum cutting speed (in m/min) for minimization of total production cost is _____.

104. (88.85)(87.5 to 90.5)

$$C = 300, n = 0.46, C_m = \text{Rs. } 10/\text{min}, C_t = \text{Rs. } 100, T_c = 2 \text{ min}$$

$$\begin{aligned} V_{\text{opt}} &= \frac{C}{\left[\left[\frac{C_t}{C_m} + T_c \right] \left[\frac{1}{n} - 1 \right] \right]^n} \\ &= \frac{300}{\left[\left[\frac{100}{10} + 2 \right] \left[\frac{1}{0.46} - 1 \right] \right]^{0.46}} = 88.85 \text{ m/min} \end{aligned}$$

Q.105 In spot welding of aluminium plates (density = 2700 kg/m³, specific heat (c) = 896 J/kgK, melting = 933K, latent heat of melting = 398 kJ/kg) at a temperature of 30°C, a pulse with energy of 0.5 J is focussed onto an area of 0.06 mm². If the entire energy is coupled into the material what will be the depth of weld? Assume the cross-sectional area of the weld circular and is uniform throughout its depth, only heat conduction in the direction of penetration and 75% of energy is utilized for melting.

- (a) 1.75 mm (b) 2.40 mm
(c) 3.71 mm (d) 3.20 mm

105. (b)

$$\rho_{Al} = 2700 \text{ kg/m}^3, c = 896 \text{ J/kgK}, T_m = 933 \text{ K}, T_0 = 30^\circ\text{C} = 303 \text{ K}, L = 398 \text{ kJ/kg}, A = 0.06$$

Let depth of spot = d mm

$$\text{Volume of nugget} = A \times d$$

$$= 0.06 \times d \text{ mm}^3$$

$$m = \rho \times v = 2700 \times 0.06 \times d \times 10^{-9} \text{ kg}$$

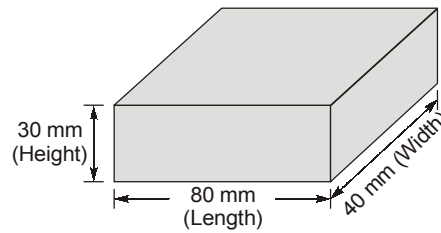
$$= 162d \times 10^{-9} \text{ kg}$$

$$\text{Heat required to melt} = mc\Delta T + mL$$

$$\begin{aligned}
 &= m[c(T_m - T_0) + L] \\
 &= 162d \times 10^{-9} [896(933 - 303) + 398 \times 1000] = 0.15592d \text{ J} \\
 \text{Heat required to melt} &= 0.75 \times \text{heat energy supplied} \\
 0.15592d &= 0.75 \times 0.5 \\
 \Rightarrow d &= 2.406 \text{ mm}
 \end{aligned}$$

Q.106 A job shown in the figure is to be made from wooden pattern by taking the following allowances

Machining allowance	3 mm each side
Shrinkage allowance	3%
Shaking allowance	1 mm



The volume of the pattern is _____ cm³.

106. 150.468(148 to 152)

Machine allowance (mA)

mA is 3 mm on each side,

$$L = 80 + 2 \times 3 = 86 \text{ mm}$$

$$W = 40 + 2 \times 3 = 46 \text{ mm}$$

$$H = 30 + 2 \times 3 = 36 \text{ mm}$$

Shaking allowance

Shaking allowance is a negative allowance and is only added to length and width. Height of pattern doesn't require any shaking allowance.

$$L = 86 - 1 = 85 \text{ mm}$$

$$H = 36 \text{ mm}$$

$$W = 46 - 1 = 45 \text{ mm}$$

Shrinkage allowance

Shrinkage allowance of 3% is added to all dimensions

$$L = 85 + 85 \times \frac{3}{100} = 87.55 \text{ mm}$$

$$W = 45 + 45 \times \frac{3}{100} = 46.35 \text{ mm}$$

$$H = 36 + 36 \times \frac{3}{100} = 37.08 \text{ mm}$$

$\therefore$ Volume of the pattern is,

$$\begin{aligned}
 V_p &= 87.55 \times 46.35 \times 37.08 \\
 &= 150468.507 \text{ mm}^3 \\
 &= 150.468 \text{ cm}^3
 \end{aligned}$$

Q.107 The mean effective pressure of an Otto cycle may be expressed as

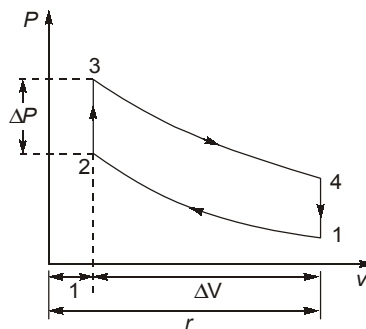
- (a) $\frac{\eta_{th} \Delta P}{(r-1)(\gamma-1)}$ (b) $\frac{\eta_{th} \Delta P}{(r-1)}$
(c) $\frac{\gamma \eta_{th} \Delta P}{(r-1)(\gamma-1)}$ (d) $\frac{\eta_{th} (\Delta P) r}{(r-1)(\gamma-1)}$

Here, η_{th} is thermal efficiency of cycle, ΔP is pressure rise during heat transfer, r compression ratio and γ is ratio of specific heats.

107. (a)

$$\text{Mean effective pressure} = \frac{\text{area of pV diagram}}{\text{length of diagram}} = \frac{\text{Work done}}{\Delta V}$$

$$\text{Now } W = \eta_{th} \times \text{heat transfer to cycle}$$



$$= \eta_{th} \times C_v [T_3 - T_2] \times m$$

Then,

$$\text{mep} = \frac{\eta_{th} C_v [T_3 - T_2] \times m}{\Delta V}$$

Now

$$C_v = \frac{R}{(\gamma-1)}$$

$$T = \frac{PV}{mR}$$

$$\Delta V = (r-1)V$$

$\therefore$

$$\text{mep} = \eta_{th} \frac{R}{(\gamma-1)} \left[\frac{P_3 V}{Rm} - \frac{P_2 V}{Rm} \right] \times \frac{m}{V(r-1)}$$

Now

$$P_3 - P_2 = \Delta P$$

$\Rightarrow$

$$\text{mep} = \frac{\eta_{th} \Delta P}{(r-1)(\gamma-1)}$$

Q.108 A Cylindrical cup without flange is to be drawn from a 2 mm thick sheet. The cup shall have 12 cm diameter and 35 cm height. Reduction ratio in the first and subsequent draws may not exceed 30% and 10% respectively. The minimum number of draws necessary will be _____.

108. (10)

$$\begin{aligned} D &= \sqrt{d^2 + 4dh} \\ &= \sqrt{12^2 + 4 \times 12 \times 35} = 42.708 \text{ cm} \\ d_1 &= 0.7D = 0.7 \times 42.708 = 30 \text{ cm} \\ d_2 &= 0.9d_1 \\ d_3 &= 0.9d_2 = 0.9^2 d_1 \\ d_n &= 0.9^{n-1} d_1 = 12 \\ 0.9^{n-1} \times 30 &= 12 \\ n &= 9.750 \simeq 10 \text{ pass} \end{aligned}$$

Q.109 Blind holes of 20 mm diameter, 100 mm deep are being drilled in steel block. Drilling spindle speed is 600 rpm, feed 0.2 mm/rev, point angle of drill is 135°. During this operation, the drill wears out after producing 300 holes. Taylor's tool life equation is of the form $VT^{0.3} = C$, where, V = cutting speed in m/min and T = tool life in minutes. Taylor's constant C will be ____.

109. (199.99)(198 to 202)

$$\text{Break through distance, } A = \frac{D}{2 \tan \alpha} = \frac{20}{2 \times \tan 67.5^\circ} = 4.142 \text{ mm}$$

$$\text{Tool travel length, } L = 100 + 4.142 = 104.142 \text{ mm}$$

$$\text{Drilling time per hole} = \frac{L}{fN} = \frac{104.142}{0.2 \times 600} = 0.8678 \text{ minutes}$$

$$\text{Total drilling time} = 0.86785 \times 300 = 260.355 \text{ min}$$

$$V = \pi DN = 3.14 \times 0.02 \times 600 = 37.7 \text{ m/min}$$

$$\therefore C = VT^{0.3} = 37.7(260.355)^{0.3} = 199.99$$

Q.110 A 20 mm thick plate is being machined by wire electro discharge machining (EDM). The wire cut metal at a speed of 1.2 m/min and the cutting width is 2.4 mm. Assume that it takes 1500 J to remove one gram of plate then the power required is _____ kW. (Take density of plate material = 8000 kg/m³)

110. (11.52)(11.3 to 11.7)

$$v = 1200 \text{ mm/min}, \rho = 8000 \text{ kg/m}^3 = 8000 \times 10^3 \text{ g/m}^3$$

$$t = 20 \text{ mm}, Q = 1500 \text{ J/g}$$

$$b = 2.4 \text{ mm}$$

$$\text{Volumetric MRR} = vbt = 1200 \times 20 \times 2.4$$

$$= 57600 \text{ mm}^3/\text{min}$$

$$= 57.6 \times 10^{-6} \text{ m}^3/\text{min}$$

$$\text{Mass MRR} = \rho \times \text{MRR}$$

$$= 8000 \times 10^3 \times 57.6 \times 10^{-6}$$

$$\begin{aligned}
 &= 460.8 \text{ g/min} \\
 \text{Power} &= Q \times \rho \times \text{MRR} = 1500 \times 460.8 \\
 &= 691200 \text{ J/min} = 11520 \text{ J/s} = 11.52 \text{ kW}
 \end{aligned}$$

Q.111 For a certain job, the cost of metal cutting is ₹ 18 C/V and the cost of tooling is ₹ 270C/(TV), where C is a constant, V is the cutting speed in m/min and T is the tool life in minutes. The Taylor's tool life equation is $VT^{0.25} = 150$. The cutting speed (in m/min) for the minimum total cost is_____.

111. (57.91)

Total cost = metal cutting cost + tooling cost

$$= \frac{18C}{V} + \frac{270C}{VT}$$

Here,

$$T = \left(\frac{150}{V} \right)^{\frac{1}{0.25}} = \left(\frac{150}{V} \right)^4$$

$$C_t = \frac{18C}{V} + \frac{270C}{V \cdot \left(\frac{150}{V} \right)^4}$$

$$\frac{dC_t}{dV} = 0$$

$$-\frac{18C}{V^2} + \frac{270C}{(150)^4} \times 3V^2 = 0$$

or

$$V^4 = \frac{150^4 \times 18}{270 \times 3}$$

$$V = 57.91 \text{ m/min}$$

Q.112 Match **List-I** (Machining processes) with **List-II** (Operating Media) and select the correct answer using the codes given below the lists:

List-I

- A. Abrasive jet machining
- B. Electron beam machining
- C. Electrochemical machining
- D. Electro-discharge machining

List-II

- 1. Dielectric
- 2. Electrolyte
- 3. Abrasive slurry
- 4. Vacuum
- 5. Air

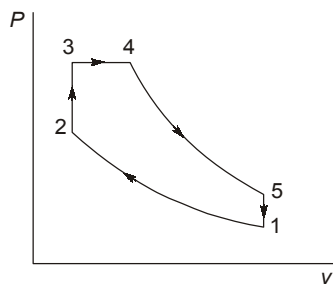
	A	B	C	D
(a)	5	4	2	1
(b)	4	5	2	1
(c)	4	2	3	5
(d)	2	4	3	5

112. (a)

Q.113 A diesel engine operates on the dual cycle in which the heat transfer to the working fluid due to combustion of fuel is 1400 kJ/kg, half of which is transferred at the constant volume and the remaining half at constant pressure process. At the beginning of compression stroke the temperature is 25°C. The compression ratio is 14. Take $\gamma = 1.41$, $C_p = 1.02$ kJ/kgK. The maximum temperature that occurs during the cycle is _____ kelvin.

113. (2533.2)(2533 to 2534)

Given: $T_1 = 25^\circ\text{C} = 298 \text{ K}$
Compression ratio, $r = 14$



Now, $T_2 = T_1(r)^{\gamma-1} = 298 \times (14)^{1.41-1} = 879.28 \text{ K}$

Heat added at constant volume = $\frac{1400}{2} = C_v[T_3 - T_2]$

$\Rightarrow 700 = \frac{C_p}{\gamma}[T_3 - T_2] \quad \left[\because C_v = \frac{C_p}{\gamma} \right]$

$\Rightarrow 700 = \frac{1.02}{1.41}[T_3 - 879.28]$

$\Rightarrow T_3 = 1846.93 \text{ K}$

Heat added at constant pressure = $700 = C_p[T_4 - T_3]$

$\Rightarrow 700 = 1.02[T_4 - 1846.93]$

$\Rightarrow T_4 = 2533.2 \text{ K}$

Q.114 Match the following:

Device	Function
P. Jig	1. Helps to place workpiece in the same position cycle after cycle
Q. Fixture	2. Holds the workpiece only
R. Clamp	3. Holds and position the workpiece
S. Locator	4. Holds and position the workpiece and guides the cutting tool during a machining operation

	P	Q	R	S
(a)	4	3	1	2
(b)	1	2	3	4
(c)	1	4	3	2
(d)	4	3	2	1

114 (d)

- Q.115** In a CNC program block, N002 G02 G91 X40 Z40..., G02 and G91 refer to
 (a) circular interpolation in counterclockwise direction and incremental dimension
 (b) circular interpolation in counterclockwise direction and absolute dimension
 (c) circular interpolation in clockwise direction and incremental dimension
 (d) circular interpolation in clockwise direction and absolute dimension

115. (c)

- Q.116** A mild steel block of width 38 mm is being milled using a straight slab cutter 60 mm diameter with 30 teeth. If the cutter rotates at 30 rpm, and depth of cut is 2 mm, then the value of maximum uncut chip thickness when the table feed is 20 mm/min, is _____ $\times 10^{-3}$ mm. (upto 4 decimals point.)

116. 7.86 (7.7 to 8.2)

Depth of cut, $d = 2$ mm

Diameter of cutter, $D = 60$ mm

$$\text{Feed for tooth, } f_t = \frac{20}{30} \times \frac{1}{30} = 0.022 \text{ mm/tooth}$$

$$\begin{aligned} \text{Maximum uncut chip thickness, } t_{\max} &= 0.022 \times 2 \sqrt{\frac{d}{D} \left(1 - \frac{d}{D}\right)} = 0.044 \sqrt{\frac{2}{60} \left(1 - \frac{2}{60}\right)} \\ &= 7.86 \times 10^{-3} \text{ mm} \end{aligned}$$

- Q.117** Gating ratio of 1 : 2 : 4 is used to design the gating system for magnesium alloy casting. This gating ratio refers to the cross-section areas of the various gating elements as given below:

1. Down sprue
2. Runner
3. Ingates

The sequence of the above elements in the ratio 1 : 2 : 4 is

- | | |
|----------------|----------------|
| (a) 1, 2 and 3 | (b) 1, 3 and 2 |
| (c) 2, 3 and 1 | (d) 3, 1 and 2 |

117. (a)

Gating ratio is ratio of cross-sectional area of sprue : runner : gates

- Q.118** Consider the following steps in forging a connecting rod from the bar stock

- | | |
|--------------|-------------|
| 1. blocking | 2. trimming |
| 3. finishing | 4. edging |

Select the correct sequence of these operations using the codes given below:

- | | |
|-------------|-------------|
| (a) 1-2-3-4 | (b) 2-3-4-1 |
| (c) 3-4-1-2 | (d) 4-1-3-2 |

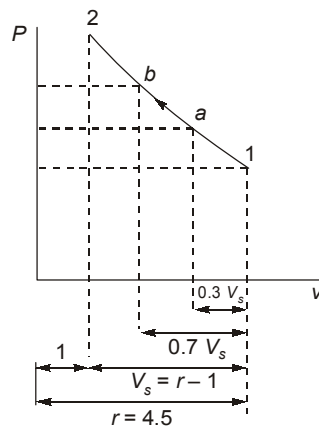
118. (d)

Correct step in forging operation is fullering $\rightarrow$ edging $\rightarrow$ blocking $\rightarrow$ finishing $\rightarrow$ trimming.

Q.119 In a petrol engine the pressure in the cylinder at 30% and 70% of the compression stroke are 1.33 bar and 2.66 bar respectively. Assuming that the compression ratio follows the law $PV^{1.33} = \text{constant}$. What is the air standard efficiency of the petrol engine?

- (a) 0.397 (b) 0.263
(c) 0.378 (d) 0.453

119. (a)



let

$$V_2 = 1$$

$$V_1 = V_s + V_2 \text{ (where } V_s \text{ is stroke volume)}$$

$$r = V_s + 1 \quad [\text{where } r \text{ is compression ratio, } r = \frac{V_2}{V_1}]$$

$\Rightarrow$

$$V_s = (r - 1)$$

Now,

$$V_a = V_s - 0.3 V_s + V_2$$

$$V_a = 1 + 0.7(r - 1) \quad \dots(1)$$

Similarly,

$$V_b = 1 + 0.3(r - 1) \quad \dots(2)$$

Now

$$\frac{V_a}{V_b} = \left[\frac{P_b}{P_a} \right]^{1/1.33} = \left(\frac{2.66}{1.33} \right)^{1/1.33} = 1.684$$

from equation (1) and (2)

$$\Rightarrow 1.684 = \frac{0.7r + 0.3}{0.3r + 0.7}$$

$$\Rightarrow r = 4.51$$

$$\text{Efficiency, } \eta = 1 - \frac{1}{(r)^{1.33-1}} = 1 - \frac{1}{(4.51)^{0.33}}$$

$$= 0.3917 = 39.17\%$$

Q.120 Circular blanks of 35 mm diameter are punched from a steel sheet of 2 mm thickness. If the clearance per side between the punch and die is to be kept as 40 microns. The sizes of punch and die should respectively be

- (a) 35 and 35.040 (b) 34.92 and 35
(c) 35 and 35.080 (d) 35.040 and 34.92

120. (b)

$$\begin{aligned}\text{Diameter of blank} &= \text{Diameter of die} \\ \text{Diameter of die} &= 35 \text{ mm} \\ \text{Clearance} &= 0.04 \text{ mm per side} \\ \text{Total clearance} &= 0.04 \times 2 = 0.08 \text{ mm} \\ \text{Diameter of punch} &= \text{Diameter of die} - \text{clearance} \\ &= 35 - 0.08 = 34.92 \text{ mm}\end{aligned}$$

Q.121 In a shaping process, the number of double strokes per minute is 40 and the quick return ratio is 0.7. If the length of the stroke is 250 mm, the average cutting velocity is _____ m/min.

121. (17)

Given:

$$\begin{aligned}\text{Double strokes per min, } N &= 40 \\ \text{Quick return ratio, } q &= 0.7 \\ \text{Stroke length, } L &= 250 \text{ mm} \\ \text{Average cutting velocity, } V &= NL(1 + q) = 40 \times 250 (1 + 0.7) \\ &= 17000 \text{ mm/min.} \\ &= 17 \text{ m/min.}\end{aligned}$$

Q.122 Two different tools A and B having nose radius of 0.6 mm and 0.33 mm respectively are used to machine C-45 steel employing feed rate of 0.2 mm/rev and 0.1 mm/rev respectively. The tool that gives better finish and the value of ideal surface roughness are

- (a) Tool A and 4.166 μm respectively
- (b) Tool B and 3.78 μm respectively
- (c) Tool A and 8.333 μm respectively
- (d) Tool B and 8.333 μm respectively

122. (b)

$$\begin{aligned}r_a &= 0.6 \text{ mm, } r_b = 0.33 \\ f_a &= 0.2 \text{ mm/rev, } f_b = 0.1 \\ R_{ta} &= \frac{f_a^2}{8r_a} = \frac{0.2^2}{8 \times 0.6} = 0.00833 \text{ mm} = 8.33 \mu\text{m} \\ R_{tb} &= \frac{f_b^2}{8r_b} = \frac{0.1^2}{8 \times 0.33} = 3.78 \mu\text{m}\end{aligned}$$

Tool B is given better surface finish because surface roughness of tool B is less.

Q.123 An unknown hydrocarbon fuel, $C_x H_y$, was allowed to react with air. The dry products of combustion gives 12% CO_2 , 4% O_2 and 1% CO . What is the chemical composition of the fuel?

- (a) C_6H_8
- (b) $\text{C}_{20}\text{H}_{44}$
- (c) $\text{C}_{20}\text{H}_{37}$
- (d) $\text{C}_{13}\text{H}_{22}$

123. (d)

Combustion equation can be written as.



Equating moles for

$$\text{Nitrogen } 3.76 a = 83$$

$$\Rightarrow a = 22.00$$

$$\text{Oxygen } 2 \times 22.00 = 2 \times 12 + 2 \times 4 + 1 + b$$

$$\Rightarrow b = 11.0$$

$$\text{Carbon } x = 12 + 1 = 13$$

$$\text{Hydrogen } y = 2b = 2 \times 11 = 22.0$$

Given equation becomes $C_{13}H_{22}$

Q.124 Consider the following machine tools

1. Hobbing machine 2. Gear shaping machine
3. Broaching machine

The tooth of internal spur gear can be cut in

- | | |
|-------------|----------------|
| (a) 1 and 2 | (b) 1 and 3 |
| (c) 2 and 3 | (d) 1, 2 and 3 |

124. (c)

Q.125 An oil engine works on the ideal diesel cycle, if the overall compression ratio is 18 : 1 and the constant pressure energy addition ceases at 10% of the stroke. What is thermal efficiency of the engine? (Use $\gamma = 1.4$)

- | | |
|-----------|---------|
| (a) 60% | (b) 47% |
| (c) 33.3% | (d) 40% |

125. (a)

Let clearance volume be 1

$$\text{Swept volume} = r - 1 = 18 - 1 = 17$$

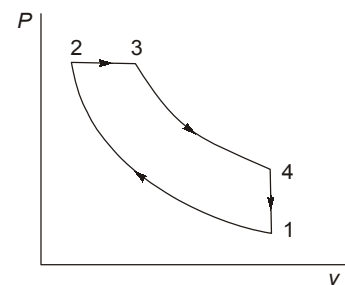
$$10\% \text{ of the swept volume} = 17 \times 0.1 = 1.7$$

$$\text{Constant pressure heat addition ceases at } 1 + 1.7 = 2.7$$

$$\therefore \text{cut off ratio, } \rho = \frac{V_3}{V_2} = \frac{2.7}{1} = 2.7$$

$$\begin{aligned} \eta_{th} &= 1 - \frac{1}{(r)^{\gamma-1}} \left[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)} \right] \\ &= 1 - \frac{1}{18^{1.4-1}} \left[\frac{2.7^{1.4} - 1}{1.4(2.7 - 1)} \right] = 1 - 0.4 = 0.6 \simeq 60\% \end{aligned}$$

■■■■





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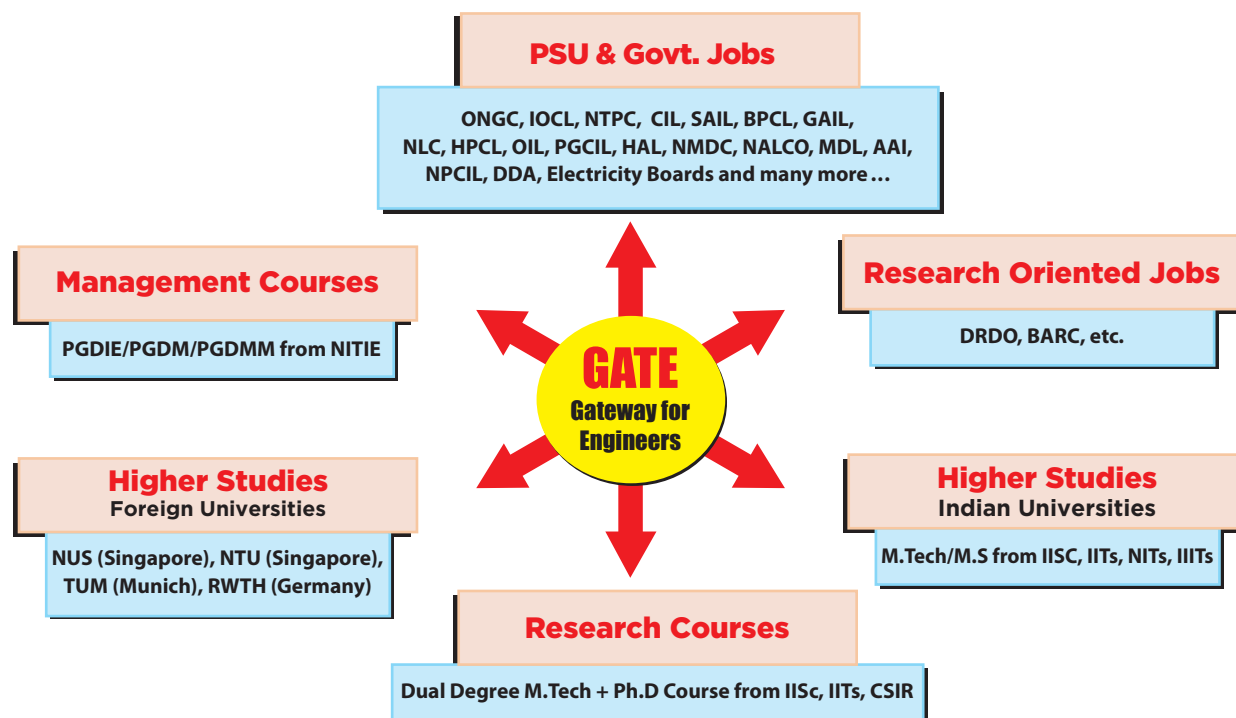
Revision through Questions for GATE 2020

ME

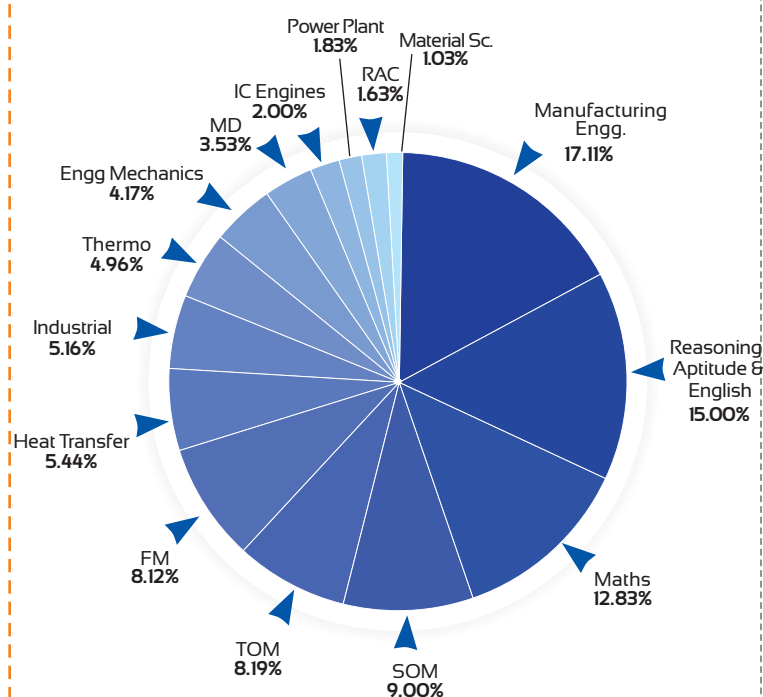
MECHANICAL ENGG.

Q.126 - Q.150
out of 200 Questions

Day 6 of 8



SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 6 : Q.126 to Q. 150 : Mechanical Engineering

Q.126 The initial temperature of a steel ingot is 100°C. It is heated in a furnace with furnace gas temperature 1200°C. The time required by the ingot to reach temperature of 800°C is 1000 seconds. Then time required by the ingot to reach the temperature of 900°C from initial 100°C is _____ seconds.

(Assume lumped parameter analysis)

126. (1284.4)(1281.00 to 1289.00)

$$\frac{t_a - t}{t_a - t_i} = \exp[-c\tau]$$

where,

$$t_a = 1200^\circ\text{C}$$

$$t = 800^\circ\text{C}$$

$$t_i = 100^\circ\text{C}$$

$$C = \text{constant}$$

$$t = 1000 \text{ sec}$$

$$\text{Initially, } \frac{1200 - 800}{1200 - 100} = \exp[-c \times 1000]$$

$$\Rightarrow \ln\left[\frac{400}{1100}\right] = -c \times 1000 \quad \dots(1)$$

$$\text{Later } \tau = ?$$

$$t = 900^\circ\text{C}$$

$$\Rightarrow \frac{1200 - 900}{1200 - 100} = \exp(-c \times \tau)$$

$$\Rightarrow \ln\left[\frac{300}{1100}\right] = -c \times \tau \quad \dots(2)$$

Dividing eq. (2) by eq. (1)

$$\Rightarrow \frac{\tau}{1000} = \frac{\ln[300/1100]}{\ln[400/1100]} = 1.2844$$

$$\Rightarrow \tau = 1284.4 \text{ seconds}$$

Q.127 A hot fluid is being conveyed through a long pipe of 4 cm outer diameter and covered with 2 cm thick insulation. It is proposed to reduce conduction heat loss to surroundings to one third of the present rate, by further covering with same insulation. The additional thickness of insulation is _____ cm. [Keeping the same temperature difference for insulation in both case]

127. (12)

$$r_1 = 2 \text{ cm} \quad \text{and} \quad r_2 = 4 \text{ cm}$$

Heat loss with existing condition,

$$Q_1 = \frac{2\pi Kl[t_1 - t_2]}{\log_e \left[\frac{r_2}{r_1} \right]} \quad \dots(1)$$

Heat loss with additional insulation,

$$\Rightarrow Q_2 = \frac{2\pi Kl(t_1 - t_2)}{\log_e \left(\frac{r_2 + x}{r_1} \right)} \quad \dots(2)$$

where x is additional insulation

According to question,

$$Q_2 = \frac{Q_1}{3}$$

Using (1) and (2), we have

$$\Rightarrow \frac{2\pi Kl[t_1 - t_2]}{\log_e \left[\frac{r_2 + x}{r_1} \right]} = \frac{1}{3} \frac{2\pi Kl[t_1 - t_2]}{\log_e \left(\frac{r_2}{r_1} \right)}$$

$$\Rightarrow \frac{r_2 + x}{r_1} = \left(\frac{r_2}{r_1} \right)^3 = \left(\frac{4}{2} \right)^3 = 8$$

$$\Rightarrow x = 8r_1 - r_2 = 8 \times 2 - 4 = 12 \text{ cm}$$

Q.128 Two rods with insulated tips A and B of the same length and diameter protrude from a surface of 120°C and are exposed to air at 25°C . The temperature measured at the ends of the rods are 50°C and 75°C respectively. If thermal conductivity of material A is 20 W/mK . Then the thermal conductivity of material B is _____ W/mK .

128. (51.136)(50.5 to 52.5)

For fin with insulated tip:

$$\frac{\theta}{\theta_0} = \frac{t - t_a}{t_0 - t_a} = \frac{\cosh m(l - x)}{\cosh ml}$$

For end ($x = l$) of rod A ,

$$\Rightarrow \frac{50 - 25}{120 - 25} = \frac{1}{\cosh m_1 L}$$

$$\Rightarrow \cosh m_1 L = \frac{95}{25} = 3.8$$

$$\Rightarrow m_1 L = 2.01 \quad \dots(i)$$

$$\frac{75 - 25}{120 - 25} = \frac{1}{\cosh m_2 L}$$

For end ($x = l$) of rod B ,

$$\Rightarrow m_2 L = 1.257 \quad \dots(ii)$$

$$\Rightarrow \frac{m_1}{m_2} = \frac{2.01}{1.257} = 1.599$$

$$\Rightarrow \sqrt{\frac{h_1 P_1}{k_1 A_1} \times \frac{k_2 A_2}{h_2 P_2}} = 1.599$$

As per given condition,

$$A_1 = A_2; P_1 = P_2 \text{ and } h_1 = h_2$$

$$\Rightarrow \sqrt{\frac{k_2}{k_1}} = 1.599$$

$$\Rightarrow k_2 = k_1 \times [1.599]^2 = 20 \times 1.599^2$$

$$\Rightarrow k_2 = 51.136 \text{ W/mK}$$

Q.129 After expansion from a gas turbine, the hot exhaust gases are used to heat the compressed air from a compressor with the help of a counter flow heat exchanger of 0.8 effectiveness. If thermal capacity of exhaust gases and compressed air is same, then number of transfer units for heat exchanger is _____.

129. (4)

Since capacity ratio is unity.

Effectiveness for counter flow heat exchanger,

$$\epsilon = \frac{NTU}{1 + NTU} \quad \{\text{for the case of balanced counter-flow HX}\}$$

$$\Rightarrow 0.8 = \frac{NTU}{1 + NTU}$$

$$\Rightarrow 0.8 = [1 - 0.8] NTU$$

$$\Rightarrow NTU = 4$$

Q.130 Water ($c_p = 4 \text{ kJ/kgK}$) enters a cross flow heat exchanger (both fluids unmixed) at 15°C and flows at the rate 7.5 kg/s . It cools air ($c_p = 1 \text{ kJ/kgK}$) flowing at the rate 10 kg/s from an inlet temperature of 120°C .

Assuming the effectiveness (ϵ) of the heat exchanger = 0.94. What is the outlet temperature of air ?

- (a) 21.3°C (b) 108°C
(c) 29°C (d) 97.2°C

130. (a)

Thermal capacity rates for hot and cold fluids,

$$C_c = m_c c_c = 7.5 \times 4 = 30 \text{ kJ/sK}$$

$$C_h = m_h c_h = 10 \times 1 = 10 \text{ kJ/sK}$$

$$\begin{aligned} \text{Heat transfer rate, } Q &= \epsilon C_{\min} [t_{h1} - t_{c1}] \\ &= 0.94 \times 10 \times [120 - 15] \\ &= 987 \text{ kJ/s} \end{aligned}$$

Energy balance of hot fluid gives,

$$Q = m_h c_h [T_{h1} - T_{h2}]$$

$$\Rightarrow 987 = 10 \times 1 [120 - T_{h2}]$$

$$\Rightarrow T_{h2} = 120 - \frac{987}{10} = 21.3^\circ\text{C}$$

Q.131 Two large parallel planes with emissivity 0.4 are maintained at different temperatures and exchange heat only by radiation. What percentage change in net radiative heat transfer would occur if two equally large radiation shields with surface emissivity 0.04 are introduced in parallel to the plates?

- (a) 91.23% (b) 92.30%
(c) 86.2% (d) 96.07%

131. (d)

$$\frac{Q_2}{Q_1} = \frac{\left[\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1 \right]}{\left[\frac{1}{\epsilon_1} + \frac{1}{\epsilon_s} - 1 \right] + \left[\frac{1}{\epsilon_s} + \frac{1}{\epsilon_s} - 1 \right] + \left[\frac{1}{\epsilon_s} + \frac{1}{\epsilon_2} - 1 \right]}$$

Q_2 - Heat transfer with shields

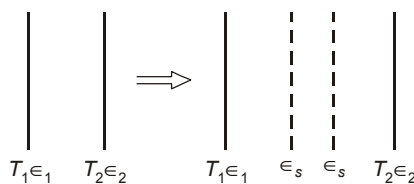
Q_1 - Heat transfer without shield

$$\epsilon_1 = \epsilon_2 = 0.4$$

$$\epsilon_s = 0.04$$

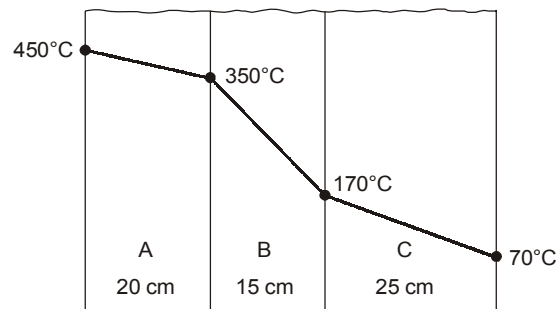
Substituting values in above equation,

$$\Rightarrow \frac{Q_2}{Q_1} = \frac{\left[\frac{1}{0.4} + \frac{1}{0.4} - 1 \right]}{\frac{1}{0.4} + \frac{1}{0.4} + \frac{4}{0.04} - 3} = \frac{4}{102}$$



Now, $\% \text{ change} = \left[1 - \frac{Q_2}{Q_1} \right] \times 100\% = \left[1 - \frac{4}{102} \right] \times 100\% = 96.07\%$

Q.132 For a composite wall made of three layers of different materials, the wall thickness and the temperatures at various wall faces are as indicated in figure.



These parameters indicate that

- (a) Layers A and C are made of same material.
- (b) There is a generation of heat at the interface of walls A and B.
- (c) Of all the materials, material A has the highest value of thermal conductivity.
- (d) Of all the materials, material B has lowest value of thermal conductivity.

132. (d)

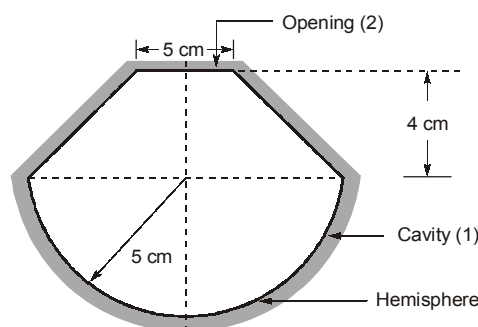
$$Q = \frac{K_A A_A \Delta t_A}{\delta_A} = \frac{K_B A_B \Delta t_B}{\delta_B} = \frac{K_C A_C \Delta t_C}{\delta_C}$$

This gives, $\frac{K_A \times 100}{0.2} = \frac{K_B \times 180}{0.15} = \frac{K_C \times 100}{0.25}$

$$\Rightarrow 5 K_A = 12 K_B = 4 K_C$$

$$\therefore K_C > K_A > K_B$$

Q.133 Shown in the figure is a cavity in the form of frustum connected with hemisphere. The value of shape factor of cavity with respect to itself is _____.



133. (0.927)(0.92 to 0.93)

Let area of cavity be A_1 .

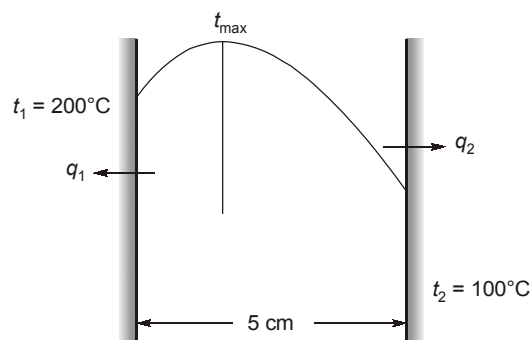
$$A_1 = \text{area of frustum} + \text{area of hemisphere}$$

$$A_1 = \pi(r_1 + r_2)\sqrt{(r_2 - r_1)^2 + h^2} + \frac{4}{2}\pi r_2^2$$

$$\Rightarrow A_1 = \pi(2.5 + 5)\sqrt{(5 - 2.5)^2 + 4^2} + \frac{1}{2} \times 4\pi \times 5^2$$

$$\begin{aligned}
 &= 111.14 + 157.08 = 268.22 \text{ cm}^2 \\
 \text{but } A_1 F_{12} &= A_2 F_{21} \\
 F_{21} &= 1 \\
 \Rightarrow F_{12} &= \frac{A_2}{A_1} \\
 \text{and } F_{12} + F_{11} &= 1 \\
 F_{11} &= 1 - F_{12} \\
 \Rightarrow F_{11} &= 1 - \frac{A_2}{A_1} \\
 \Rightarrow F_{11} &= 1 - \frac{\frac{\pi}{4} \times 5^2}{268.22} = 1 - 0.0732 = 0.927
 \end{aligned}$$

Q.134 A 5 cm thick steel plate of thermal conductivity 60 W/m°C has uniform volumetric heat generation $50 \times 10^6 \text{ W/m}^3$. The temperature, at one outer surface of plate is 200°C and that at the other is 100°C. The value of maximum temperature across the plate is _____ °C.



134. (412.8)(411 to 414)

The temperature distribution is prescribed by the relation.

$$\begin{aligned}
 t &= \left[\frac{q_g}{2k} [b-x] + \frac{t_2 - t_1}{b} \right] x + t_2 \\
 &= \left[\frac{50 \times 10^6}{2 \times 60} \times (0.05 - x) + \frac{100 - 200}{0.05} \right] x + 200 \\
 t &= 200 + 18833.33x - 4.167 \times 10^5 x^2
 \end{aligned}$$

Position of maximum temperature,

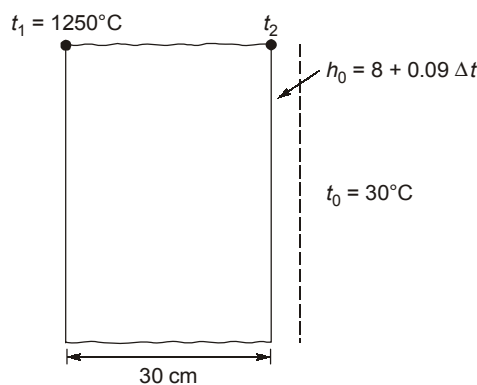
$$\begin{aligned}
 \Rightarrow \frac{dt}{dx} &= 0 \\
 \Rightarrow 18833.33 - 2 \times 4.167 \times 10^5 x &= 0 \\
 \Rightarrow x &= 0.0226 \text{ m} \\
 \text{Now, } t_{\max} &= 200 + 18833.33 \times (0.0226) - 4.167 \times 10^5 \times (0.0226)^2 \\
 &= 412.8^\circ\text{C}
 \end{aligned}$$

Q.135 A 30 cm thick furnace wall ($k = 1.5 \text{ W/mK}$) has inner surface temperature of 1250°C . If the heat transfer coefficient on the outer surface is prescribed by the relation $h_0 = 8 + 0.09 \Delta t$; where, Δt is the temperature difference between the outer wall surface and surrounding. What is the value of outer surface heat transfer coefficient at steady state condition?

Take surrounding temperature as 30°C .

- (a) $37 \text{ W/m}^2\text{K}$ (b) $10 \text{ W/m}^2\text{K}$
(c) $26 \text{ W/m}^2\text{K}$ (d) $57 \text{ W/m}^2\text{K}$

135. (c)



Considering unit area of the furnace wall,

$$Q = \frac{t_1 - t_0}{\frac{\delta_1}{k} + \frac{1}{h_0}} = \frac{t_2 - t_0}{\frac{1}{h_0}}$$

$$\Rightarrow [t_2 - t_0] = \frac{1}{h_0} \left[\frac{t_1 - t_0}{\frac{\delta_1}{k} + \frac{1}{h_0}} \right] = C \left[\frac{1250 - 30}{\frac{0.3}{1.5} + C} \right], \text{ where } C = \frac{1}{h_0}$$

Substituting $[t_2 - t_0]$ in the given expression of h_0 i.e. $h_0 = 8 + 0.09 \Delta t$,

$$\Rightarrow h_0 = 8 + 0.09C \times \left[\frac{1220}{0.2 + C} \right]$$

$$\Rightarrow \frac{1}{C} = 8 + 0.09C \times \frac{1220}{0.2 + C}$$

Upon simplification,

$$\Rightarrow 117.8 C^2 + 0.6 C - 0.2 = 0$$

On solving,

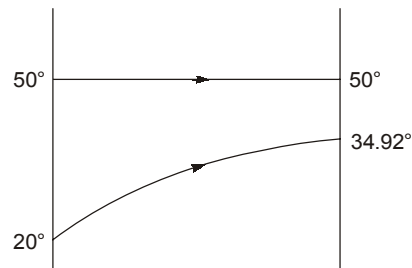
$$\Rightarrow C = 0.03874$$

$$\text{Now, } h_0 = \frac{1}{C} = \frac{1}{0.03874} = 25.82 \text{ W/m}^2\text{K} \simeq 26 \text{ W/m}^2\text{K}$$

Q.136 For a steam condenser, the steam condenses on the outer surface of the tubes at condensation temperature 50°C. Water enters the tube at 20°C and leaves at 35.95°C. What is the NTU for the heat exchanger?

- (a) 0.7586 (b) 0.5317
(c) 0.9569 (d) Can't be determined from given data

136. (a)



Given heat exchanger is a condenser,

$$C_h = C_{\max} = \infty$$

$$C_{\min} = C_c$$

$$\text{Effectiveness} = \frac{C_c [t_{c2} - t_{c1}]}{C_{\min} [t_{h1} - t_{c1}]} = \frac{t_{c2} - t_{c1}}{t_{h1} - t_{c1}} \quad [\because C_{\min} = C_c]$$

$$= \frac{35.95 - 20}{50 - 20} = 0.5317$$

Effectiveness of condenser.

$$\epsilon = 1 - \exp[-NTU] \quad (\text{Since } C = 0)$$

$$\Rightarrow 0.5317 = 1 - \exp[-NTU]$$

$$\Rightarrow \exp[-NTU] = 1 - 0.5317 = 0.4683$$

$$\Rightarrow -NTU = \log_e 0.4683 = -0.7586$$

$$\Rightarrow NTU = 0.7586$$

Q.137 The temperature profile at a particular location on the surface of the plate is prescribed by the

identities: $\frac{t_s - t}{t_s - t_\infty} = \frac{1}{7} \left[\frac{y}{0.6} \right]^5 + \frac{1}{3} y^3 + \left(\frac{3}{2} \right) y$. If thermal conductivity of air is 0.04 W/mK. The value of convective heat transfer coefficient _____ W/m²K.

137. (0.06)(0.05 to 0.065)

$$\frac{d}{dy} \left[\frac{t_s - t}{t_s - t_\infty} \right] = \frac{5}{7} \frac{y^4}{(0.6)^5} + \frac{3y^2}{3} + \frac{3}{2}$$

$$-K \left(\frac{\partial T}{\partial y} \right)_{y=0} = h(t_s - t_\infty)$$

$$\Rightarrow \left[\frac{dt}{dy} \right]_{y=0} = -(t_s - t_\infty) \times \frac{3}{2}$$

$$= \frac{3k}{2} = 3 \times \frac{0.04}{2} = 0.06 \text{ W/m}^2\text{K}$$

Q.138 A solid copper sphere has radius twice that of a solid aluminium sphere. Both are heated to same temperature and are allowed to cool under identical surrounding temperature. Assume emissivity of both the spheres as same. What is the ratio of rate of fall of temperature of Al sphere to the rate of fall of temperature of copper sphere?

Specific heat Al = 900 J/kg°C; Specific heat Cu = 390 J/kg°C; $\rho_{cu} = 3.4 \rho_{Al}$

(Take at $t = 0$, $T_{al} = T_{cu} = T$ and at $t = T$, $T_{al} = T_{cu} = T_{\infty}$)

- (a) 3.4 : 1 (b) 5.7 : 1
(c) 2.9 : 1 (d) 11.8 : 1

138. (c)

Let given values of copper be denoted by subscript 'c' and that of aluminium by subscript 'Al'

Given: $T_c = T_{Al}$, $\epsilon_c = \epsilon_{Al}$, $R_c = 2R_{Al}$

Surrounding temperature = T_{∞}

We know that, $\dot{Q}_c = \epsilon_c \sigma A_c (T_c^4 - T_{\infty}^4)$

$$\Rightarrow m_c C_{p,c} \left(\frac{dT_c}{dt} \right) = \epsilon_c \sigma A_c (T_c^4 - T_{\infty}^4) \quad \left[\dot{Q} = mc_p \frac{dT}{dt} \right] \quad \dots(1)$$

Similarly for aluminium sphere;

$$\dot{Q}_{Al} = \epsilon_{Al} \sigma A_{Al} (T_{Al}^4 - T_{\infty}^4)$$

$$m_{Al} c_{p,Al} \left(\frac{dT_{Al}}{dt} \right) = \epsilon_{Al} \sigma (A)_{Al} (T_{Al}^4 - T_{\infty}^4) \quad \left[\dot{Q} = mc_p \frac{dT}{dt} \right] \quad \dots(2)$$

Dividing (2) by (1) we get,

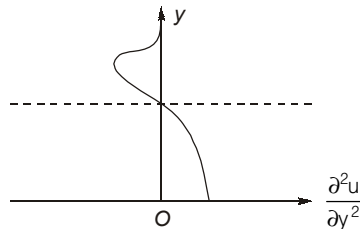
$$\frac{m_{Al} c_{p,Al} \left(\frac{dT}{dt} \right)_{Al}}{m_c c_{p,c} \left(\frac{dT}{dt} \right)_c} = \frac{\epsilon_{Al} (\sigma) A_{Al} (T_{Al}^4 - T_{\infty}^4)}{\epsilon_c (\sigma) A_c (T_c^4 - T_{\infty}^4)}$$

$$\Rightarrow \frac{\left(\frac{dT}{dt} \right)_{Al}}{\left(\frac{dT}{dt} \right)_c} = \left(\frac{c_{p,c}}{c_{p,Al}} \right) \left(\frac{\rho_c}{\rho_{Al}} \right) \left(\frac{V_c}{A_c} \right) \left(\frac{A_{Al}}{V_{Al}} \right) \quad [m = \rho V]$$

$$= \frac{390}{900} \times 3.4 \times \frac{R_c}{R_{Al}} \quad \left[\text{For sphere } \frac{V}{A} = \frac{R}{3} \right]$$

$$= \frac{390 \times 3.4 \times 2}{900} = 2.94$$

Q.139 Consider the figure which shows the variation of $\frac{\partial^2 u}{\partial y^2}$ and y inside a laminar boundary layer:



This distribution is correct for

- (a) $\frac{\partial P}{\partial x} > 0$ (b) $\frac{\partial P}{\partial x} < 0$
(c) $\frac{\partial P}{\partial x} = 0$ (d) Both $\frac{\partial P}{\partial x} > 0$ and $\frac{\partial P}{\partial x} < 0$

139. (a)

As seen in the graph, there is a point where $\frac{\partial^2 u}{\partial y^2} = 0$. It means the velocity profile has a point of inflection which is possible only at the point of separation.

Q.140 A fluid flow is represented by the velocity $\vec{v} = 2x\hat{i} + 4y\hat{j}$. The equation of stream line passing through a point (2, 4) is

- (a) $x^2 - y = 0$ (b) $x - y^2 = 0$
(c) $x^2 + y = 0$ (d) $x + y^2 = 0$

140. (a)

For the equation of stream line,

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\Rightarrow \frac{dx}{2x} = \frac{dy}{4y}$$

$$\Rightarrow \int \frac{2dx}{x} = \int \frac{dy}{y} \Rightarrow 2\ln x = \ln y + C$$

$$\Rightarrow \ln x^2 - \ln y = C$$

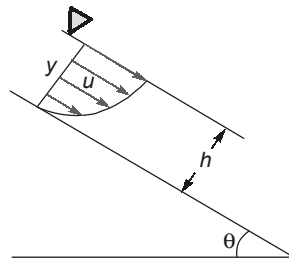
$$\Rightarrow \ln \frac{x^2}{y} = C$$

Now at (2, 4),

$$C = \ln \frac{4}{4} = \ln 1 \quad \therefore C = 0$$

$$\Rightarrow x^2 - y = 0$$

Q.141 A Newtonian liquid flows down an inclined plane surface in a steady and fully developed laminar state as shown in figure



The shear stress distribution is given by, $\tau = \rho g \sin \theta (h - y)$

If the width of inclined surface is b , then the volume flow rate is given by

- (a) $\frac{\rho g \sin \theta b h^3}{3\mu}$ (b) $\frac{\rho g \cos \theta b h^3}{3\mu}$
(c) $\frac{\rho g \sin \theta b h^3}{2\mu}$ (d) $\frac{\rho g \cos \theta b h^3}{2\mu}$

141. (a)

Given: $\tau = \rho g \sin \theta (h - y)$

Now for newtonian fluid,

$$\tau = \mu \frac{\partial u}{\partial y}$$

$$\Rightarrow \int_0^u \partial u = \int_0^y \frac{\rho g \sin \theta}{\mu} (h - y) \partial y$$

$$\Rightarrow u = \frac{\rho g \sin \theta}{\mu} \left(hy - \frac{y^2}{2} \right)$$

Now, $Q = \int_A u dA = \int_0^h u b dy$ ($dA = b dy$, as width b is constant)

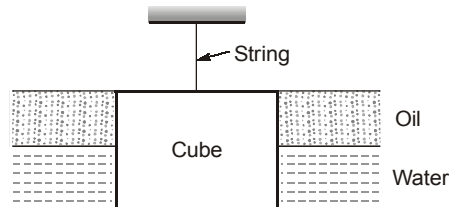
$$\therefore Q = \int_0^h \frac{\rho g \sin \theta}{\mu} b \left(hy - \frac{y^2}{2} \right) dy$$

$$Q = \frac{\rho g \sin \theta b}{\mu} \left[\frac{h^3}{2} - \frac{h^3}{6} \right]$$

$$Q = \frac{\rho g \sin \theta b h^3}{3\mu}$$

Q.142 A copper cube of 200 mm side length is suspended by a string in oil and water as shown in figure. The cube is submerged with half of it being in oil and the other half in water. The tension developed in the string is

(Take $\rho_{\text{oil}} = 900 \text{ kg/m}^3$; $\rho_{\text{water}} = 1000 \text{ kg/m}^3$; and $\rho_{\text{Copper}} = 8000 \text{ kg/m}^3$)



- (a) 624.8 N (b) 421.7 N
(c) 268.4 N (d) 553.3 N

142. (d)

The tension developed will be,

$$T = W - F_B$$

where,

W = Weight of cube

F_B = Total buoyancy force

Now,

$$W = mg = \rho Vg = 8000 \times 0.2^3 \times 9.81 = 627.84 \text{ N}$$

$$F_B = \rho_o g V_1 + \rho_w g V_2$$

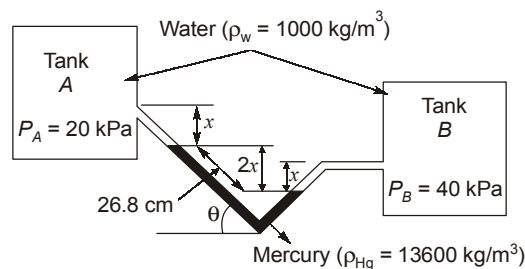
$$= 900 \times 9.81 \times \frac{0.2^3}{2} + 1000 \times 9.81 \times \frac{0.2^3}{2}$$

$$= 74.556 \text{ N}$$

$\therefore$

$$T = 627.84 - 74.556 = 553.284 \text{ N}$$

Q.143 Two water tanks are connected to each other through a mercury manometer with inclined tubes as shown in figure. The value of θ is _____ degree. (Take $g = 9.81 \text{ m/s}^2$)



143. (34)(33.5 to 34.5)

We know that the pressure at the same horizontal line in a same fluid is equal.

$$\text{So, } P_A + \rho_w g x + \rho_{\text{Hg}} g(2x) = P_B + \rho_w g x$$

$$\Rightarrow x = \frac{P_B - P_A}{2\rho_{\text{Hg}} g} = \frac{(40 - 20)}{2 \times 13600 \times 9.81} \times 1000$$

$$\Rightarrow x = 0.07495 \text{ m} = 7.495 \text{ cm}$$

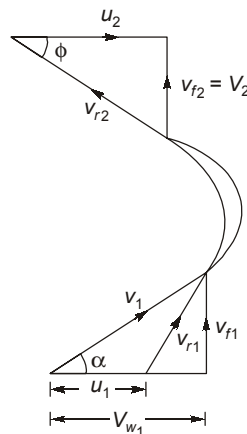
$$\text{So, } \sin \theta = \frac{2x}{26.8} = \frac{2 \times 7.495}{26.8} = 0.559$$

$$\therefore \theta = \sin^{-1}(0.559) = 34^\circ$$

Q.144 An inward flow reaction turbine has external and internal diameters as 0.9 m and 0.45 m respectively. The turbine is running at 200 rpm. The guide blades make an angle of 10° to the tangent of the wheel and discharge at outlet is radial. Head at inlet of the turbine is _____ m.

[Velocity of flow at inlet and outlet = 1.8 m/s and assume no friction loss]

144. (9.97)(9.5 to 10.5)



Given: External diameter, $D_1 = 0.9$ m

Internal diameter, $D_2 = 0.45$ m

Speed, $N = 200$ rpm

Velocity of flow, $V_{f1} = V_{f2} = 1.8$ m/s

Absolute velocity at outlet

$$V_2 = V_{f2} = 1.8 \text{ m/s}$$

$$V_{w1} = V_1 \cos \alpha = \frac{V_{f1}}{\sin \alpha} \cos \alpha = V_{f1} \cot \alpha$$

$$\Rightarrow V_{w1} = 1.8 \cot 10^\circ = 10.208 \text{ m/s}$$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.9 \times 200}{60} = 9.424 \text{ m/s}$$

Now, head at inlet of turbine, H

$$\Rightarrow H - \frac{V_2^2}{2g} = \frac{1}{g} [V_{w1} u_1 \pm V_{w2} u_2] = \frac{V_{w1} u_1}{g} \quad [\because V_{w2} = 0]$$

$$\Rightarrow H = \frac{V_2^2}{2g} + \frac{V_{w1} u_1}{g} = \frac{1 \times 1.8^2}{2 \times 9.81} + \frac{10.208 \times 9.424}{9.81}$$

$$\Rightarrow H = 9.97 \text{ m}$$

Q.145 Consider two tubes of radii r_1 and r_2 , and length L_1 and L_2 respectively. They are connected in series and a liquid flows through them in streamline laminar conditions. P_1 and P_2 are the pressure differences across the two tubes. If $P_2 = 4P_1$ and $L_2 = \frac{L_1}{4}$, then the ratio $\frac{r_2}{r_1}$ is _____.

145. (0.5)(0.49 to 0.51)

In stream line laminar flow,

$$\Delta P \propto \frac{\mu \bar{v} L}{D^2}$$

$$\Rightarrow \Delta P \propto \frac{L}{D^4} \propto \frac{L}{r^4} \quad \left(\because \bar{v} = \frac{Q}{A} = \frac{4Q}{\pi D^2} \right)$$

Now, $P_1 = \frac{kL_1}{r_1^4}$ and $P_2 = \frac{kL_2}{r_2^4}$

$$\Rightarrow \frac{P_1}{P_2} = \frac{L_1}{r_1^4} \times \frac{r_2^4}{L_2}$$

$$\Rightarrow \frac{P_1}{4P_1} = \frac{L_1}{r_1^4} \times \frac{r_2^4}{L_1/4}$$

$$\Rightarrow \left(\frac{r_2}{r_1} \right)^4 = \frac{1}{16}$$

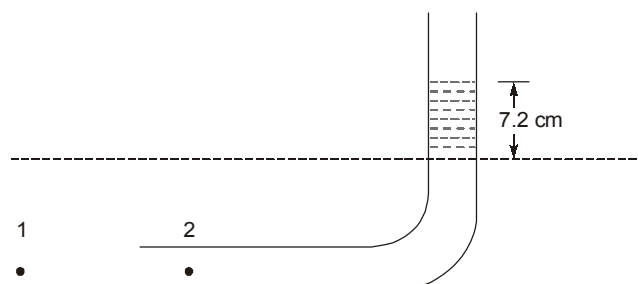
$$\therefore \frac{r_2}{r_1} = \frac{1}{(16)^{1/4}} = \frac{1}{2} = 0.5$$

Q.146 A pelton wheel has to be designed for following specifications:

Power to be developed = 6000 kW; Net head available = 300 m, Speed = 500 rpm. Ratio of jet diameter to wheel diameter = 1/10. Overall efficiency = 0.85; Coefficient of velocity $C_v = 0.98$. Speed ratio $\phi = 0.46$. What are the number of jets required ?

- (a) 2 (b) 4
(c) 3 (d) 6

146. (c)



$$V_1 = C_v \sqrt{2gH} = 0.98 \times \sqrt{2 \times 9.81 \times 300} = 75.19 \text{ m/s}$$

$$V_b = \phi \sqrt{2gH} = 0.46 \times \sqrt{2 \times 9.81 \times 300} = 35.29 \text{ m/s}$$

efficiency, $\eta_0 = \frac{P}{\rho g Q H} = \frac{6000 \times 10^3}{1000 \times Q \times 9.81 \times 300} = 0.85$

$$\Rightarrow Q = \frac{20}{9.81 \times 0.85} = 2.4 \text{ m}^3/\text{s}$$

$$\Rightarrow V_b = \frac{\pi DN}{60} = \frac{\pi D \times 500}{60} = 35.29$$

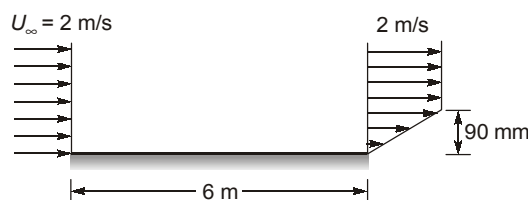
Where, D = wheel diameter

$$\Rightarrow D = \frac{35.29 \times 60}{\pi \times 500} = 1.348 \text{ m}$$

$$\text{Jet diameter for each jet, } d = \frac{D}{10} = 0.1348 \text{ m}$$

$$\begin{aligned} \text{Number of jet} &= \frac{Q}{V_1 \times \frac{\pi}{4} d^2} = \frac{2.4}{75.19 \times \frac{\pi}{4} \times (0.1348)^2} \\ &= 2.237 \approx 3 \text{ jets} \end{aligned}$$

Q.147 Consider the flow of water past a (6 m × 2 m) plate as shown in figure. Assuming that the pressure is same everywhere in the flow field, the drag force on the plate is _____ N. (Take $\rho = 1000 \text{ kg/m}^3$)



147. (120)(119.5 to 120.5)

By Von-Karman momentum equation,

$$\frac{\tau}{\rho U_\infty^2} = \frac{\partial \theta}{\partial x}$$

Now, for a small strip (∂x),

$$\tau = \frac{\partial F}{b \partial x} \quad (b = \text{plate width})$$

$$\Rightarrow \partial F = \rho U_\infty^2 b \partial x \times \left(\frac{\partial \theta}{\partial x} \right) = \rho U_\infty^2 b \partial \theta$$

$$\text{So, } \int_0^F \partial F = \rho U_\infty^2 b \int_0^{\theta_L} \partial \theta = \rho U_\infty^2 b \theta_L$$

$$\Rightarrow F = \rho U_\infty^2 b \theta_L \quad \dots(1)$$

The velocity profile is linear at the trailing edge,

$$\frac{U}{U_\infty} = \frac{y}{\delta} \quad (\delta = \text{Boundary layer thickness})$$

$$\text{So, } \theta_L = \int_0^\delta \frac{U}{U_\infty} \left(1 - \frac{U}{U_\infty} \right) dy = \frac{\delta}{2} - \frac{\delta}{3} = \frac{\delta}{6}$$

Now from eq. (1) we get,

$$\therefore F = \frac{\rho U_{\infty}^2 b \delta}{6} = \frac{1000 \times 4 \times 2 \times 0.09}{6} = 120 \text{ N}$$

Q.148 The velocity along the centreline of a nozzle of length L is given by

$$v = 2t \left(1 - \frac{x}{2L} \right)^2$$

where,

v = velocity in m/s;

t = time in seconds;

x = distance from inlet of nozzle

The total acceleration in m/s^2 , when $t = 3\text{s}$, $x = 0.5 \text{ m}$ and $L = 1 \text{ m}$, is _____.

148. (-14.0625)(-14.1 to -13.95)

$$a = \frac{\partial v}{\partial t} + \frac{v \partial v}{\partial x}$$

$$\frac{\partial v}{\partial t} = 2 \left(1 - \frac{x}{2L} \right)^2$$

$$\therefore \left. \frac{\partial v}{\partial t} \right|_{(t=3, x=0.5)} = 2 \left(1 - \frac{0.5}{2 \times 1} \right)^2 = 1.125 \text{ m/s}^2$$

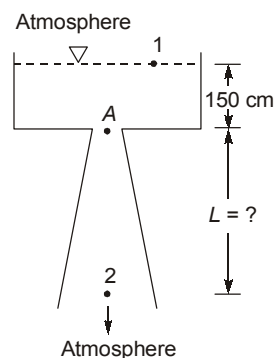
$$\frac{v \partial v}{\partial x} = (2t)^2 \times 2 \left(1 - \frac{x}{2L} \right)^3 \times \left(\frac{-1}{2L} \right)$$

$$\left. \frac{v \partial v}{\partial x} \right|_{(t=3, x=0.5)} = (2 \times 3)^2 \times 2 \times \left(1 - \frac{0.5}{2} \right)^3 \times \left(\frac{-1}{2} \right) = -15.1875 \text{ m/s}^2$$

$$\therefore \text{Total acceleration} = 1.125 - 15.1875$$

$$a_T = -14.0625 \text{ m/s}^2$$

Q.149 The outlet at the bottom of a tank is so formed that the velocity of water at a point A as shown in the figure below is 2.0 times the mean velocity within the outlet pipe (atmospheric pressure = 95.48 kPa(absolute) and vapour pressure = 4.00 kPa (absolute) and neglect all other losses). The greatest length of pipe L which may be used without cavitation is _____ m.



149. (1.21)

$$P_A = \text{Vapour pressure} = 4.00 \text{ kPa(abs)}$$

$$P_1 = P_2 = \text{atmospheric pressure} = 95.47 \text{ kPa(abs)}$$

By applying Bernoulli's equation to point 1 and A.

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_A}{\rho g} + \frac{v_A^2}{2g} + z_A$$

$$\left(\frac{95.48}{9.81}\right) + 0 + 1.5 = \left(\frac{4.00}{9.81}\right) + \frac{v_A^2}{2g} + 0$$

$$\frac{v_A^2}{2g} = \frac{95.48 - 4.00}{9.81} + 1.5 = 10.825 \text{ m}$$

$$v_A = (2 \times 9.81 \times 10.825)^{1/2} = 14.57 \text{ m/sec}$$

$$v_2 = \frac{V_A}{2} = \frac{14.57}{2} = 7.28 \text{ m/sec}$$

By applying Bernoulli's equation to point 1 and 2, with datum at point 2.

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

$$\frac{95.48}{9.81} + 0 + (L + 1.50) = \left(\frac{95.48}{9.81}\right) + \frac{(7.28)^2}{2 \times 9.81} + 0$$

$$L = 1.21 \text{ m}$$

Q.150 A turbine works under a head of 19 m and has a maximum flow rate of 3 m³/s and a speed of 600 rpm. If it has to work in another plant under a head of 5 m, the maximum flow rate will be _____ m³/s.

150. (1.539)(1.50 to 1.58)

$$H_1 = 19 \text{ m}, Q_1 = 3 \text{ m}^3/\text{sec}, N_1 = 600 \text{ rpm}, H_2 = 5 \text{ m}$$

$$\frac{Q_1}{D_1^3 N_1} = \frac{Q_2}{D_2^3 N_2}$$

$$Q_2 = Q_1 \times \frac{N_2}{N_1} = Q_1 \times \sqrt{\frac{H_2}{H_1}}$$

$$\therefore \frac{gH_1}{D_1^2 N_1^2} = \frac{gH_2}{D_2^2 N_2^2}$$

$$\frac{N_2}{N_1} = \sqrt{\frac{H_2}{H_1}}$$

$$Q_2 = 3 \times \sqrt{\frac{5}{19}}$$

$$Q_2 = 1.539 \text{ m}^3/\text{sec}$$

■■■■



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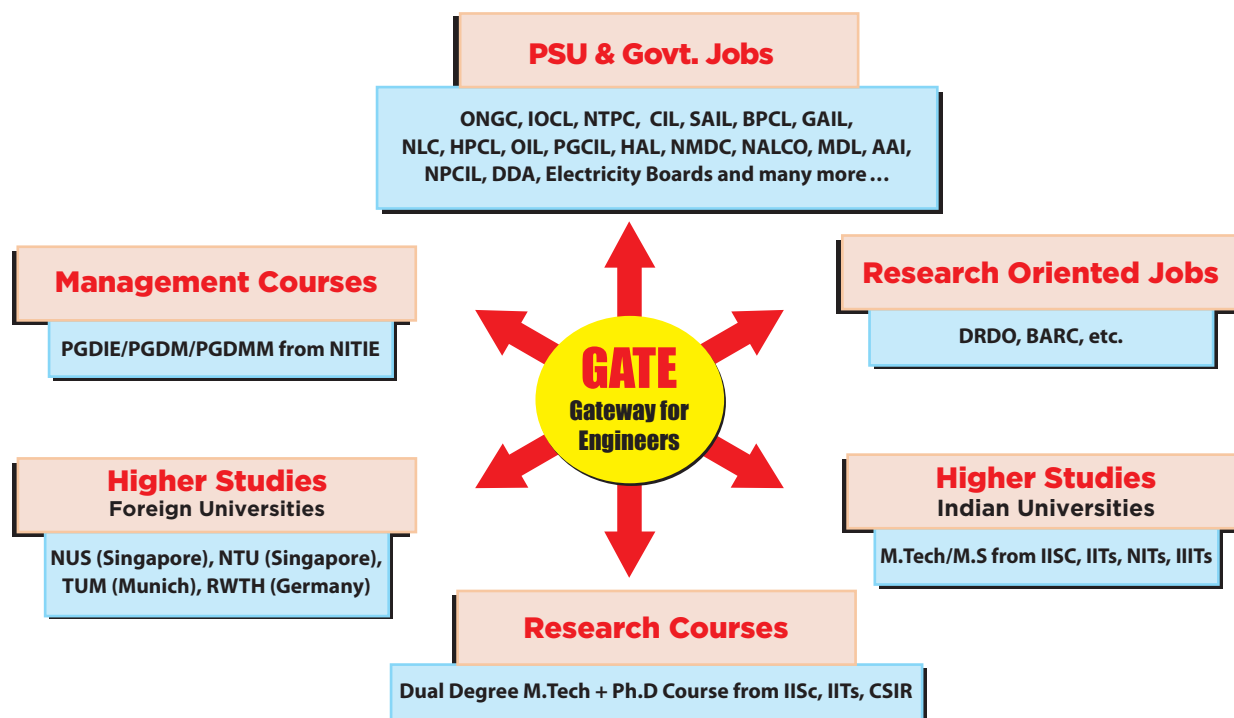
Revision through Questions for GATE 2020

ME

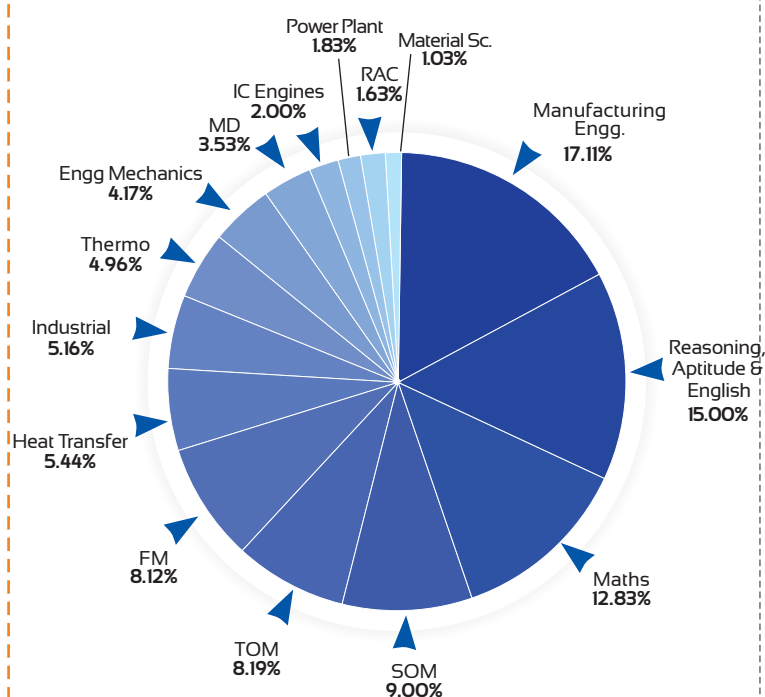
MECHANICAL ENGG.

Q.151 - Q.175
out of 200 Questions

Day 7 of 8



SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 7 : Q.151 to Q.175 : Mechanical Engineering

Q.151 A heat engine operates at 75% of the efficiency of a Carnot engine operating between the same two temperatures. The engine has power output of 100 W and discharge heat into the 27°C low temperature reservoir at a rate of 300 J/s. The temperature of high temperature reservoir will be

- (a) 450°C (b) 77°C
(c) 177°C (d) 127°C

151. (c)

Here,

$$\begin{aligned}Q_H - Q_L &= 100 \text{ J} \\Q_L &= 300 \text{ J} \\Q_H &= 300 + 100 = 400 \text{ J}\end{aligned}$$

$$\text{Efficiency, } \epsilon = 1 - \frac{300}{400} = 0.25$$

This is efficiency of engine

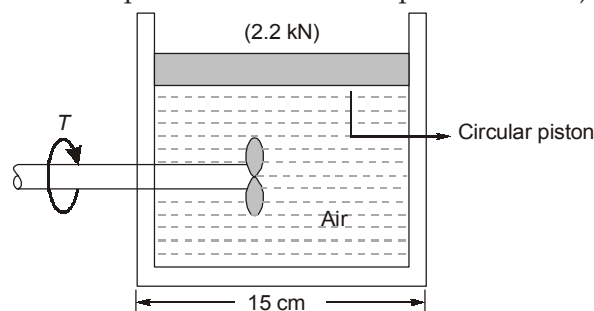
$$\begin{aligned}\text{Given } \epsilon_{\text{engine}} &= 0.75 \epsilon_{\text{carnot}} \\ \epsilon_{\text{carnot}} &= \frac{0.25}{0.75} = \frac{1}{3} = 1 - \frac{T_L}{T_H}\end{aligned}$$

$$\frac{1}{3} = 1 - \frac{300}{T_H}$$

$$\frac{300}{T_H} = \frac{2}{3}$$

on solving, $T_H = 450 \text{ K} = 177^\circ\text{C}$

Q.152 A paddle wheel as shown in the figure requires a torque of 27 Nm to rotate it at 100 rpm. The atmospheric pressure is 101.3 kPa. If it rotates for 20s and the frictionless piston raises by 0.6 m during this time, then the net work done by the air is _____ J. (Assume pressure of air remains constant and the shape of cross-section of piston is circle)



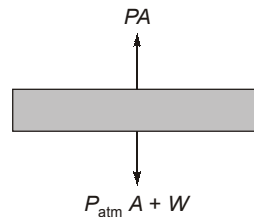
152. (- 3260.85)(- 3262 to - 3259)

The work input by the Paddle wheel is,

$$W_1 = T\omega t = 27 \times \left(\frac{2\pi \times 100}{60} \right) \times 20$$

$$W_1 = 5654.87 \text{ J}$$

The pressure of air can be found by the force balance of piston,



$$\Rightarrow PA = P_{\text{atm}} A + W$$

$$\Rightarrow P = P_{\text{atm}} + \frac{W}{A} = 101.3 + \frac{2.2}{\frac{\pi}{4}(0.15^2)} = 225.79 \text{ kPa}$$

$\therefore$ Work done by the air to raise the piston is,

$$\begin{aligned} W_2 &= F \times x = (PA) \times 0.6 \\ &= 225.79 \times \frac{\pi}{4}(0.15^2) \times 0.6 = 2.39402 \text{ kJ} = 2394.02 \text{ J} \end{aligned}$$

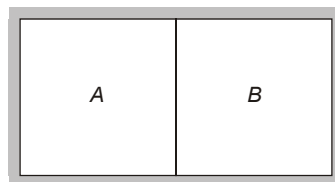
$\therefore$ Net work done on the air is,

$$W_{\text{net}} = W_2 - W_1 = -3260.85 \text{ J}$$

Q.153 Block A of mass 5 kg and temperature 300°C. Block B of mass 10 kg and temperature -50°C. The outer boundary of blocks are insulated such that heat lost to the surrounding is zero. Specific heat of block A and B be 1.0 and 0.4 kJ/kgK. The irreversibility of the system is (Take $T_0 = 27^\circ\text{C}$)

- (a) 276 kJ (b) 371 kJ
(c) 527 kJ (d) 205 kJ

153. (a)



Given: $m_A = 5 \text{ kg}$, $m_B = 10 \text{ kg}$, $T_A = 573 \text{ K}$, $T_B = 223 \text{ K}$, $c_A = 1 \text{ kJ/kgK}$, $c_B = 0.4 \text{ kJ/kgK}$

Let final temperature be T_f

By energy balance,

$$\Rightarrow m_A c_A [T_A - T_f] = m_B c_B [T_f - T_B]$$

$$\Rightarrow 5 \times 1 [573 - T_f] = 10 \times 0.4 [T_f - 223]$$

$$\Rightarrow T_f = 417.4 \text{ K}$$

$$\begin{aligned} S_{\text{gen}} &= m_A c_A \ln \frac{T_f}{T_A} + m_B c_B \ln \frac{T_f}{T_B} \\ &= 5 \times 1 \ln \left(\frac{417.4}{573} \right) + 10 \times 0.4 \ln \left(\frac{417.4}{223} \right) \end{aligned}$$

$$\begin{aligned}
 &= -1.58 + 2.507 = 0.92 \text{ kJ/K} \\
 \text{Irreversibility, } I &= T_0 \Delta S = (273 + 27) \times 0.92 \\
 &= 300 \times 0.92 \\
 &= 276 \text{ kJ}
 \end{aligned}$$

Q.154 The exergy of 0.4 kg of wet steam at 0.1 bar and 0.85 quality is _____ kJ.

(Assume dead state of 1 bar and 300 K)

Data:

At 1 bar, 300 K

$$h_0 = 113.2 \text{ kJ/kg}; s_0 = 0.395 \text{ kJ/kgK}$$

At 0.1 bar, 0.85 quality

$$h_f = 192 \text{ kJ/kg}; h_g = 2582 \text{ kJ/kg}$$

$$s_f = 0.649 \text{ kJ/kgK}; s_g = 8.148 \text{ kJ/kgK}$$

- (a) 48.8 kJ (b) 57.9 kJ
(c) 112.6 kJ (d) 93.8 kJ

154. (a)

At dead state: $T_0 = 300 \text{ K}$, $h_0 = 113.2 \text{ kJ/kg}$, $s_0 = 0.395 \text{ kJ/kgK}$, $m = 0.4 \text{ kg}$

$$\text{Exergy of system, } \phi = m[\phi_1 - \phi_0]$$

$$\begin{aligned}
 \text{Now, } h_0 - T_0 s_0 &= 113.2 - (300 \times 0.395) \\
 &= -5.3 \text{ kJ/kg}
 \end{aligned}$$

At 0.1 bar, 0.85 steam quality,

$$\begin{aligned}
 h &= h_f + x[h_g - h_f] \\
 &= 192 + 0.85 [2582 - 192] \\
 \Rightarrow h &= 2223.5 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 s &= s_f + 0.85[s_g - s_f] \\
 &= 0.649 + 0.85 [8.148 - 0.649] = 7.023 \text{ kJ/kgK}
 \end{aligned}$$

$$\begin{aligned}
 \text{Now, } h - T_0 s &= 2223.5 - 300 \times 7.023 \\
 &= 116.6 \text{ kJ/kg}
 \end{aligned}$$

$$\begin{aligned}
 \text{Now, Exergy} &= m[116.6 - (-5.3)] \\
 &= 0.4 \times 121.9 = 48.76 \text{ kJ}
 \end{aligned}$$

Q.155 A blower handles 1 kg/s of air at 20°C and consumes a power of 15 kW. The inlet and outlet velocities are 100 m/s and 150 m/s respectively. The exit air temperature, assuming adiabatic conditions is _____ °C. (Take c_p of air as 1.005 kJ/kgK)

155. (28.70)(28.5 to 28.9)

Given, $\dot{m} = 1 \text{ kg/s}$, $T_1 = 20^\circ\text{C}$, $W = -15 \text{ kW}$, $V_1 = 100 \text{ m/s}$, $V_2 = 150 \text{ m/s}$, $c_p = 1.005 \text{ kJ/kgK}$

$$\text{Using SFEE, } \dot{m} \left(h_1 + \frac{V_1^2}{2000} \right) = \dot{m} \left(h_2 + \frac{V_2^2}{2000} \right) + W$$

$$\frac{T_{f2}}{T_2} = \left(\frac{V_2}{V_{f2}} \right)^{\gamma-1} = \left(\frac{2}{3} \right)^{0.5} \quad \dots(2)$$

Dividing equation (1) and (2)

$$\frac{T_{f1}}{T_{f2}} = \sqrt{3} \quad (\because T_1 = T_2)$$

Q.157 Consider a heat engine placed between two finite bodies at temperature 900 K and 400 K and heat capacity 4200 J/K. What is the final temperature obtained by the two bodies for maximum possible work extraction and the maximum work respectively?

- (a) 600 K, 2100 kJ (b) 500 K, 2100 kJ
(c) 600 K, 420 kJ (d) 700 K, 420 kJ

157. (c)

Given: $T_1 = 900$ K, $T_2 = 400$ K, $C_p = 4200$ J/K

Maximum work is obtained when the heat engine is working reversibly between the two bodies.

$$\begin{aligned} \Delta S_{\text{univ}} &= 0 \\ \Delta S_1 + \Delta S_2 &= 0 \\ C_p \ln \frac{T_f}{T_1} + C_p \ln \frac{T_f}{T_2} &= 0 \end{aligned}$$

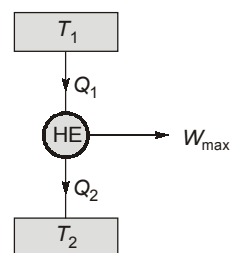
$$C_p \ln \frac{T_f^2}{T_1 T_2} = 0$$

$$\therefore T_f = \sqrt{T_1 T_2} = \sqrt{900 \times 400} = 600 \text{ K}$$

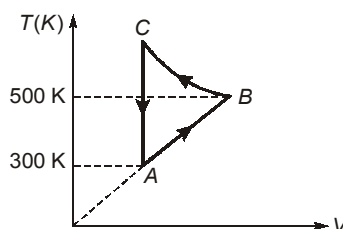
And, $W_{\text{max}} = C_p (\sqrt{T_1} - \sqrt{T_2})^2$

$$W_{\text{max}} = \frac{4200}{1000} (30 - 20)^2$$

$$W_{\text{max}} = 420 \text{ kJ}$$



Q.158 Consider a cyclic process ABCA performed by a sample of 2 moles of an ideal gas as shown in figure. If the net heat transfer during the cyclic process is -1200 J, the work done during the process BC (Take $R = 8.314$ J/mol-K)



- (a) -3324.4 J (b) -4526 J
(c) -6520 J (d) +4526 J

158. (b)

Given: $Q_{\text{net}} = -1200 \text{ J}$, $T_A = 300 \text{ K}$, $T_B = 500 \text{ K}$, $n = 2 \text{ moles}$

Since, it is a cyclic process,

$$Q_{\text{net}} = W_{\text{net}}$$

$$\therefore W_{AB} + W_{BC} + W_{CA} = -1200$$

$$W_{BC} = -1200 - W_{AB} - W_{CA}$$

Now, $W_{CA} = 0$, since it is a constant volume process.

$$\therefore W_{BC} = -1200 - W_{AB}$$

Now, line AB passes through origin,

$$T = KV$$

$$500 = KV_2$$

$$300 = KV_1$$

$$\therefore K(V_2 - V_1) = 200 \quad \dots(1)$$

$$\text{Now, } W_{AB} = \int_{V_1}^{V_2} P dV$$

$$\text{Also, } PV = n\bar{R}T$$

$$P = \frac{n\bar{R}KV}{V} = n\bar{R}K$$

$$\text{So, } W_{AB} = \int_{V_1}^{V_2} n\bar{R}K dV = n\bar{R}K(V_2 - V_1) = 2 \times 8.314 \times 200 = 3325.6 \text{ J}$$

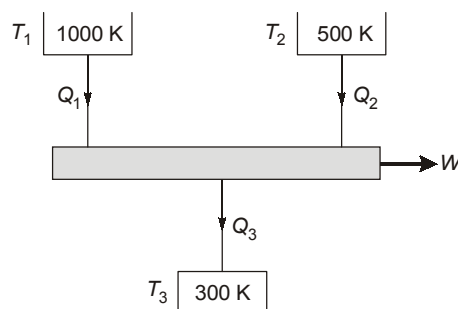
$$\text{Hence, } W_{BC} = -1200 - 3325.6 = -4525.6 \text{ J}$$

Q.159 A heat engine receives half of its heat supply at 1000 K and half at 500 K, while rejecting heat to the sink at 300 K. What is the maximum thermal efficiency of the engine?

- (a) 90% (b) 45%
(c) 55% (d) 60%

159. (c)

Maximum efficiency is obtained when engine works on reversible cycle,



For maximum efficiency

$$\Delta S_{\text{isolated system}} = 0$$

$$\text{or } \oint \frac{dQ}{T} = 0$$

$$\Rightarrow 0 = \frac{Q_1}{1000} + \frac{Q_2}{500} - \frac{Q_3}{300}$$

According to question,

$$Q_1 = Q_2 = Q$$

$$\Rightarrow \frac{Q_3}{300} = Q \left[\frac{1}{1000} + \frac{1}{500} \right]$$

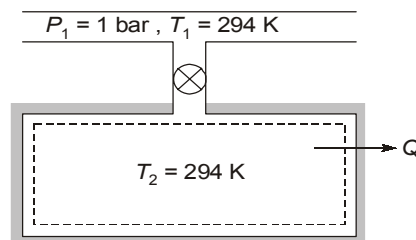
$$\Rightarrow \frac{Q_3}{Q} = \frac{300}{1000} + \frac{300}{500} = 0.9 \quad \dots(1)$$

Now, Efficiency, $\eta = \frac{W}{Q_1 + Q_2} = \frac{W}{2Q}$

$$\eta_{\max} = \frac{2Q - Q_3}{2Q} = 1 - \frac{Q_3}{2Q} \quad [\text{using equation (1)}]$$

$$= 1 - \frac{0.9}{2} = 0.55$$

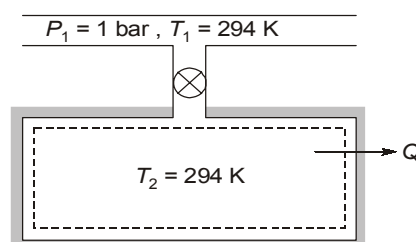
Q.160 A rigid tank of volume 0.5 m^3 is initially evacuated. A thin small hole develops in the wall, and air from surrounding at 1 bar, 21°C leaks in. Final pressure in the tank is 1 bar and final temperature in the tank 21°C . What is the amount of heat transfer between tank and surroundings?



- (a) 50 kJ
(c) 70 kJ

- (b) 100 kJ
(d) 150 kJ

160. (a)



$$V = 0.5 \text{ m}^3$$

$$P_1 = 1 \text{ bar}, P_2 = 1 \text{ bar}$$

$$T_1 = 294 \text{ K}$$

Mass of air entering chamber,

$$m_i = \frac{PV}{RT}$$

$$= \frac{10^5 \times 0.5}{287 \times 294} = 0.59 \text{ kg}$$

Now, $\left. \frac{dE}{dt} \right|_{cv} = \dot{Q} + m_i[h_1] - m_e h_e$

On integrating

$$\Rightarrow m_2 u_2 - m_1 u_1 = Q + [m_2 - m_1] h_1$$

$$m_1 = 0 \text{ as tank is initially evacuated}$$

$$m_e = 0 \text{ as no air exit cylinder}$$

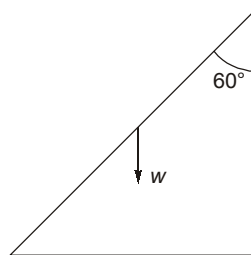
$$\Rightarrow m_2 c_v T_2 = Q + m_2 c_p T_1$$

$$\Rightarrow m_2 [c_v - c_p] \times T_2 = Q$$

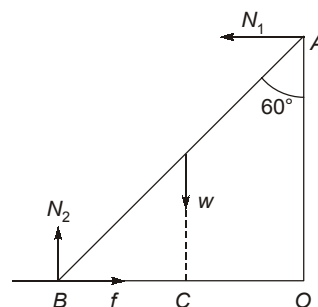
$$\Rightarrow Q = 0.59 \times [-0.287] \times 294$$

$$= -50 \text{ kJ} \quad (-\text{ve sign indicates that heat is lost to surroundings})$$

Q.161 A uniform ladder of weight 100 N leans against a smooth vertical wall making an angle of 60° with it. The other end rests on rough horizontal floor. The friction force that the floor exerts on ladder is _____ N.



161. (86.6)(85 to 87)



Now $N_1 = f$
 $N_2 = W$

Taking torque about B,

$$N_1 \times OA = W(CB)$$

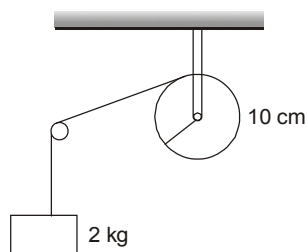
$$N_1 \times OA = W \left(\frac{AB}{2} \right) \times \sin 60^\circ$$

$$\Rightarrow N_1 \times AB \cos 60^\circ = \frac{W}{2} (AB) \sin 60^\circ$$

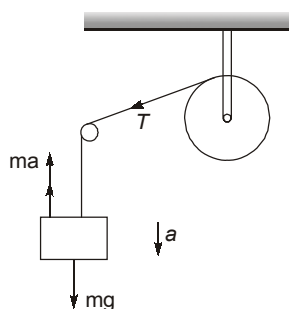
$$\Rightarrow N_1 = \frac{W}{2} \tan 60^\circ$$

$$f = N_1 = \frac{100}{2} \times \tan 60^\circ = 86.6 \text{ N}$$

Q.162 A string is wrapped on a wheel of moment of inertia 0.2 kgm^2 and radius 10 cm and goes through a light pulley to support a block of mass 2.0 kg as shown in figure. The acceleration of block is _____ m/s^2 .



162. (0.89)(0.87 to 0.91)



$$I = 0.2 \text{ kgm}^2$$

$$r = 0.1$$

$$m = 2 \text{ kg}$$

$$\therefore mg - T = ma$$

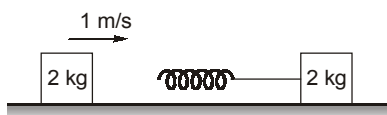
$$\text{Now } T = \frac{Ia}{r^2}$$

$$\Rightarrow mg = \left(m + \frac{I}{r^2}\right)a$$

$$\Rightarrow 2 \times 9.81 = \left(2 + \frac{0.2}{0.01}\right)a$$

$$\Rightarrow a = 0.89 \text{ m/s}^2$$

Q.163 A block of mass 2 kg is moving on a horizontal frictionless surface with velocity of 1 m/s , towards another block of equal mass kept at rest. The spring constant of the spring fixed at one end is 100 N/m . The maximum compression in the spring (in cm) is _____.



163. (10)

Mass of each block M_A and M_B is 2 kg .

Initially, $V_A = 1 \text{ m/s}$, $V_B = 0$

$K = 100 \text{ N/m}$

Let final velocity of both block is V and the compression in spring is x .

Since no external force acting, so applying conservation of momentum,

$$\Rightarrow M_A V_A + M_B V_B = (M_A + M_B) V$$

$$\Rightarrow 2 \times 1 = 4 \times V$$

$$\Rightarrow V = 0.5 \text{ m/s}$$

Using conservation of energy

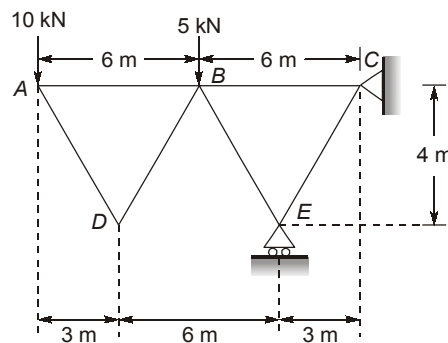
$$\Rightarrow \frac{1}{2} M_A V_A^2 = \frac{1}{2} (M_A + M_B) V^2 + \frac{1}{2} K x^2$$

$$\Rightarrow \frac{1}{2} \times 2 \times (1)^2 = \frac{1}{2} \times 4 \times (0.5)^2 + \frac{1}{2} \times 100 x^2$$

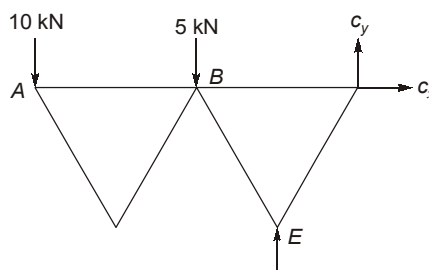
$$\Rightarrow x^2 = \frac{1}{100}$$

$$\Rightarrow x = 0.1 \text{ m} = 10 \text{ cm}$$

Q.164 The net reaction at C is _____ kN.



164. (35)



$$\Sigma M_c = 0$$

$$\Rightarrow 10 \times 12 + 5 \times 6 - E \times 3 = 0$$

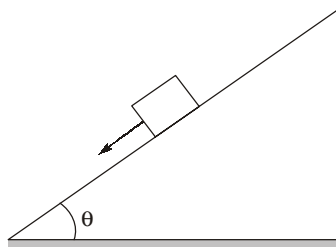
$$\Rightarrow E = 50 \text{ kN} \uparrow$$

$$\Sigma F_x = 0 = C_x$$

$$\Sigma F_y = 0 = -10 \text{ kN} - 5 \text{ kN} + 50 \text{ kN} + C_y$$

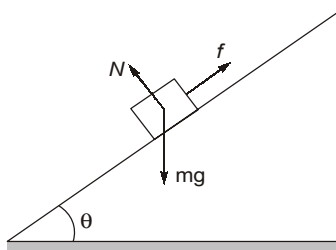
$$\Rightarrow C_y = -35 \text{ kN} \downarrow$$

Q.165 A block slides down an incline plane of angle 30° with an acceleration $\frac{g}{4}$. (Where g is acceleration due to gravity). The value of coefficient of kinematic friction is _____.



165. (0.2887)(0.28 to 0.30)

Taking components parallel to inclined plane.



$$\Rightarrow mg \sin 30^\circ - f = \frac{mg}{4}$$

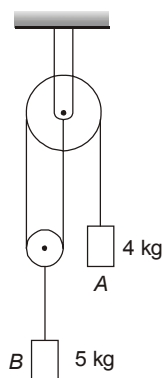
$$\text{or} \quad f = \frac{mg}{4} \quad \dots(1)$$

Components perpendicular to inclined plane.

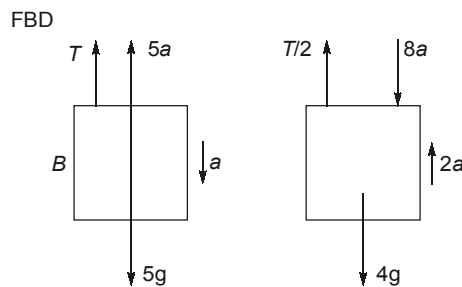
$$\Rightarrow N = mg \cos 30^\circ = mg \frac{\sqrt{3}}{2}$$

$$\text{Now,} \quad \mu = \frac{f}{N} = \frac{mg/4}{mg\sqrt{3}/2} = \frac{1}{2\sqrt{3}} = 0.2887$$

Q.166 The acceleration of block A in the given arrangement is _____ m/s^2 . (Take $g = 10 \text{ m/s}^2$)



166. (2.86)(2.85 to 2.87)



$$\Rightarrow 5a + T - 5g = 0$$

$$\Rightarrow T = 5g - 5a$$

...(1)

and $\frac{T}{2} - 4g - 8a = 0$

$$T = 8g + 16a$$

...(2)

From eq. (1) and (2), we get

$$\Rightarrow 5g - 5a = 8g + 16a$$

$$\Rightarrow a = -\frac{1}{7}g$$

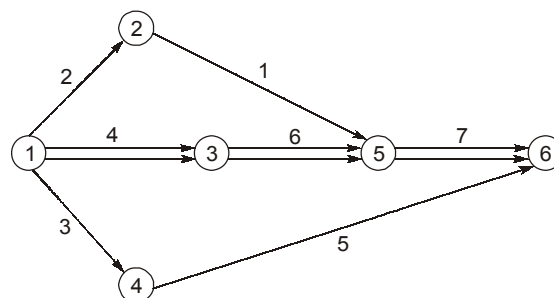
$$\therefore \text{of 4 kg mass, } 2a = \frac{2g}{7} = 2.86 \text{ m/s}^2$$

Q.167 The 2 time estimates (in weeks) and expected time for the activities of a PERT network are given below.

Activity	Optimistic time, t_o	Pessimistic time, t_p	Expected time
1-2	1	7	2
1-3	1	7	4
1-4	2	8	3
2-5	1	1	1
3-5	2	14	6
4-6	1	8	5
5-6	3	15	7

The standard deviation for the project is _____ weeks.

167. (3)(2.94 to 3.06)



Critical path 1 - 3 - 5 - 6

Variance of project, $V = V_{1-3} + V_{3-5} + V_{5-6}$

$$= \sum \left[\frac{t_p - t_0}{6} \right]^2 = \left[\frac{7-1}{6} \right]^2 + \left[\frac{14-2}{6} \right]^2 + \left[\frac{15-3}{6} \right]^2 = 1 + 4 + 4 = 9$$

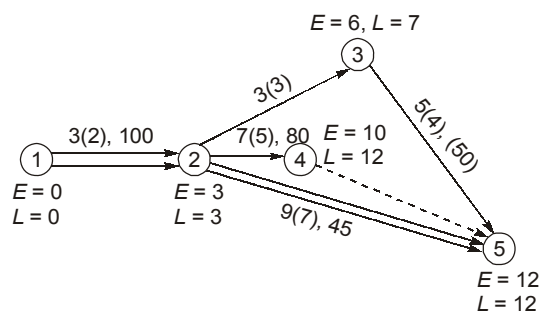
$$\sigma = \sqrt{9} = 3 \text{ weeks}$$

Q.168 The following table gives data on normal time and cost and crash time and cost for a project

Activity	Normal		Crash	
	Time (Weeks)	Cost (₹)	Time (Weeks)	Cost (₹)
1 - 2	3	300	2	400
2 - 3	3	30	3	30
2 - 4	7	420	5	580
2 - 5	9	720	7	810
3 - 5	5	250	4	300
4 - 5	0	0	0	0

Indirect costs are ₹ 50/week. The most optimum project cost (in ₹) is _____. (Crash relevant activities)

168. (2315)



Activity	Cost Slope
1 - 2	100
2 - 3	—
2 - 4	80
2 - 5	45
3 - 5	50
4 - 5	—

Critical path of project 1 - 2 - 5

Normal duration 12 week

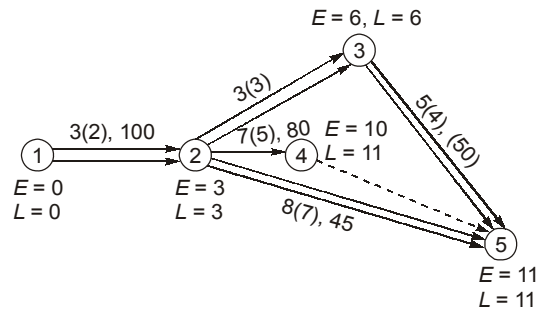
$$\text{Normal cost} = (300 + 30 + 420 + 720 + 250) + 12 \times 50 = 2320$$

Crash activity, 2 - 5 by, 1 week

Project duration = 11 weeks

Crash cost = ₹ 45

$$\text{Total cost} = 2320 + 45 - 50 = ₹ 2315$$



Now critical paths are 1 - 2 - 3 - 5 and 1 - 2 - 5

Now if we crash activity 2- 5 and activity 3 - 5 by one day then

Cumulative cost slope = 45 + 50 = ₹ 95

Which is greater than indirect cost per week so above solution is optimum.

Q.169 Consider the following:

Demand = 1000 units

Unit cost = ₹ 100

Order cost = ₹ 160 per order

Inventory carrying cost = ₹ 20 per unit per year

Back order cost = ₹ 10

Then what will be selling cost per unit for no profit and no loss condition.

- (a) ₹ 100 (b) ₹ 101.5
(c) ₹ 102.5 (d) ₹ 105

169. (b)

$$EOQ, Q = \sqrt{\frac{2DC_0}{C_h} \left(\frac{C_b + C_h}{C_b} \right)} = \sqrt{\frac{2 \times 1000 \times 160}{20} \left(\frac{10 + 20}{10} \right)} = 219 \text{ units}$$

$$\text{Maximum inventory level, } Q_m = Q \left(\frac{C_h}{C_b + C_h} \right) = 219 \left(\frac{10}{10 + 20} \right) = 73 \text{ units}$$

Overall total cost = material cost + carrying cost + ordering cost + shortage cost

$$\begin{aligned} &= C \times D + \frac{1}{2} \frac{Q_m^2}{Q} \times C_h + \frac{D}{Q} \times C_0 + \frac{(Q - Q_m)^2}{2Q} \times C_b \\ &= 100 \times 1000 + \frac{1}{2} \times \frac{73^2}{219} \times 20 + \frac{1000}{219} \times 160 + \frac{(219 - 73)^2}{2 \times 219} \times 10 \\ &= 101460.6 \end{aligned}$$

For no profit, No loss,

total sales = total cost

$$1000 \times \text{S.C.} = 101460.6$$

$$\Rightarrow \text{S.C.} = ₹ 101.46$$

Q.170 An item is produced at the rate of 50 items per day. The demand occurs at the rate of 25 items per day. If the set up cost is ₹ 100 per set up and holding cost is ₹ 0.01 per unit per day, minimum total cost for one run is ₹ _____. Assuming that shortages are not permitted.

170. (200)(196 to 204)

$$\begin{aligned} P &= 50 \text{ items per day} \\ C_0 &= ₹ 100 \text{ per set up} \\ D &= 25 \text{ items per day} \\ C_h &= ₹ 0.01 \text{ per unit per day} \end{aligned}$$

$$\begin{aligned} \text{Now, minimum cost} &= \sqrt{2DC_0C_h\left(\frac{P-D}{P}\right)} \\ &= \sqrt{2 \times 25 \times 100 \times 0.01 \left(\frac{50-25}{50}\right)} = ₹ 5 \text{ per day} \end{aligned}$$

$$Q^* = \sqrt{\frac{2 \times 25 \times 100}{0.01} \left(\frac{50}{50-25}\right)} = 1000 \text{ items}$$

$$\text{Cycle time} = \frac{Q^*}{D} = \frac{1000}{25} = 40$$

Therefore, minimum cost per run = $5 \times 40 = ₹ 200$

Q.171 A steel company faced the following demand for its products during past few months, presently, the company is using last year's corresponding monthly sales as this year forecast.

Month	Forecasted demand (in metric tons)	Actual demand (in metric tons)
July	21100	20000
August	23600	22000
September	22400	21000
October	27500	26500

The BIAS for the forecasted demand is _____.

171. (-1275)(-1280 to -1270)

For four period, $n = 4$

$$\text{Bias} = \frac{\sum_{t=1}^n (D_t - F_t)}{n} = \frac{\sum_{t=1}^n D_t - \sum_{t=1}^n F_t}{n}$$

$$\therefore \sum_{t=1}^n F_t = 21100 + 23600 + 22400 + 27500 = 94600 \text{ units}$$

$$\sum_{t=1}^n D_t = 20000 + 22000 + 21000 + 26500 = 89500 \text{ units}$$

$$\text{Bias} = \frac{89500 - 94600}{4} = -1275$$

Q.172 If the arrival and departure rates in a M/M/1 queue are 1/2 per minute and 2/3 per minute respectively. The average waiting time of a customer in the queue _____ minutes.

172. (4.5)

$$E(w_q) = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{1/2}{\frac{2}{3}\left(\frac{2}{3} - \frac{1}{2}\right)} = 4.5 \text{ minutes}$$

Q.173 A company manufacturing rivets, whose selling prices is ₹ 10 per packet. The variable costs are ₹ 8 per packet. If the annual fixed costs of the firm are estimated as ₹100000. If the firm has an estimated capacity of 80000 units of the rivet packets. The margin of safety

- (a) 50000 units (b) 30000 units
(c) 80000 units (d) 40000 units

173. (b)

$$\text{Break-even point units} = \frac{100000}{10 - 8} = 50000$$

$$\text{Capacity} = 80000$$

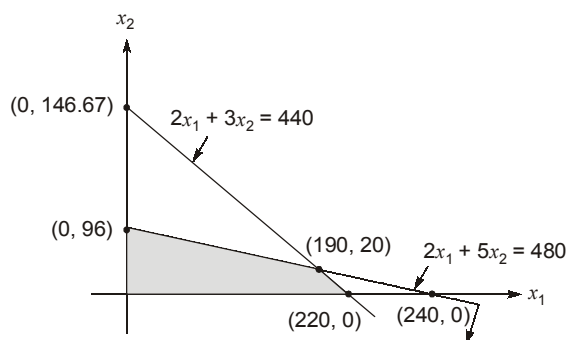
$$\text{Margin of safety} = 80000 - 50000 = 30000$$

Q.174 A firm produces two products. These products are processed on two different machines. The time required to manufacture each product and the daily capacity of each machine is given below:

Machine	Time per unit (minutes)		Machine capacity (minutes/day)
	Product 1	Product 2	
M_1	2	3	440
M_2	2	5	480

The profit per unit for product 1 and 2 is ₹ 4, ₹ 3 respectively. The maximum daily profit will be _____ ₹.

174. (880)



x_1 be units of Product 1

x_2 be units of Product 2

Objective maximize $Z = 4x_1 + 3x_2$

Constraints $x_1, x_2 \geq 0$
 $2x_1 + 3x_2 \leq 440$
 $2x_1 + 5x_2 \leq 480$

Solution of $2x_1 + 3x_2 = 440$
 $2x_1 + 5x_2 = 480$

is $x_1 = 190; x_2 = 20$
 $z_1 = 4 \times 190 + 3 \times 20 = 820$

other solution $x_2 = 0; x_1 = 220$
 $z_2 = 4 \times 220 = 880$

and $x_1 = 0; x_2 = \frac{480}{5} = 96$
 $z_3 = 96 \times 3 = 288$

Now $z_{\max} = z_2 = 880$

Q.175 A machine operator has to perform two operations, turning and threading, on a number of different jobs. The processing time for these jobs is

Job	Turning (minutes)	Threading (minutes)
1	3	8
2	12	10
3	5	9
4	2	6
5	9	3
6	11	1

The optimal make span time (in minutes) for the shop is _____.

175. (43)

Using Johnson's rule the optimal sequence is:

4 1 3 2 5 6

Job	Turning		Threading	
	In	Out	In	Out
4	0	2	2	8
1	2	5	8	16
3	5	10	16	25
2	10	22	25	35
5	22	31	35	38
6	31	42	42	43

Optimal MST = 43 min

■■■■



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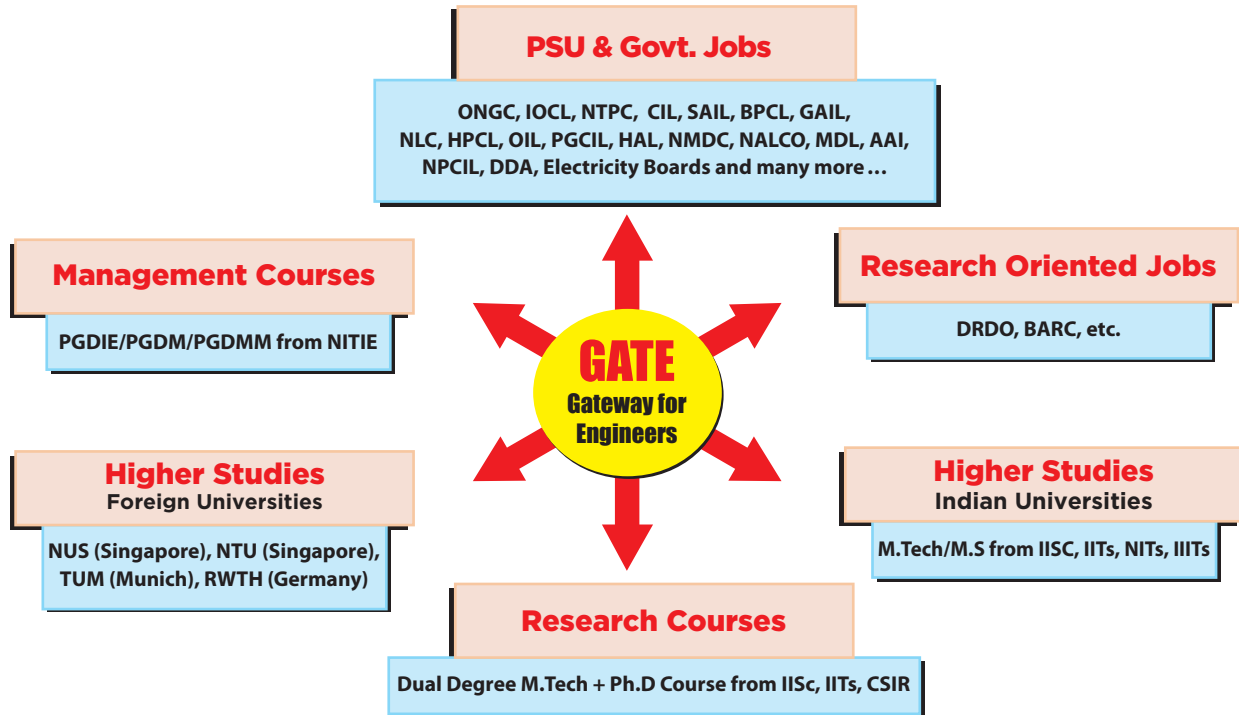
Revision through Questions for GATE 2020

ME

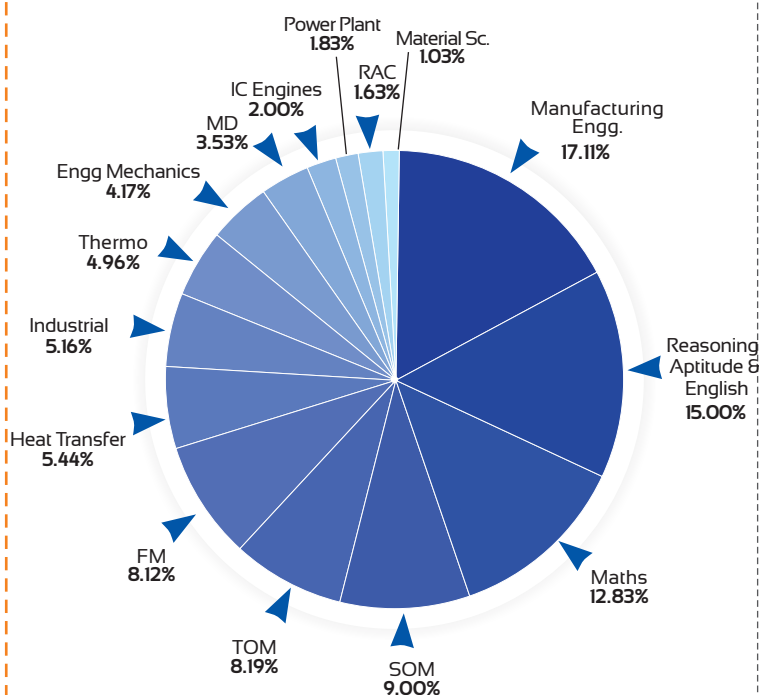
MECHANICAL ENGG.

Q.176 - Q.200
out of 200 Questions

Day 8 of 8



SUBJECTWISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	17.11%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.83%
Strength of Materials	9.00%
Theory of Machines	8.19%
Fluid Mechanics & Fluid Machines	8.12%
Heat Transfer	5.44%
Industrial Engineering	5.16%
Thermodynamics	4.96%
Engineering Mechanics	4.17%
Machine Design	3.53%
Internal Combustion Engines	2.00%
Power Plant Engineering	1.83%
Refrigeration & Air Conditioning	1.63%
Material Science	1.03%
Total	100%

Day 8 : Q.176 to Q.200 : Mechanical Engineering

- Q.176** In a gas turbine power plant, temperature of air at entry to combustion chamber is 670 K. Maximum cycle temperature is 1173 K. If the calorific value of fuel is 40800 kJ/kg and combustion efficiency is 95%. What is the air-fuel ratio of this power plant? Take $C_p = 1.005$ kJ/kgK
- (a) 74.34 (b) 83.5
(c) 97.2 (d) 69.8

176. (a)

Given: $T_3 = 1173$ K; $T_2 = 670$ K

Energy balance in combustion chamber

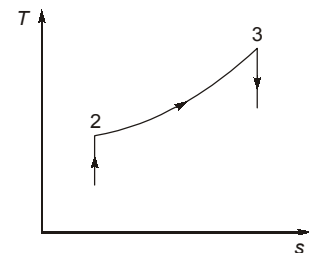
$$M_a c_p T_2 + m_f \times C_v \times \eta = (m_a + m_f) \times c_{pg} \times T_3$$

$$\frac{m_a}{m_f} c_p T_2 + \eta \times C_v = \left(\frac{m_a}{m_f} + 1 \right) c_{pg} \times T_3$$

Let $\frac{m_a}{m_f} = x$

$$x \times 1.005 \times 670 + 0.95 \times 40800 = (x + 1) \times 1.005 \times 1173$$

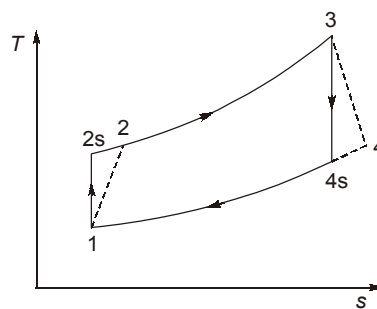
Solving for x , we have $x = 74.34$



- Q.177** In a gas turbine plant, working on Brayton cycle, the air at inlet to the compressor is at 0.1 MPa, 30°C, the pressure ratio is 6 and the maximum cycle temperature is 900°C. The ratio of specific heat of working fluid is 1.4. If the turbine and compressor have each an efficiency of 80%. The approximate final temperature in Kelvin at the end of compression and expansion processes are respectively
- (a) 505, 705 (b) 555, 797
(c) 465, 798 (d) 465, 705

177. (b)

Pressure ratio, $r_p = 6$



$$T_1 = 30 + 273 = 303 \text{ K}$$

$$\Rightarrow \frac{T_{2s}}{T_1} = (r_p)^{\gamma-1/\gamma} = 6^{0.4/1.4} = 1.668$$

$$\Rightarrow T_{2s} = 303 \times 1.668 = 505 \text{ K}$$

$$\text{Now, } (T_2 - T_1) = \frac{T_{2s} - T_1}{\eta_c} = \frac{505 - 303}{0.8}$$

$$\begin{aligned} \Rightarrow T_2 - T_1 &= 252.5 \text{ K} \\ T_2 &= 252.5 + 303 = 555.5 \text{ K} \\ \Rightarrow T_3 &= 900 + 273 = 1173 \text{ K} \\ \Rightarrow \frac{T_3}{T_{4s}} &= (r_p)^{\gamma-1/\gamma} = 6^{0.4/1.4} = 1.668 \\ \Rightarrow T_{4s} &= \frac{1173}{1.668} = 703 \text{ K} \end{aligned}$$

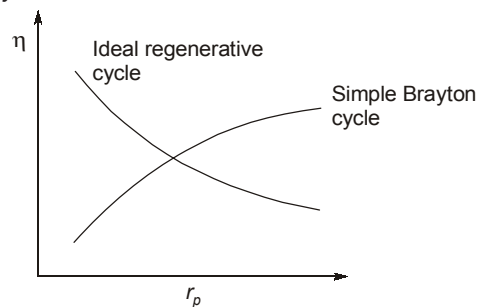
$$\begin{aligned} \text{Now, } T_3 - T_4 &= \eta_T (T_3 - T_{4s}) = 0.8(1173 - 703) \\ \Rightarrow 1173 - T_4 &= 376 \text{ K} \\ \Rightarrow T_4 &= 797 \text{ K} \end{aligned}$$

Q.178 For a simple Brayton cycle with ideal regenerator, the ratio of maximum cycle temperature to minimum cycle temperature is constant. With increase in pressure ratio, cycle efficiency.

- (a) Increases (b) Decreases
(c) No change (d) Increases but work output of the cycle decreases

178. (b)

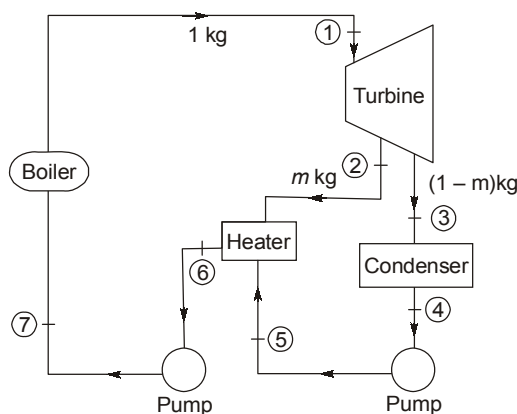
For ideal regeneration cycle



$$\eta = 1 - \left[\frac{T_{\min}}{T_{\max}} \right] (r_p)^{\gamma-1/\gamma}$$

Hence as r_p increases, η decreases.

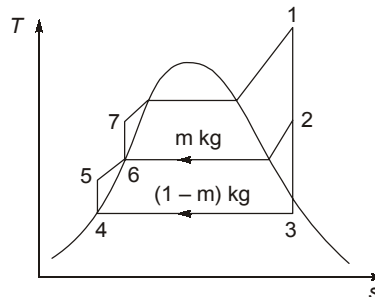
Q.179 A thermal power plant operates on a regenerative cycle with a single direct contact type feed water heater. For the state points shown, the specific enthalpies are $h_1 = 3230.9 \text{ kJ/kg}$; $h_2 = 2796 \text{ kJ/kg}$; $h_3 = 2192.2 \text{ kJ/kg}$; $h_4 = 191.83 \text{ kJ/kg}$; $h_6 = 640.23 \text{ kJ/kg}$.



What is the regenerative cycle efficiency? (Neglect pump work)

- (a) 27.8 % (b) 40.2 %
(c) 31.8 % (d) 36.1 %

179. (d)



Neglecting pump work,

$$h_4 = 191.83 = h_5$$

$$h_6 = 640.23 = h_7$$

Energy balance for heater gives,

$$m(h_2 - h_6) = (1 - m)(h_6 - h_5)$$

$$\Rightarrow m(2796 - 640.23) = (1 - m)(640.23 - 191.83)$$

$$\Rightarrow 2155.77 m = 448.4 - 448.4 m$$

$$\Rightarrow m = 0.172$$

$$W_T = (h_1 - h_2) + (1 - m)(h_2 - h_3)$$

$$= (3230.9 - 2796) + (1 - 0.172)(2796 - 2192.2) = 934.85 \text{ kJ/kg}$$

$$Q_1 = h_1 - h_6 = 3230.9 - 640.23 = 2590.67 \text{ kJ/kg}$$

$$\Rightarrow \eta_b = \frac{W_T}{Q} = \frac{934.85}{2590.67} = 0.3608 \approx 36.1 \%$$

Q.180 The fraction of proeutectoid cementite in 1.4 % carbon steel is

- (a) 0.29 (b) 0.37
(c) 0.08 (d) 0.10

180. (d)

Eutectoid is made of 0.8 % C, in iron-iron carbide diagram.

$$\text{Proeutectoid cementite} = \frac{1.4 - 0.8}{6.67 - 0.8} = 0.1022 \approx 0.10$$

Q.181 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

- A. Annealing
B. Nitriding
C. Martempering
D. Normalising

List-II

1. Refined grain structure
2. Improve the hardness of whole mass
3. Increase surface hardness
4. Improve ductility

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	3	4	2
(c)	4	2	1	3
(d)	2	1	3	4

181. (a)

Q.182 Consider the following statements:

1. Molybdenum decreases the susceptibility of temper embrittlement in steel.
2. BCC and HCP crystal structures are most susceptible to hydrogen embrittlement.
3. Hydrogen embrittlement is decreased by slow strain rates.

Which of the above statements are correct?

- | | |
|-------------|----------------|
| (a) 1 and 2 | (b) 3 only |
| (c) 2 and 3 | (d) 1, 2 and 3 |

182. (a)

- Temper embrittlement may occur when steels are slowly cooled after tempering through the temperature range between 450°C to 550°C.
- This is due to the segregation of impurities such as phosphorous, arsenic, antimony and tin on the grain boundaries.
- The molybdenum atom is very large relative to other alloying elements and impurities. It effectively impedes the migration of those elements and thereby provides resistance to temper embrittlement.
- Due to crystallographic cleavage in BCC and HCP it is most susceptible to hydrogen embrittlement.
- Hydrogen tends to preferentially accumulate on specific boundaries during tensile deformation at slow strain rates.

On the other hand, in case of higher strain rate, hydrogen distributed uniformly because there was no enough time for hydrogen to accumulate on specific site.

Q.183 Identify the incorrect statement/s related to TTT diagram

1. Retained martensite appears in case of hypoeutectoid steel
2. It is non equilibrium diagram only for eutectoid composition
3. Incubation period does not depend upon alloy content

- | | |
|-------------|----------------|
| (a) 1 and 2 | (b) 1 and 3 |
| (c) 2 only | (d) 1, 2 and 3 |

183. (d)

Q.184 A thin cylindrical shell of 1.2 m diameter is subjected to an internal pressure of 1.5 MN/m². If material yields at 200 MN/m². Thickness of shell according to Von Mises Theory is _____ mm.

Consider FOS = 3. Take cylinder closed at ends.

184. (11.7)(11.5 to 11.9)

$$\text{Circumferential stress, } \sigma_c = \frac{Pd}{2t} = \frac{1.5 \times 1.2}{2t} = \frac{0.9}{t} \text{ MN/m}^2 = \sigma_1$$

$$\text{Longitudinal stress, } \sigma_l = \frac{Pd}{4t} = \frac{1.5 \times 1.2}{4t} = \frac{0.45}{t} \text{ MN/m}^2 = \sigma_2$$

According to Von Mises Theory,

$$\Rightarrow \sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 = \sigma^2$$

$$\Rightarrow \left[\frac{0.9}{t} \right]^2 + \left[\frac{0.45}{t} \right]^2 - \left[\frac{0.9}{t} \right] \left[\frac{0.45}{t} \right] = \left[\frac{200}{3} \right]^2$$

$$\Rightarrow \frac{0.6075}{t^2} = 4444.44$$

$$\Rightarrow t^2 = 1.367 \times 10^{-4}$$

$$\Rightarrow t = 0.0117 \text{ m}$$

$$\Rightarrow t = 11.7 \text{ mm}$$

Q.185 A weight of 200 N is dropped on to a helical spring of 15 mm diameter wire. Mean diameter of spring is 120 mm and number of coils in the spring is 20. The height of drop if instantaneous compression is 80 mm will be _____ mm. (Take $G_{\text{spring}} = 84 \text{ GN/m}^2$)

185. (166)(164 to 168)

Let gradually applied load which produces same deflection be W .

$$\text{We know, } \delta = \frac{64WR^3n}{Gd_w^4}$$

$$d_w = 0.015 \text{ m}$$

$$R = \frac{D}{2} = 0.06 \text{ m}$$

$$n = 20$$

$$\delta = 0.08$$

$$G = 84 \times 10^9$$

$$\Rightarrow 0.08 = \frac{64W \times 0.06^3 \times 20}{84 \times 10^9 \times [0.015]^4}$$

On solving, we get

$$W = 1230 \text{ N}$$

Energy supplied by impact = Energy stored by gradually applied load

$$\Rightarrow P[h + \delta] = \frac{1}{2} W \delta$$

$$\Rightarrow 200[h + 0.08] = \frac{1}{2} \times 1230 \times 0.08$$

$$\Rightarrow h + 0.08 = 0.246$$

$$\Rightarrow h = 0.166 \text{ m} = 166 \text{ mm}$$

Q.186 A bar of length 4 m when used as a simply supported beam and subjected to a UDL of 30 kN/m over the whole span, deflects 15 mm at the centre. The crippling load when it is used as a column with one end fixed and other hinged will be _____ kN.

186. (8224.6)(8223 to 8225)

Length of bar, $l = 4$

$$w = 30 \text{ kN/m}$$

$$\delta = 15 \text{ mm} = 0.015 \text{ m}$$

We know,
$$\delta = \frac{5}{384} \frac{wl^4}{EI}$$

$$\Rightarrow EI = \frac{5}{384} \frac{wl^4}{\delta} = \frac{5}{384} \times \frac{30 \times 1000 \times 4^4}{0.015}$$

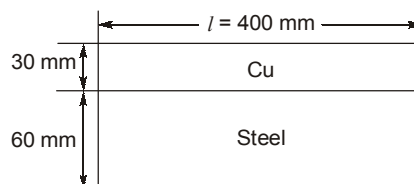
$$= 6.66 \times 10^6 \text{ Nm}^2$$

$$P_{\text{euler}} = \frac{2\pi^2 EI}{l^2} = \frac{2 \times \pi^2 \times 6.66 \times 10^6}{4^2} \times 10^{-3} \text{ kN}$$

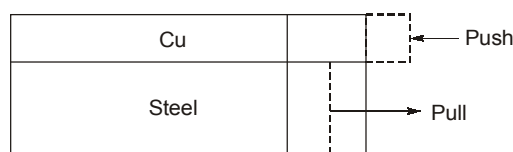
$$= 8224.6 \text{ kN}$$

Q.187 A copper flat measuring 60 mm × 30 mm is brazed to another 60 mm × 60 mm mild steel flat. Combination is heated by 120°C. Then the value of shear force that tends to rupture the brazing is _____ kN.

Take: $\alpha_{\text{cu}} = 18.5 \times 10^{-6}/^\circ\text{C}$; $\alpha_{\text{steel}} = 12 \times 10^{-6}/^\circ\text{C}$; $E_{\text{cu}} = 110 \text{ GN/m}^2$; $E_{\text{steel}} = 220 \text{ GN/m}^2$



187. (123.5)(122 to 125)



Sum of strain,

$$\Rightarrow \epsilon_{cu} + \epsilon_{steel} = [\alpha_{cu} - \alpha_{steel}] \Delta T$$

$$\Rightarrow \frac{\sigma_{cu}}{E_{cu}} + \frac{\sigma_s}{E_s} = [18.5 - 12] \times 10^{-6} \times 120 \quad \left[\because \epsilon = \frac{\sigma}{E} \right]$$

$$\Rightarrow \frac{\sigma_{cu}}{110 \times 10^9} + \frac{\sigma_s}{220 \times 10^9} = 6.5 \times 10^{-6} \times 120$$

$$\Rightarrow 2\sigma_{cu} + \sigma_s = 171.6 \times 10^6 \quad \dots(1)$$

Pull on steel = Push of copper

$$\Rightarrow \sigma_s A_s = \sigma_{cu} A_{cu}$$

$$\Rightarrow \sigma_s \times 60 \times 60 \times 10^{-6} = \sigma_{cu} \times 30 \times 60 \times 10^{-6}$$

$$\Rightarrow \sigma_s = 0.5 \sigma_{cu} \quad \dots(2)$$

On solving equations (1) and (2) we get,

$$\Rightarrow \sigma_s = 34.32 \times 10^6 \text{ N/m}^2$$

$$\begin{aligned} \text{Shear force} &= \sigma_s \times A_s \\ &= 34.32 \times 10^6 \times 60 \times 60 \times 10^{-6} \\ &= 123552 \text{ N} = 123.5 \text{ kN} \end{aligned}$$

Q.188 What will be the dimensions of the strongest section that can be cut out of a circular log of wood 25 cm in diameter?

$b \rightarrow$ breadth; $d \rightarrow$ depth

(a) $b = 20.41 \text{ cm}$; $d = 14.4 \text{ cm}$

(b) $b = 15 \text{ cm}$; $d = 20 \text{ cm}$

(c) $b = 20 \text{ cm}$; $d = 15 \text{ cm}$

(d) $b = 14.4 \text{ cm}$; $d = 20.41 \text{ cm}$

188. (d)

From the given figure,

$$\Rightarrow b^2 + d^2 = (25^2)$$

$$\Rightarrow d^2 = 625 - b^2 \quad \dots(1)$$

Now for the strongest section, section modulus Z must be maximum.

$$\Rightarrow Z = \frac{I}{Y} = \frac{bd^3}{12 \times d/2} = \frac{bd^2}{6}$$

$$\Rightarrow = \frac{b}{6} (625 - b^2) = \frac{625}{6} b - \frac{b^3}{6}$$

$$\text{For } Z_{\max} \quad \frac{dZ}{db} = 0$$

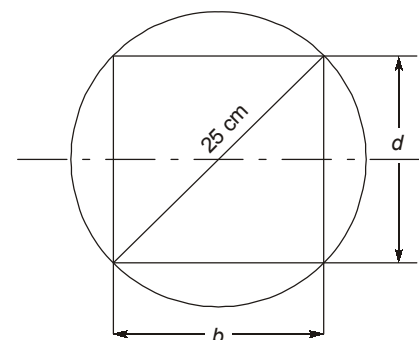
$$\Rightarrow \frac{625}{6} - \frac{3b^2}{6} = 0$$

$$\Rightarrow b^2 = \frac{625}{3}$$

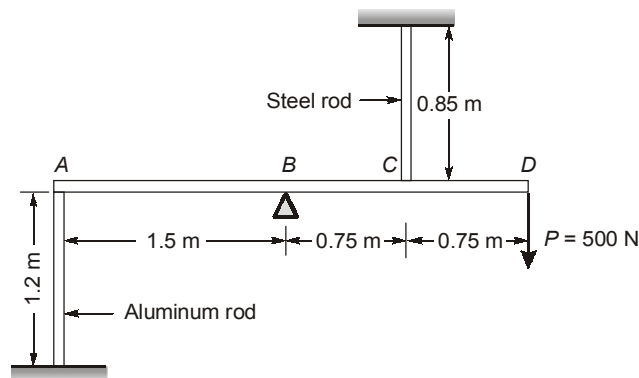
$$\Rightarrow b = 14.4 \text{ cm}$$

From equation (1)

$$\Rightarrow d = 20.41 \text{ cm}$$



Q.189

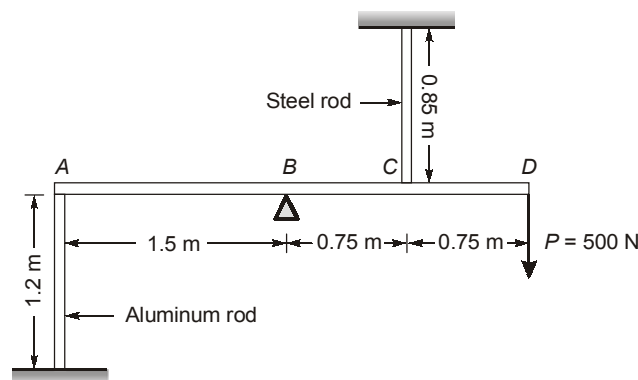


A rigid bar $ABCD$ pinned at B and connected to two vertical rods as shown in figure. Assuming the bar initially horizontal and rods stress free. Determine the value of load in each bar if $P = 500$ N is applied on end D .

Take $E_{\text{steel}} = 200 \text{ GN/m}^2$; $E_{\text{Al}} = 100 \text{ GN/m}^2$; Cross-section area of steel bar = 200 mm^2 ;
Cross-section area of aluminium bar = 300 mm^2

- (a) $P_S = 333 \text{ N}$; $P_{\text{Al}} = 333.33 \text{ N}$ (b) $P_S = 100 \text{ N}$; $P_{\text{Al}} = 450 \text{ N}$
(c) $P_S = 320 \text{ N}$; $P_{\text{Al}} = 340 \text{ N}$ (d) $P_S = 300 \text{ N}$; $P_{\text{Al}} = 200 \text{ N}$

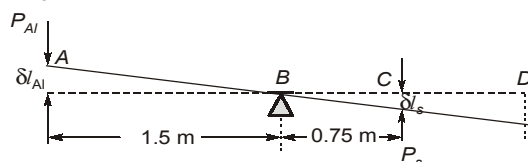
189. (c)



At equilibrium about B ,

$$P_{\text{Al}} \times 1.5 + P_S \times 0.75 = P \times 1.5 = 500 \times 1.5$$

$$\Rightarrow 2P_{\text{Al}} + P_S = 1000 \quad \dots(1)$$



Let the deflection in steel rod and deflection in Aluminium rod be δl_s and δl_{Al} respectively,
From above figure,

$$\Rightarrow \frac{\delta l_s}{0.75} = \frac{\delta l_{\text{Al}}}{1.5}$$

$$\Rightarrow \delta l_s = 0.5 \delta l_{\text{Al}}$$

$$\Rightarrow \frac{P_s l_s}{A_s E_s} = 0.5 \left[\frac{P_{Al} l_{Al}}{A_{Al} \times E_{Al}} \right] \quad \left[\because \delta l = \frac{Pl}{AE} \right]$$

$$\Rightarrow \frac{P_s \times 0.85}{200 \times 10^{-6} \times 200 \times 10^9} = 0.5 \times \frac{P_{Al} \times 1.2}{300 \times 10^{-6} \times 100 \times 10^9}$$

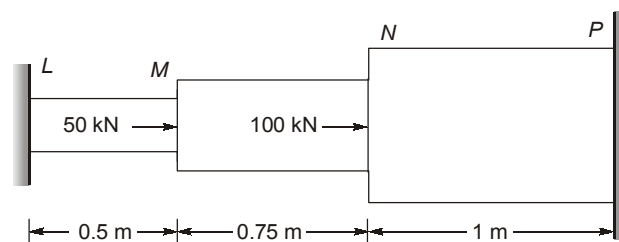
$$\Rightarrow P_s = \frac{P_{Al}}{1.0625} \quad \dots(2)$$

On solving eqn. (1) and eqn. (2) we get,

$$\Rightarrow P_{Al} = 340 \text{ N}$$

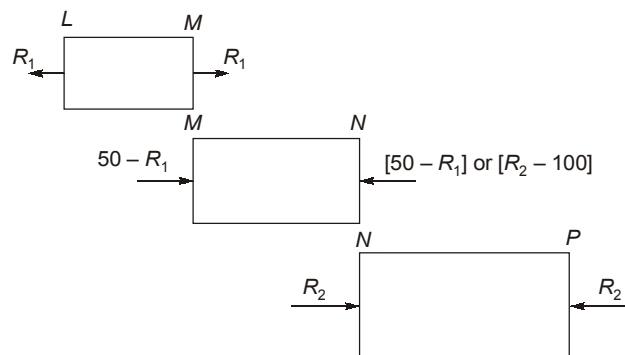
$$\Rightarrow P_s = 320 \text{ N}$$

Q.190 In the below figure if end supports are non yielding. What is value of stress in section NP?
Take Area of cross-section $A_{LM} = 1000 \text{ mm}^2$; $A_{MN} = 1500 \text{ mm}^2$; $A_{NP} = 2000 \text{ mm}^2$.



- (a) 41.66 MN/m² (b) 70.67 MN/m²
(c) 83.33 MN/m² (d) 106.67 MN/m²

190. (a)



From FBD, $50 - R_1 = R_2 - 100$
 $\Rightarrow R_1 + R_2 = 150 \quad \dots(1)$

Since end supports are rigid,

Extension in LM = Contraction in MN and NP

$$\Rightarrow \delta l_1 = \delta l_2 + \delta l_3$$

$$\Rightarrow \frac{P_1 l_1}{EA_1} = \frac{P_2 l_2}{EA_2} + \frac{P_3 l_3}{EA_3}$$

Here subscript 1, 2, 3 denotes section LM, MN, NP respectively.

$$\Rightarrow \frac{R_1 \times 0.5}{1000 \times 10^{-6}} = \frac{[50 - R_1] \times 0.75}{1500 \times 10^{-6}} + \frac{R_2 \times 1}{2000 \times 10^{-6}}$$

$$\Rightarrow R_1 - 0.5 R_2 = 25 \quad \dots(2)$$

On solving eqn. (1) and (2) we get,

$$\Rightarrow R_2 = 83.33 \text{ kN}$$

$$\Rightarrow \sigma_{NP} = \frac{R_2}{A_{NP}} = \frac{83.33}{2000 \times 10^{-6}} = 41.66 \times 10^3 \text{ kN/m}^2$$

$$\Rightarrow \sigma_{NP} = 41.66 \text{ MN/m}^2$$

Q.191 A shaft is subjected to a maximum torque of 10 kNm and a maximum bending moment of 7.5 kNm at a particular section. If allowable equivalent stress in simple tension is 160 MN/m². The diameter of the shaft according to Maximum Shear Stress Theory will be _____ mm.

191. (92.6)(91 to 94)

Principal stress in combined bending and torsion are,

$$\sigma_1 = \frac{16}{\pi d^3} [M + \sqrt{M^2 + T^2}]$$

$$\sigma_2 = \frac{16}{\pi d^3} [M - \sqrt{M^2 + T^2}]$$

According to Maximum Shear Stress Theory,

$$\begin{aligned} \sigma_{YT} &= \sigma_1 - \sigma_2 \\ &= \frac{16}{\pi d^3} [M + \sqrt{M^2 + T^2}] - \frac{16}{\pi d^3} [M - \sqrt{M^2 + T^2}] \\ &= \frac{32}{\pi d^3} \sqrt{M^2 + T^2} \end{aligned}$$

$$\Rightarrow d^3 = \frac{32}{\pi \sigma_{YT}} \sqrt{M^2 + T^2}$$

Putting the given values and solving

$$d^3 = \frac{32 \times 10^3}{\pi \times 160 \times 10^6} \sqrt{7.5^2 + 10^2} = 7.957 \times 10^{-4}$$

$$\Rightarrow d = 0.0926 \text{ m} = 92.6 \text{ mm}$$

Q.192 A boiler shell is to be made of 15 mm thick plate having tensile stress of 120 MN/m². If the efficiencies of longitudinal and circumferential joints are 70% and 30% respectively. Maximum permissible diameter of thin shell for an internal pressure of 2 MN/m² is _____ m.

192. (1.08)(1.05 to 1.10)

Let the maximum permissible diameter be d ,

Consider circumferential stress as 120 MN/m²,

$$\sigma_c = \frac{Pd}{2t\eta_l}$$

$$\Rightarrow 120 \times 10^6 = \frac{2 \times 10^6 \times d}{2 \times 15 \times 10^{-3} \times 0.7}$$

$$\Rightarrow d = 1.26 \text{ m}$$

Consider longitudinal stress as 120 MN/m^2 ,

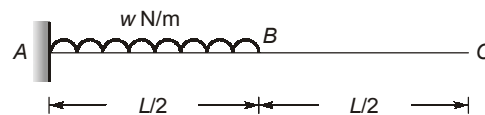
$$\Rightarrow \sigma_l = \frac{Pd}{4t\eta_c}$$

$$\Rightarrow 120 \times 10^6 = \frac{2 \times 10^6 \times d}{4 \times 15 \times 10^{-3} \times 0.3}$$

$$\Rightarrow d = 1.08 \text{ m}$$

To satisfy both conditions, we will consider minimum of the two values i.e., $d = 1.08 \text{ m}$.

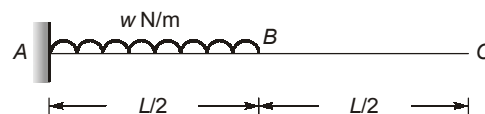
Q.193 A cantilever beam of length L is carrying uniformly distributed load of $w \text{ N/m}$ upto half length from fixed end. The deflection of beam at free end is $\frac{awL^4}{EI}$. Where E is Young's modulus, then the value of a is



- (a) 0.018
(c) 0.384

- (b) 0.081
(d) 0.058

193. (a)



$$\delta_B = \frac{w \times \left(\frac{L}{2}\right)^4}{8EI} = \frac{wL^4}{128EI}$$

Now,

$$\delta_C = \delta_B + \theta_B \times (CB)$$

$$\theta_B = \frac{w \left(\frac{L}{2}\right)^3}{6EI} = \frac{wL^3}{48EI}$$

So,

$$\delta_C = \frac{wL^4}{128EI} + \frac{wL^3}{48EI} \times \frac{L}{2} = \frac{7wL^4}{384EI}$$

Hence,

$$a = \frac{7}{384} = 0.01823$$

Q.194 A thin cylinder of 150 mm internal diameter and 5 mm thickness is subjected to an internal pressure of 15 MPa and a torque of 30 kNm. The magnitude of maximum in plane shear stress is _____ MPa.

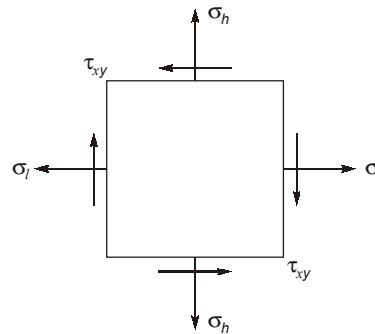
194. (178.84)(176 to 180)

$$\sigma_h = \frac{pd}{2t} = \frac{15 \times 150}{2 \times 5} = 225 \text{ MPa}$$

$$\sigma_l = \frac{pd}{4t} = \frac{15 \times 150}{4 \times 5} = 112.5 \text{ MPa}$$

$$\tau_{xy} = \frac{T}{z_p} = \frac{30000 \times 10^3}{\frac{\pi}{2}(150)^2 \times 5} = 169.76 \text{ MPa}$$

State of stress,

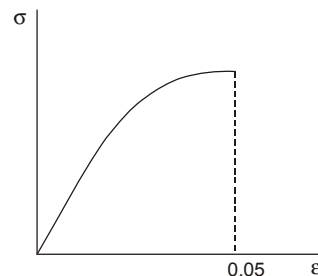


$$\sigma_{1,2} = \frac{\sigma_l + \sigma_h}{2} \pm \sqrt{\left(\frac{\sigma_l - \sigma_h}{2}\right)^2 + \tau_{xy}^2} = 168.75 \pm 178.84$$

$$\Rightarrow \sigma_1 = 347.59 \text{ MPa}; \sigma_2 = -10.09 \text{ MPa}$$

$$\text{In plane, } \tau_{\max} = \frac{\sigma_1 - \sigma_2}{2} = 178.84 \text{ MPa}$$

Q.195 The equation of stress strain curve is $(\sigma + 1)^2 = 4\epsilon + 1$. The modulus of toughness _____ $\times 10^{-3}$.



195. (2.422)(2.42 to 2.45)

$$\text{MOT} = \int \sigma d\epsilon = \int_0^{0.05} (\sqrt{4\epsilon + 1} - 1) d\epsilon$$

Let $4\epsilon + 1 = t, 4d\epsilon = dt$

$$\text{MOT} = \frac{1}{4} \int_1^{1.2} (\sqrt{t} - 1) dt = \frac{1}{4} \left(\frac{t^{3/2}}{3/2} - t \right)_1^{1.2}$$

$$\text{MOT} = 2.422 \times 10^{-3}$$

Hence, answer is 2.422.

Q.196 A thin walled tube of outer radius R is subjected to pure torque T . If the length of the tube is L , the maximum shear stress is $\tau_{\max}$ and the specific weight of material is γ , then the approximate expression for the strength-weight ratio (T/W) of such tube will be?

- (a) $\frac{2R\tau_{\max}}{L\gamma}$ (b) $\frac{R\tau_{\max}}{L\gamma}$
(c) $\frac{R\tau_{\max}}{2L\gamma}$ (d) $\frac{3R\tau_{\max}}{2L\gamma}$

196. (b)

Outer radius = R

Inner radius = $R - t$

So, Approximate polar moment of inertia

$$J = 2\pi R^3 t$$

Now, we know, $\frac{T}{J} = \frac{\tau}{r}$

For $\tau_{\max}$, $r = R$

$$\text{So, } T = \frac{\tau_{\max} J}{R} = 2\pi R^2 t \tau_{\max}$$

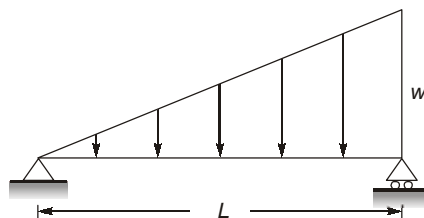
Now, weight of tube (W) = γLA , where A is the cross-section area,

$$\text{So, } A \approx 2\pi R t$$

$$\text{So, } W = 2\pi R t L \gamma$$

$$\therefore \frac{T}{W} = \frac{2\pi R^2 t \tau_{\max}}{2\pi R t L \gamma} = \frac{R \tau_{\max}}{L \gamma}$$

Q.197 The maximum bending moment will be



- (a) $\frac{WL}{3}$ (b) $\frac{2WL}{9\sqrt{3}}$
(c) $\frac{WL}{4}$ (d) $\frac{WL}{9\sqrt{3}}$

(where, W is the total load)

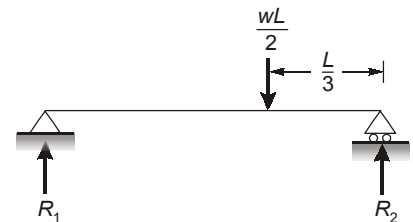
197. (b)

$$\Sigma V = 0 \Rightarrow R_1 + R_2 = \frac{wL}{2}$$

$$\Sigma M = 0 \Rightarrow \frac{wL}{2} \times \frac{2L}{3} = R_2 \times L$$

$$\text{So, } R_2 = \frac{wL}{3}$$

$$R_1 = \frac{wL}{2} - \frac{wL}{3} = \frac{wL}{6}$$



Bending moment at x distance from left end,

$$BM_x = \frac{wLx}{6} - \frac{wx^2}{2L} \times \frac{x}{3} = \frac{wLx}{6} - \frac{wx^3}{6L} \quad \dots(i)$$

For maximum BM, $\frac{dBM_x}{dx} = 0$

$$\text{So, } \frac{wL}{6} - \frac{3wx^2}{6L} = 0$$

$$\Rightarrow, \quad x^2 = \frac{wL}{6} \times \frac{6L}{3w} = \frac{L^2}{3}$$

$$\Rightarrow \quad x = \frac{L}{\sqrt{3}}$$

So, from equation (i),

$$(BM)_{\max} = \frac{wL}{6} \times \frac{L}{\sqrt{3}} - \frac{w}{6L} \times \frac{L^3}{\sqrt{3} \times \sqrt{3} \times \sqrt{3}} = \frac{wL^2}{6\sqrt{3}} - \frac{wL^2}{18\sqrt{3}} = \frac{2wL^2}{18\sqrt{3}} = \frac{wL^2}{9\sqrt{3}} \quad \dots(ii)$$

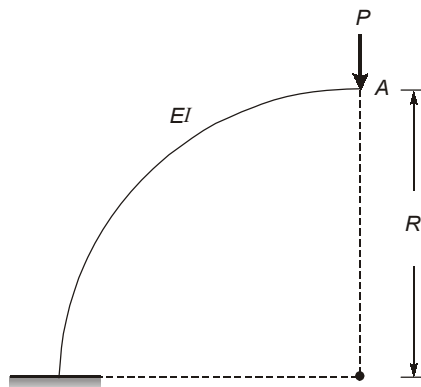
$$\text{Now, } \frac{1}{2} \times w \times L = W$$

$$\Rightarrow \quad wL = 2W$$

Substituting in (ii),

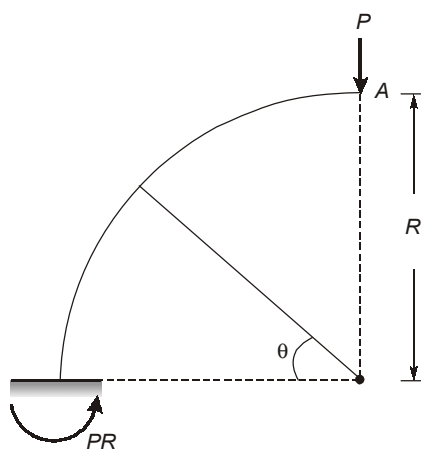
$$\text{So, } (BM)_{\max} = \frac{2WL}{9\sqrt{3}}$$

Q.198 The vertical displacement at point A will be



- (a) $\frac{\pi PR^3}{3EI}$ (b) $\frac{\pi PR^3}{4EI}$
(c) $\frac{\pi PR^3}{EI}$ (d) $\frac{\pi PR^3}{2EI}$

198. (b)



$$M = PR \cos \theta$$

$$\frac{\partial M}{\partial P} = R \cos \theta$$

Now,

$$\delta_v = \frac{\partial U}{\partial P} \quad (\text{where } U = \text{strain energy})$$

$$\frac{\partial U}{\partial P} = \int_0^{\pi/2} \frac{2M \times \left(\frac{\partial M}{\partial P} \right) R d\theta}{2EI}$$

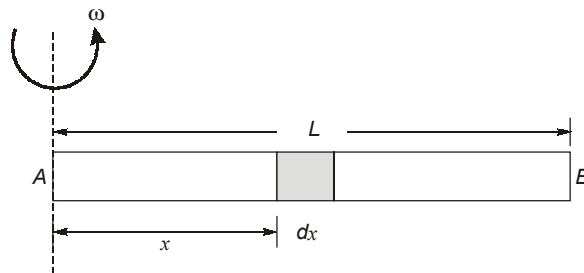
$$= \frac{PR^3}{EI} \int_0^{\pi/2} \cos^2 \theta d\theta$$

$$\delta_v = \frac{\pi PR^3}{4EI}$$

Q.199 A rod of mass 'm' and length 'L' have a cross section area 'A'. It is rotated in a horizontal plane, about one of its end with a constant angular velocity ω , then the maximum stress produced in the rod will be

- (a) $\frac{mL\omega^2}{A}$ (b) $\frac{mL\omega^2}{2A}$
(c) $\frac{mL\omega^2}{3A}$ (d) $\frac{mL\omega^2}{4A}$

199. (b)



Consider an element of length dx at a distance x from end A.

So,
$$dF = (dm) \times x \times \omega^2$$

Now,
$$dm = \frac{m}{L} dx$$

So,
$$dF = \frac{mx\omega^2 dx}{L}$$

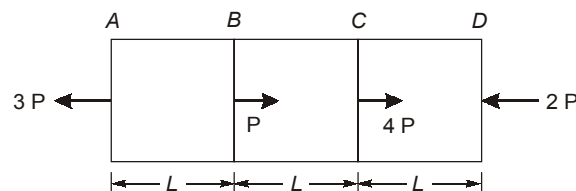
Maximum force will be at a cross section about which it is rotating

$$F_{\max} = \int_0^L \frac{mx\omega^2 dx}{L}$$

$\therefore F_{\max} = \frac{m\omega^2 L}{2}$

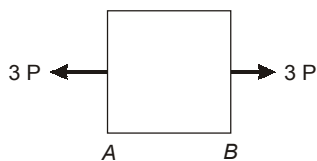
Maximum stress will be $\sigma = \frac{F_{\max}}{A} = \frac{m\omega^2 L}{2A}$

Q.200 A bar is loaded as shown in the figure. If A is cross-sectional area and E is modulus of elasticity, then the total strain energy stored is

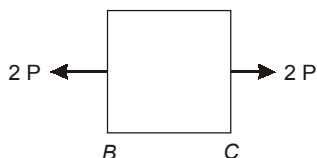


- (a) $\frac{15P^2L}{2AE}$ (b) $\frac{17P^2L}{4AE}$
(c) $\frac{17P^2L}{2AE}$ (d) $\frac{15P^2L}{4AE}$

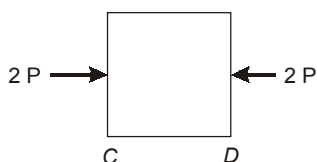
200. (c)



$$U_{AB} = \frac{9P^2L}{2AE} \quad (\text{Strain energy due to axial load } 3P)$$



$$U_{BC} = \frac{4P^2L}{2AE} \quad (\text{Strain energy due to axial load } 2P)$$



$$U_{CD} = \frac{4P^2L}{2AE} \quad (\text{Strain energy due to axial load } 2P)$$

So,

$$U_{\text{Total}} = U_{AB} + U_{BC} + U_{CD} = \frac{17P^2L}{2AE}$$

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