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GRADE 12

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

NOVEMBER 2022

MARKS: 200

TIME: 3 hours

This question paper consists of 16 pages and a 6-page formula sheet.

INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the spaces provided on the ANSWER BOOK.
2. Read ALL the questions carefully.
3. Answer ALL the questions.
4. Number the answers correctly according to the numbering system used in this question paper.
5. Start EACH question on a NEW page.
6. Show ALL calculations and units. Round off final answers to TWO decimal places.
7. Candidates may use non-programmable scientific calculators and drawing instruments.
8. The value of gravitational acceleration should be taken as 10 m/s^2 .
9. All dimensions are in millimetres, unless stated otherwise in the question.
10. Write neatly and legibly.
11. A formula sheet is attached at the end of the question paper.
12. Use the criteria below to assist you in managing your time.

QUESTION	CONTENT	MARKS	TIME IN MINUTES
	GENERIC		
1	Multiple-choice Questions	6	6
2	Safety	10	10
3	Materials	14	14
	SPECIFIC		
4	Multiple-choice Questions	14	10
5	Terminology (Lathe and Milling Machine)	18	20
6	Terminology (Indexing)	28	25
7	Tools and Equipment	13	10
8	Forces	33	33
9	Maintenance	18	12
10	Joining Methods	18	12
11	Systems and Control (Drive Systems)	28	28
TOTAL		200	180

QUESTION 1: MULTIPLE-CHOICE QUESTIONS (GENERIC)

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (1.1 to 1.6) in the ANSWER BOOK, e.g. 1.7 E.

- 1.1 Which ONE of the following is the last stage when applying first aid?
- A Examination
 - B Treatment
 - C Diagnosis
 - D Transport
- (1)
- 1.2 What is the maximum thickness of sheet metal that a manual guillotine can cut?
- A 0,2 mm
 - B 1,2 mm
 - C 2,2 mm
 - D 3,2 mm
- (1)
- 1.3 Which part of a hydraulic press is used to safely keep the platform at a desired height?
- A Return spring
 - B Plunger
 - C Supporting pin
 - D Base
- (1)
- 1.4 Which ONE of the following tests is used to determine resistance to penetration?
- A File test
 - B Machining test
 - C Hardness test
 - D Sound test
- (1)
- 1.5 Which machine is used to conduct a spark test on carbon steels?
- A Bench grinder
 - B Drilling machine
 - C Lathe
 - D Milling machine
- (1)
- 1.6 Which ONE of the following materials will have a high ringing sound when tapped with a hammer during a sound test?
- A Cast iron
 - B Cast steel
 - C Mild steel
 - D Aluminium
- (1)

[6]

QUESTION 2: SAFETY (GENERIC)

- 2.1 Name TWO vital functions of an injured person that must be checked when first aid is applied. (2)
- 2.2 Give a reason why safety goggles must be worn when working with an angle grinder. (1)
- 2.3 Name TWO types of safety guards that are used where the opening at the guillotine shears is greater than 10 mm. (2)
- 2.4 State THREE safety precautions that must be adhered to before gas welding is undertaken. (3)
- 2.5 State TWO disadvantages of the product layout of machines. (2)
- [10]**

QUESTION 3: MATERIALS (GENERIC)

- 3.1 State THREE properties that can be obtained from heat-treatment processes. (3)
- 3.2 Describe the following heat-treatment processes:
- 3.2.1 Tempering (4)
- 3.2.2 Hardening (3)
- 3.3 Give TWO examples of case-hardened products used in the industry. (2)
- 3.4 Why is steel cooled in still air, away from a draught, during the normalising process? (2)
- [14]**

QUESTION 4: MULTIPLE-CHOICE QUESTIONS (SPECIFIC)

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (4.1 to 4.14) in the ANSWER BOOK, e.g. 4.15 E.

- 4.1 Identify the lathe component in FIGURE 4.1 below.

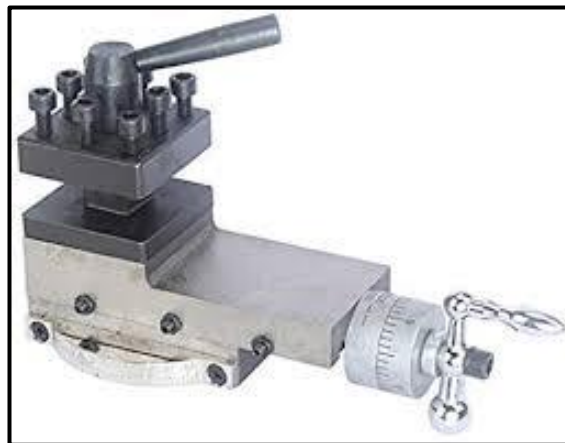


FIGURE 4.1

- A Cross slide
B Revolving centre
C Compound slide
D Chuck (1)
- 4.2 What is the purpose of a centre gauge?
A To set the cutting tool square to the axis
B To assist with centre drilling
C To check if the screw thread has been cut accurately
D To assist in counting the number of cutting tools needed (1)
- 4.3 A CNC (computer numerical control) machine ...
A counts the number of work pieces cut.
B is fed with figures and letters (data input).
C can only be operated manually.
D can switch on by itself. (1)
- 4.4 From where is absolute motion measured during CNC milling?
A The last position of the cutting tool
B The middle of the work piece
C The beginning of the work piece
D A common point (1)

4.5 Which hardness tester uses a diamond cone to indent material?

- A Moment hardness tester
- B Force hardness tester
- C Rockwell hardness tester
- D Brinell hardness tester

(1)

4.6 Identify the type of micrometer in FIGURE 4.6 below.

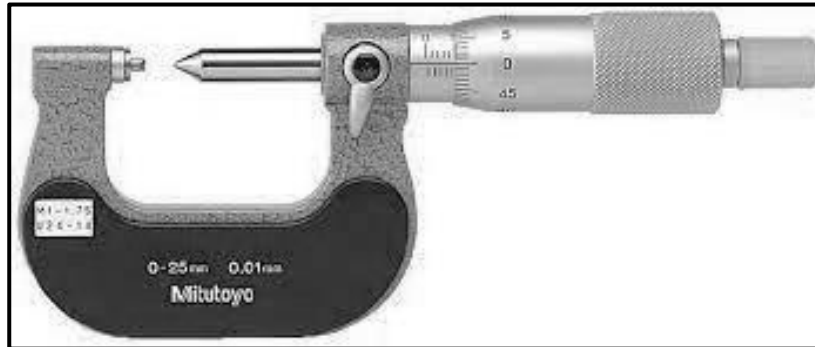


FIGURE 4.6

- A Screw-thread micrometer
- B Inside micrometer
- C Outside micrometer
- D Depth micrometer

(1)

4.7 Which ONE of the following is the definition of *load*?

- A The internal resistance in a body
- B The external force acting upon matter
- C The quantity of matter a body contains
- D The internal force present in material

(1)

4.8 Identify **R** in the stress-strain diagram in FIGURE 4.8 below.

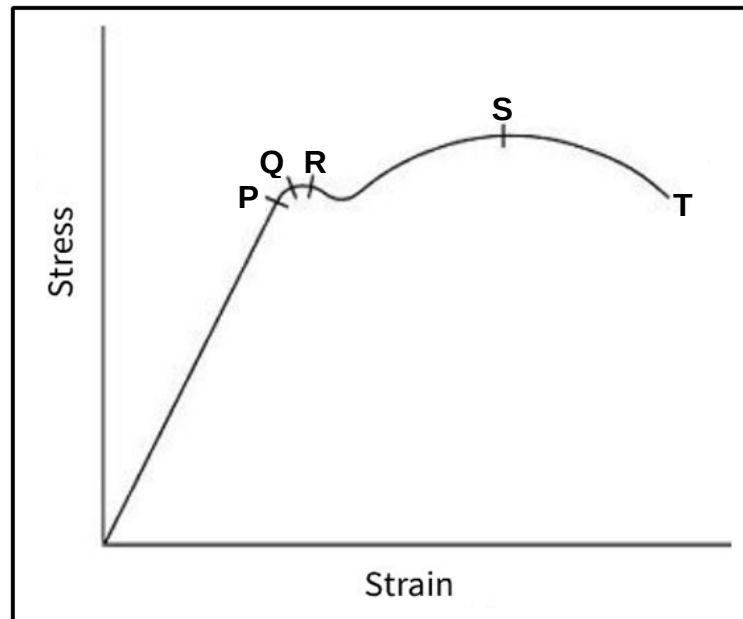


FIGURE 4.8

- A Stress point
- B Yield point
- C Elastic limit
- D Maximum stress

(1)

4.9 Which ONE of the following is manufactured from bakelite?

- A Roof sheeting
- B Water pipe
- C Distributor rotor
- D Shopping bag

(1)

4.10 Which ONE of the following is an advantage of Vesconite?

- A Very versatile
- B Low load-bearing strength
- C Low chemical resistance
- D Poor machinability

(1)

4.11 Which diameter on the screw thread bears the maximum load?

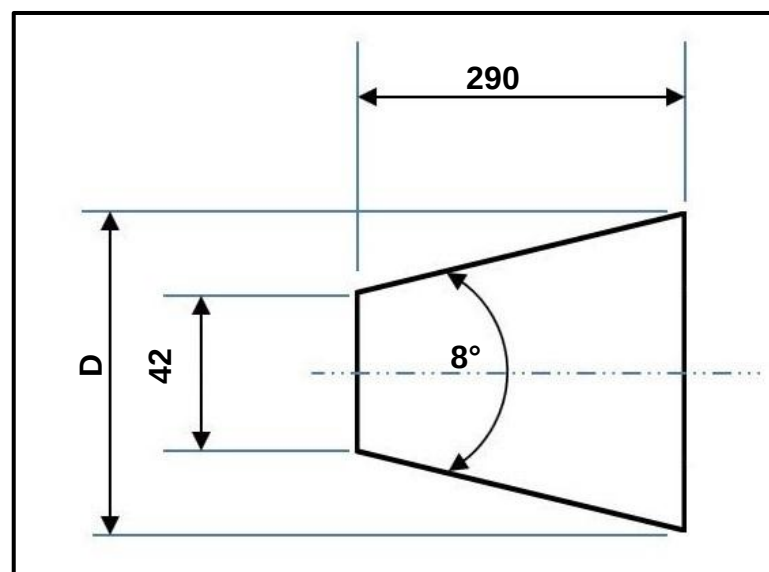
- A Major diameter
- B Pitch diameter
- C Root diameter
- D Crest diameter

(1)

- 4.12 The sides of the cutting tool used to cut a square screw thread should be ground at an angle ...
- A conforming to the helix angle of the screw thread.
 - B smaller than the helix angle.
 - C bigger than the helix angle.
 - D square to the square screw thread.
- (1)
- 4.13 Which ONE of the following is an example of a pulley system?
- A Engine horn
 - B Scissors car jack
 - C Car brake system
 - D Block and tackle
- (1)
- 4.14 How is the fluid in a hydraulic system kept clean?
- A Raise the temperature of the fluid in the system.
 - B Constantly top up the fluid in the system.
 - C Insert a check valve in the system.
 - D Insert a filter in the system.
- (1)

[14]**QUESTION 5: TERMINOLOGY (LATHE AND MILLING MACHINE) (SPECIFIC)**

- 5.1 State TWO advantages of cutting a taper on a lathe by using the tailstock set-over method.
- (2)
- 5.2 FIGURE 5.2 below shows a taper with an included angle of 8° which should be cut on a lathe by using the compound slide method. Calculate the diameter (D) of the taper.

**FIGURE 5.2****(4)**

- 5.3 Calculate the following dimensions for a parallel key suitable for a 65 mm diameter shaft:
- 5.3.1 Width (2)
- 5.3.2 Thickness (2)
- 5.3.3 Length (2)
- 5.4 State ONE disadvantage of straddle milling. (1)
- 5.5 Name TWO types of milling processes that can be done by using vertical milling. (2)
- 5.6 A 12 mm milling cutter must be centred on a 60 mm diameter work piece by using the steel ruler method on a milling machine as shown in FIGURE 5.6 below. Calculate **X** in order to centre the milling cutter. (3)

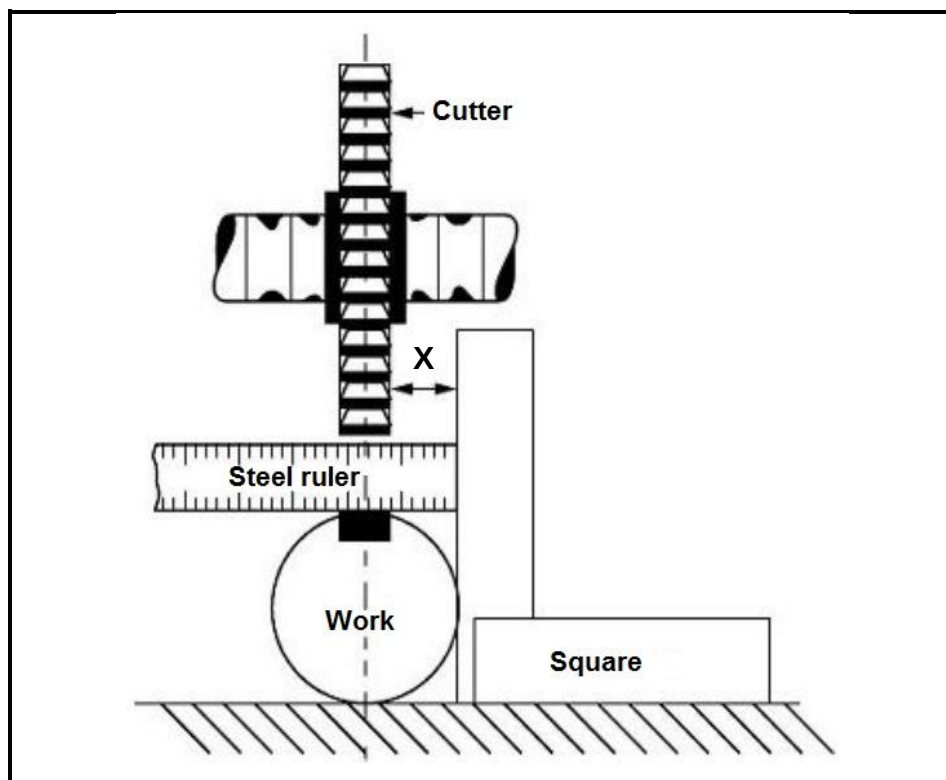


FIGURE 5.6

(3)
[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

- 6.1 A spur gear, with a pitch-circle diameter of 165 mm and 110 teeth, is needed for a gearbox.

Calculate the following:

6.1.1 Module (2)

6.1.2 Outside diameter (2)

- 6.2 FIGURE 6.2 below shows an external dovetail that must be manufactured for a compound slide of a centre lathe.

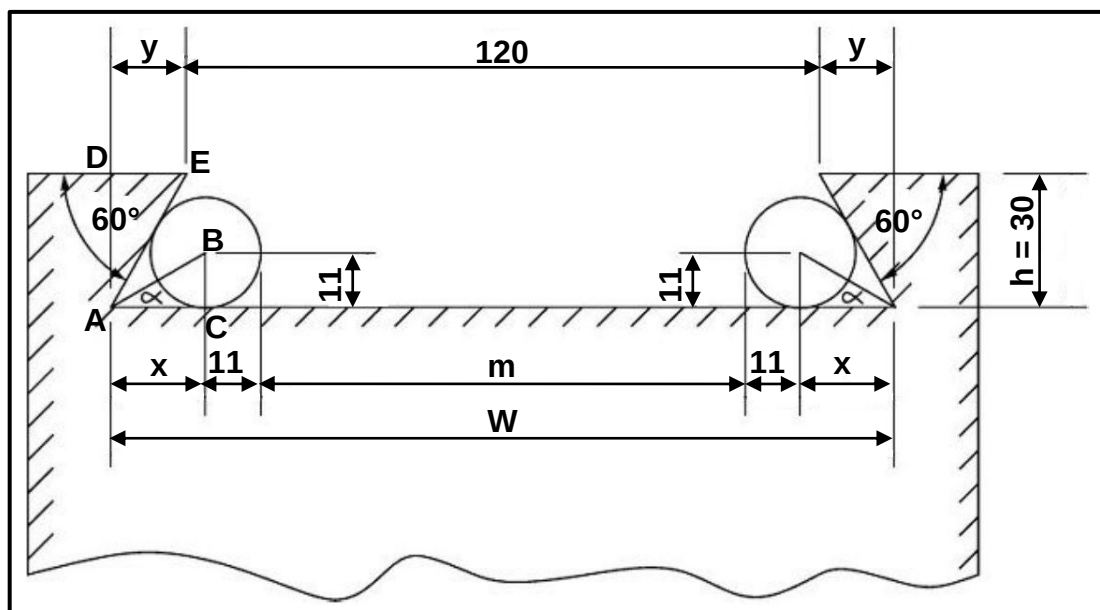


FIGURE 6.2

Calculate the following:

6.2.1 Maximum width (W) of the dovetail (6)

6.2.2 Distance (m) between the precision rollers (6)

- 6.3 A spur gear with 163 teeth has to be manufactured for a hoist crane. The dividing head has a ratio of 40 : 1.

HINT: A = 160 divisions for the simple indexing

6.3.1 Calculate the indexing that is needed. (3)

6.3.2 Calculate the change gears that are required. (5)

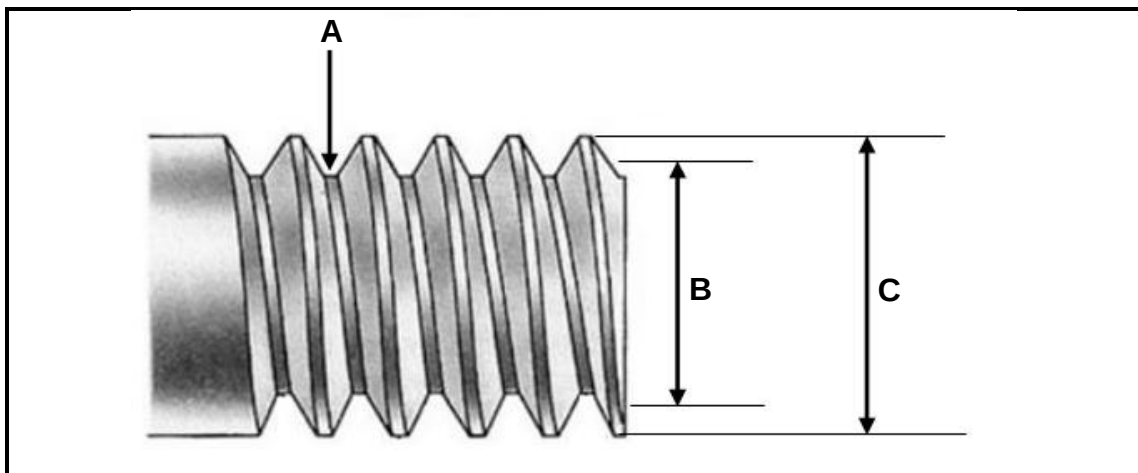
6.4 Name TWO types of balancing methods. (2)

6.5 State TWO advantages of balancing the rotating components of a machine. (2)

[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

- 7.1 Describe the function of a screw-thread micrometer. (2)
- 7.2 The Brinell hardness tester is used to determine the hardness of metal. Use a neat labelled drawing to demonstrate how the test is performed. (4)
- 7.3 Name TWO types of forces that can act on a body. (2)
- 7.4 FIGURE 7.4 below shows a metric screw thread. Answer the questions that follow.

**FIGURE 7.4**

- 7.4.1 Label **A–C**. (3)
- 7.4.2 Calculate the pitch diameter of an M12 x 1,75 screw thread. (2)
- [13]**

QUESTION 8: FORCES (SPECIFIC)

- 8.1 FIGURE 8.1 below shows a system of four forces acting on the same point. Answer the questions that follow.

HINT: Draw and complete the diagram for the forces shown in FIGURE 8.1. Show ALL the horizontal and vertical components before doing the calculations.

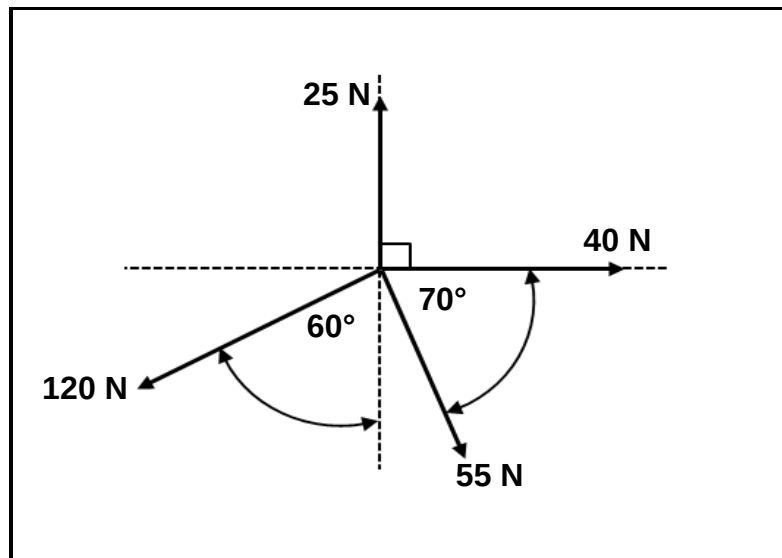


FIGURE 8.1

Calculate the following:

- | | | |
|-------|--|-----|
| 8.1.1 | The sum of the horizontal components | (4) |
| 8.1.2 | The sum of the vertical components | (4) |
| 8.1.3 | The magnitude of the resultant | (2) |
| 8.1.4 | The angle and direction of the resultant | (3) |

- 8.2 FIGURE 8.2 below shows a uniform beam supported by two vertical supports, **A** and **B**. Two point loads and a uniformly distributed load (**UDL**) are exerted onto the beam.

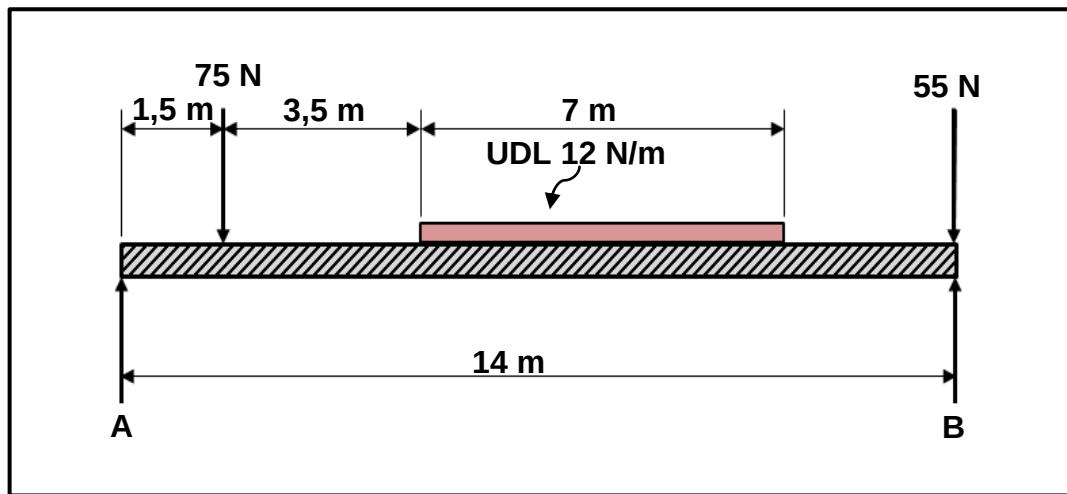


FIGURE 8.2

Calculate the following:

- 8.2.1 The uniformly distributed load on the beam (1)
- 8.2.2 The magnitude of the reaction force at **A** (5)
- 8.2.3 The magnitude of the reaction force at **B** (5)

- 8.3 A compressive force of 85 kN, that causes a stress of 36 MPa, is exerted onto a round tube. The original length of the tube is 120 mm.

Calculate the following:

- 8.3.1 The resistance area (3)
- 8.3.2 The change in length, in millimetres, caused by the force if Young's modulus for this material is 90 GPa (6)

[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

- 9.1 Name THREE important consequences of failing to conduct preventative maintenance in an engineering workshop. (3)
- 9.2 State THREE different types of mechanical drive systems. (3)
- 9.3 Name the element used to enhance the strength of glass fibre. (1)

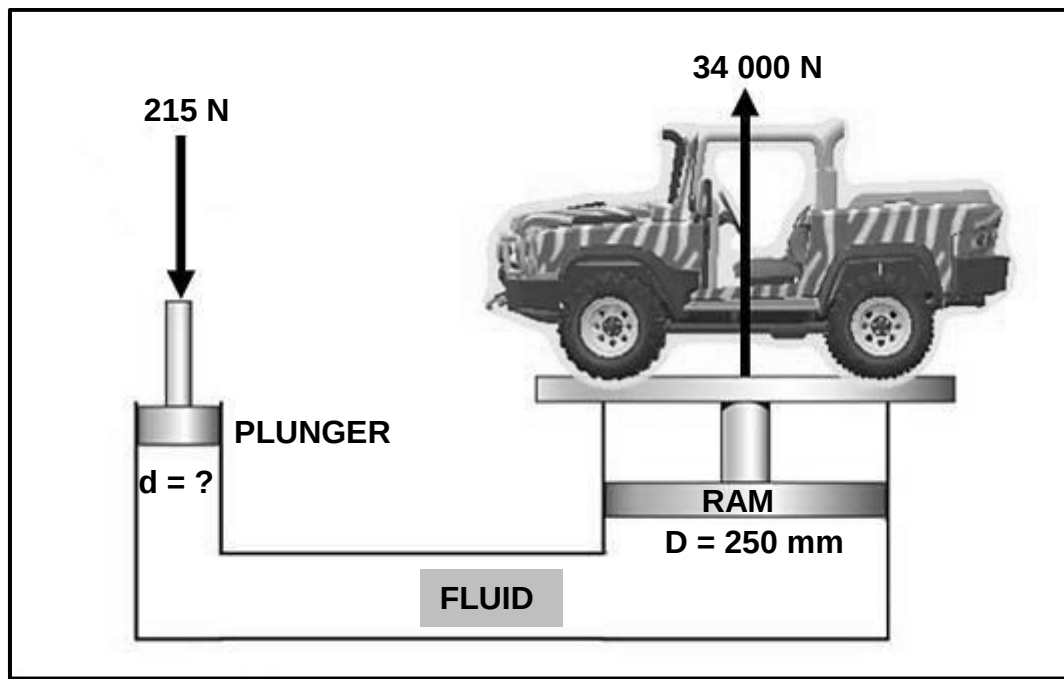
- 9.4 State TWO properties of EACH of the following products:
- 9.4.1 Bakelite (2)
- 9.4.2 Carbon fibre (2)
- 9.5 Name ONE natural substance that is used to manufacture PVC. (1)
- 9.6 Name THREE ways of conducting preventative maintenance on mechanical equipment. (3)
- 9.7 Name the TWO main types of plastic composites. (2)
- 9.8 Which plastic composite is used for non-stick coatings on frying pans? (1)
- [18]**

QUESTION 10: JOINING METHODS (SPECIFIC)

- 10.1 Explain the following terms as applicable to screw thread terminology:
- 10.1.1 Lead (4)
- 10.1.2 Helix angle (2)
- 10.2 A two-start square threaded bar needs to be manufactured. The lead of the square thread is 42 mm and the crest diameter is 90 mm. The clearance angle on the cutting tool must be 3°.
- Calculate the following:
- 10.2.1 Pitch (3)
- 10.2.2 Pitch diameter (2)
- 10.2.3 Helix angle of the thread (3)
- 10.2.4 Leading angle (2)
- 10.2.5 Following angle (2)
- [18]**

QUESTION 11: SYSTEMS AND CONTROL (DRIVE SYSTEMS) (SPECIFIC)

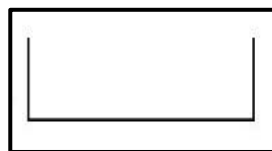
- 11.1 FIGURE 11.1 below shows a hydraulic lift. The lift needs to raise a maximum load of 34 000 N at the ram with a diameter of 250 mm. The force applied on the plunger is 215 N. Answer the questions that follow.

**FIGURE 11.1**

Calculate the following:

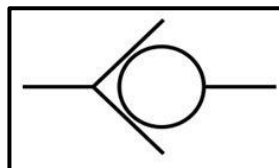
- 11.1.1 The fluid pressure in the hydraulic system in MPa (4)
- 11.1.2 The diameter of the plunger in mm (5)
- 11.2 Name TWO types of hydraulic filters. (2)
- 11.3 Identify the hydraulic symbols in FIGURES 11.3.1 and 11.3.2 below.

11.3.1

**FIGURE 11.3.1**

(1)

11.3.2

**FIGURE 11.3.2**

(1)

- 11.4 A belt pulley with a diameter of 0,15 m is mounted on the shaft of a petrol engine that drives a fuel pump. The engine rotates at 1 330 r/min. A pulley with a diameter of 0,32 m is fitted to the fuel pump. The tensile force of the belt in the tight side is 175 N and the force in the slack side is 130 N.

Calculate the following:

- 11.4.1 The rotational frequency in r/s of the driven pulley on the fuel pump (3)

- 11.4.2 The power transmitted in watt (4)

- 11.5 FIGURE 11.5 below shows a gear drive system. The number of teeth for each gear is shown in the diagram. Driver gear **A** is fixed on the input shaft. The rotational frequency of the output shaft is 625 r/min. Answer the questions that follow.

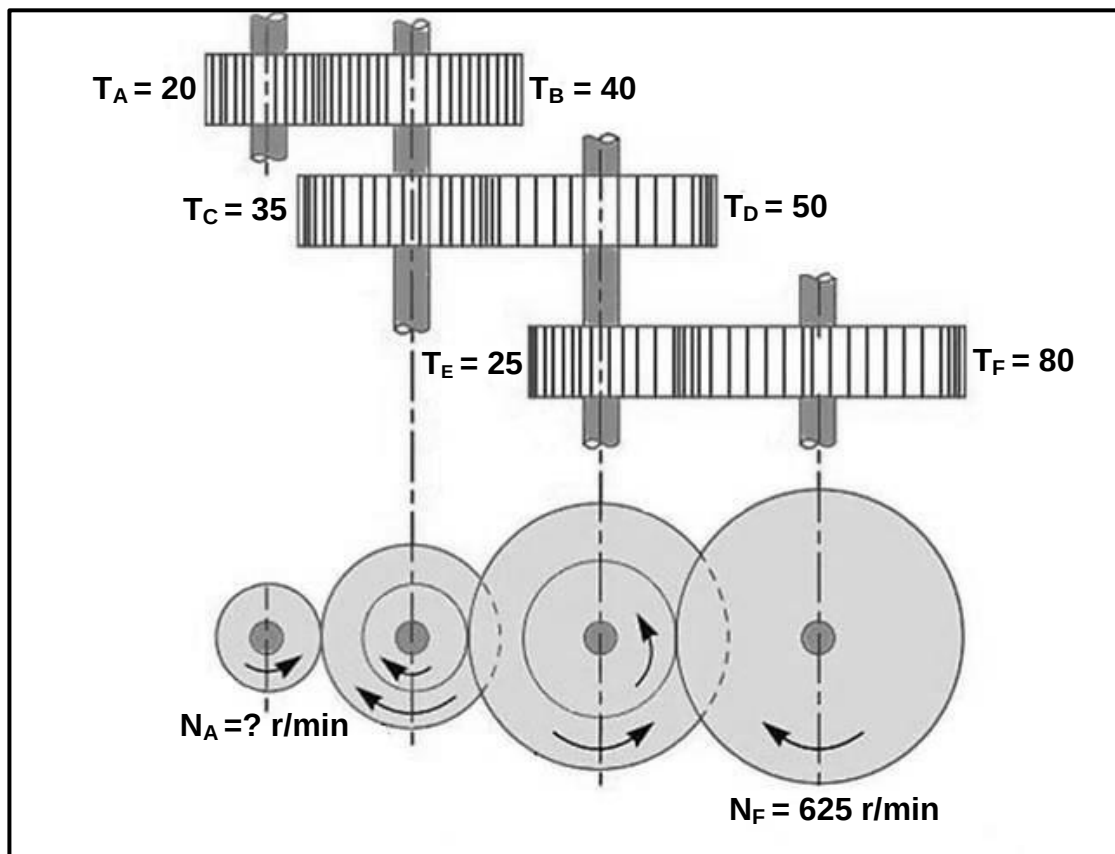


FIGURE 11.5

- 11.5.1 Identify the type of gear drive system shown in FIGURE 11.5. (1)

- 11.5.2 Calculate the rotational frequency of the input shaft. (4)

- 11.6 During a machining test on a lathe, it was found that the tangential force on the cutting tool was 250 N. The diameter of the work piece was 50 mm. Calculate the torque on the lathe spindle. (3)

[28]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY: FITTING AND MACHINING

1. BELT DRIVES

$$1.1 \quad \text{Belt speed} = \frac{\pi D N}{60}$$

$$1.2 \quad \text{Belt speed} = \frac{\pi(D+t) \times N}{60} \quad (t = \text{belt thickness})$$

$$1.3 \quad \text{Belt mass} = \text{Area} \times \text{Length} \times \text{Density} \quad (A = \text{thickness} \times \text{width})$$

$$1.4 \quad \text{Speed ratio} = \frac{\text{Diameter of driven pulley}}{\text{Diameter of driver pulley}}$$

$$1.5 \quad \text{Belt length (flat)} = [(D + d) \times 1,57] + (2 \times \text{centre distance})$$

$$1.6 \quad \text{Open-belt length} = \frac{\pi(D + d)}{2} + \frac{(D + d)^2}{4c} + 2c$$

$$1.7 \quad \text{Crossed-belt length} = \frac{\pi(D + d)}{2} + \frac{(D + d)^2}{4c} + 2c$$

$$1.8 \quad \text{Power (P)} = \frac{(T_1 - T_2) \pi D N}{60}$$

Where:

T_1 = force in the tight side

T_2 = force in the slack side

$T_1 - T_2$ = effective tensile force (T_e)

$$1.9 \quad \text{Ratio between tight side and slack side} = \frac{T_1}{T_2}$$

$$1.10 \quad \text{Width} = \frac{T_1}{\text{Permissible tensile force}}$$

$$1.11 \quad N_{DR} \times D_{DR} = N_{DN} \times D_{DN}$$

2. STRESS AND STRAIN

$$2.1 \quad A_{\text{shaft}} = \frac{\pi d^2}{4}$$

$$2.2 \quad A_{\text{pipe}} = \frac{\pi(D^2 - d^2)}{4}$$

$$2.3 \quad \text{Safety factor} = \frac{\text{Maximum stress/Break stress}}{\text{Safe working stress}}$$

$$2.4 \quad \text{Stress} = \frac{\text{Force}}{\text{Area}} \quad \text{OR} \quad \sigma = \frac{F}{A}$$

$$2.5 \quad \text{Strain} = \frac{\text{Change in length}}{\text{Original length}} \quad \text{OR} \quad \varepsilon = \frac{\Delta L}{oL}$$

$$2.6 \quad \text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}} \quad \text{OR} \quad E = \frac{\sigma}{\varepsilon}$$

3. HYDRAULICS

$$3.1 \quad \text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{OR} \quad P = \frac{F}{A}$$

$$3.2 \quad \text{Volume} = \text{Area} \times \text{Stroke length} \quad (l \text{ or } s)$$

$$3.3 \quad \text{Work done} = \text{Force} \times \text{distance}$$

$$3.4 \quad P_A = P_B$$

$$3.5 \quad \frac{F_A}{A_A} = \frac{F_B}{A_B}$$

4. GEAR DRIVES

$$4.1 \quad \text{Power (P)} = \frac{2\pi NT}{60}$$

$$4.2 \quad \text{Gear Ratio} = \frac{\text{Product of teeth on driven gear}}{\text{Product of teeth on driver gear}} \quad \text{OR} \quad \text{Speed ratio} = \frac{N_{\text{input}}}{N_{\text{output}}}$$

$$4.3 \quad \frac{N_{input}}{N_{output}} = \frac{\text{Product of teeth on driven gear}}{\text{Product of teeth on driver gear}}$$

$$4.4 \quad N_A \times T_A = N_B \times T_B$$

$$4.5 \quad \text{Torque} = \text{Force} \times \text{Radius}$$

$$4.6 \quad \text{Torque transmitted} = \text{Gear ratio} \times \text{Input torque}$$

$$4.7 \quad \text{Module} = \frac{\text{Pitch-circle diameter}}{\text{Number of teeth}} \quad \text{OR} \quad m = \frac{PCD}{T}$$

$$4.8 \quad \text{Pitch-circle diameter} = \frac{\text{Circular pitch} \times \text{Number of teeth}}{\pi}$$

OR

$$PCD = \frac{CP \times T}{\pi}$$

$$4.9 \quad \text{Outside diameter (OD)} = PCD + 2(m)$$

$$4.10 \quad \text{Addendum} = \text{Module} \quad \text{OR} \quad a = m$$

$$4.11 \quad \text{Dedendum (b)} = 1,157 \times m \quad \text{OR} \quad \text{Dedendum (b)} = 1,25 \times m$$

$$4.12 \quad \text{Cutting depth (h)} = 2,157 \times m \quad \text{OR} \quad \text{Cutting depth (h)} = 2,25 \times m$$

$$4.13 \quad \text{Clearance (c)} = 0,157 \times m \quad \text{OR} \quad \text{Clearance (c)} = 0,25 \times m$$

$$4.14 \quad \text{Circular pitch (CP)} = m \times \pi$$

$$4.15 \quad \text{Working depth (WD)} = 2 \times m \quad \text{OR} \quad \text{Working depth (WD)} = 2 \times a$$

5. PULLEYS

$$5.1 \quad N_{DR} \times D_{DR} = N_{DN} \times D_{DN}$$

$$5.2 \quad \text{Power (P)} = \frac{2\pi NT}{60}$$

$$5.3 \quad \text{Velocity ratio} = \frac{\text{Diameter of driven pulley}}{\text{Diameter of driver pulley}}$$

6. KEYWAYS

$$6.1 \quad \text{Width (W)} = \frac{D}{4}$$

$$6.2 \quad \text{Thickness (T)} = \frac{D}{6}$$

$$6.3 \quad \text{Length (L)} = 1,5 \times D$$

Where:

D = Diameter of shaft

$$6.4 \quad \text{Standard taper for taper key: 1 in 100 or 1 : 100}$$

7. CINCINNATI DIVIDING HEAD TABLE FOR MILLING MACHINE

<i>Hole circles</i>											
<i>Side 1</i>	24	25	28	30	34	37	38	39	41	42	43
<i>Side 2</i>	46	47	49	51	53	54	57	58	59	62	66
<i>Change gears</i>											
<i>Gears</i>	24 x 2	28	32	40	44	48	56	64	72	86	100

$$7.1 \quad \text{Indexing} = \frac{40}{n} \quad (n = \text{number of divisions})$$

$$7.2 \quad \frac{Dr}{Dn} = \frac{A-n}{A} \times \frac{40}{1} \quad \text{OR} \quad \frac{Dr}{Dn} = (A-n) \times \frac{40}{A}$$

Where:

A = chosen number of divisions

n = real number of divisions

8. DOVETAILS

Where:

R = Radius of precision roller

y = Distance from top edge of dovetail in relation to bottom corner of dovetail

x = Distance from middle of precision roller to bottom corner of dovetail

θ = Dovetail included angle (normally 60°)

h = Height of dovetail

w = Minimum width of dovetail

W = Maximum width of dovetail

m = Distance between rollers

M = Distance over rollers

9. TAPERS

$$9.1 \quad \tan \frac{\theta}{2} = \frac{D - d}{2 \times l} \quad (l = \text{Taper length})$$

$$9.2 \quad \text{Tail stock set - over} = \frac{L(D - d)}{2 \times l} \quad (L = \text{Distance between centres})$$

10. SCREW THREADS

$$10.1 \quad \text{Mean diameter} = \text{Outside diameter} - (\frac{1}{2} \times \text{Pitch}) \quad \text{OR} \quad D_m = OD - \frac{P}{2}$$

$$10.2 \quad \text{Effective diameter } (D_{\text{eff}}) = \text{Pitch diameter } (D_p) = \text{Mean diameter } (D_m)$$

$$10.3 \quad \text{Lead} = \text{Pitch} \times \text{Number of starts}$$

$$10.4 \quad \text{Height of screw thread} = 0,866 \times \text{Pitch } (P)$$

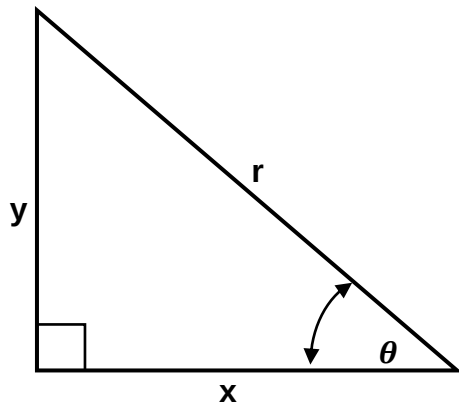
$$10.5 \quad \text{Depth of screw thread} = 0,613 \times \text{Pitch } (P)$$

$$10.6 \quad \text{Helix angle: } \tan \theta = \frac{\text{Lead}}{\pi \times D_m}$$

$$10.7 \quad \text{Leading angle} = 90^\circ - (\text{Helix angle} + \text{Clearance angle})$$

$$10.8 \quad \text{Following angle} = 90^\circ + (\text{Helix angle} - \text{Clearance angle})$$

$$10.9 \quad D_p = D_N - (0,866 \times P)$$

11. PYTHAGORAS' THEOREM AND TRIGONOMETRY

$$11.1 \quad \sin \theta = \frac{y}{r}$$

$$11.2 \quad \cos \theta = \frac{x}{r}$$

$$11.3 \quad \tan \theta = \frac{y}{x}$$

$$11.4 \quad r^2 = x^2 + y^2$$