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NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2025

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

MARKS: 200

TIME: 3 hours

This question paper consists of pages 24, including a 6-page formula sheet.

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INSTRUCTIONS AND INFORMATION

1. Write your NAME 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. You may use a non-programmable scientific calculator and drawing instruments.
8. The value of gravitational force should be taken as 10 m/s^2 .
9. ALL dimensions are in millimeters, unless stated otherwise in the question.
10. A formula sheet is attached to the question paper.
11. Write neatly and legibly.
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)	18	18
6	Terminology (Indexing)	28	25
7	Tools and Equipment	13	10
8	Forces	33	26
9	Maintenance	18	18
10	Joining Methods	18	18
11	Systems and Control (Drive systems)	28	25
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, for example 1.7 A.

- 1.1 Which ONE is the first stage of the basic first aid treatment to apply to an injured person?
- A Examination
 - B Diagnosis
 - C Treatment
 - D None of the above
- (1)
- 1.2 It contains common guidelines on how employers, employees and trade unions should respond to HIV/Aids in the workplace.
- A The Labour Relations Act (LRA) (No. 66 of 1995).
 - B The Constitution – Bill of Rights.
 - C The Code of good practice on HIV/Aids and employment.
 - D Occupational Health and Safety Act (OHS Act No. 85 of 1993)
- (1)
- 1.3 What is the maximum thickness of sheet metal that the manual guillotine can cut?
- A 120 mm
 - B 12 mm
 - C 1,2 mm
 - D 0,12 mm
- (1)
- 1.4 Which ONE of the following safety precautions is applicable when using the drill press?
- A Always wear tinted safety goggles.
 - B Do not hold the work piece by hand.
 - C You may leave the key in the drill chuck.
 - D You may leave the machine running unattended.
- (1)
- 1.5 When mild steel material is tested it produces a ... sound.
- A medium metallic
 - B lower ringing
 - C high ringing
 - D very dull
- (1)
- 1.6 During normalising of iron-based alloys, it is heated to approximately ... above the upper critical temperature.
- A 356°C
 - B 256°C
 - C 156°C
 - D 56°C
- (1)

[6]

QUESTION 2: SAFETY (GENERIC)

- 2.1 State TWO safety precautions that must be adhered to when using a power saw.



(2)

- 2.2 Name TWO responsibilities of an EMPLOYEE regarding safety in the workplace.

(2)

- 2.3 Give TWO safety rules that should be followed while the Bench grinder is in operation.

(2)



- 2.4 State TWO advantages of the product layout.

(2)

- 2.5 Name the TWO main categories into which the causes of accidents can be divided according to the Occupational Health and Safety Act.

(2)

[10]

**QUESTION 3: MATERIALS (GENERIC)**

- 3.1 Name any THREE tests used to distinguish between the different types of materials. (3)
- 3.2 Name the THREE groups of carbon steel and state the percentage carbon content range of each. (6)
- 3.3 What is the purpose of normalising ferrous metals? (2)
- 3.4 Describe the tempering process of steel. (3)
- [14]**



QUESTION 4: MULTIPLE-CHOICE QUESTIONS (SPECIFIC)

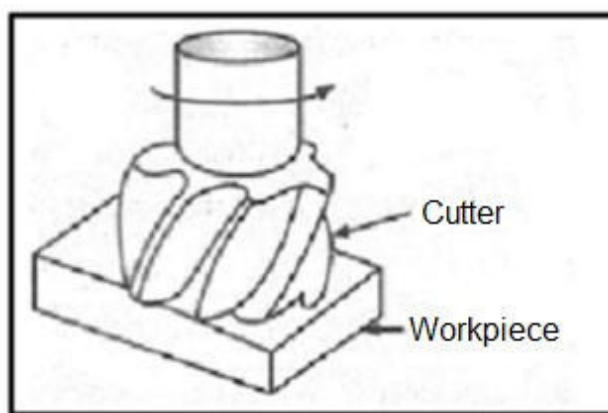
Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (4.1 to 4.14) in the ANSWER BOOK, for example 4.15 A.

- 4.1 The following apparatus is used on a milling machine to divide a work piece into even divisions.

- A Machine vice
- B Tilting head
- C Dividing head
- D Spindle

(1)

- 4.2 Which milling operation is shown in FIGURE 4.2 below:

**FIGURE 4.2**

- A Straddle milling
- B Gang milling
- C Face milling
- D End milling

(1)

- 4.3 Which ONE of the following is an advantage of down-cut milling?

- A Vibration experienced is less
- B Coarse feed may be used
- C The finishing obtained is finer
- D The strain on the cutter and arbore is less

(1)

- 4.4 Which indexing process will be easiest to cut a hexagon bolt head if the universal diving head is used?

- A Rapid indexing
- B Simple indexing
- C Angular indexing
- D Differential indexing

(1)

4.5 Which lathe operation is shown in FIGURE 4.5 below.

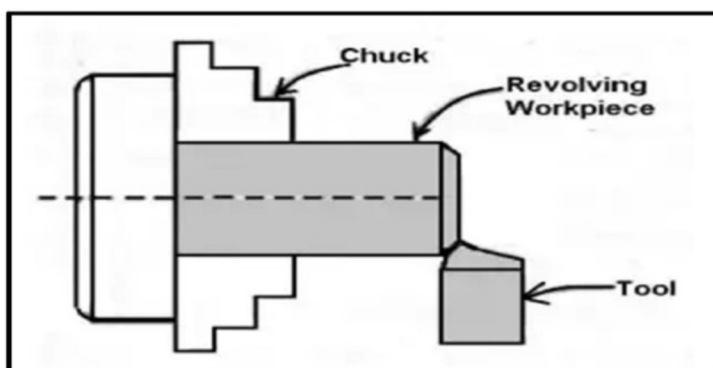


FIGURE 4.5

- A Parallel turning
- B Chamfering
- C Screw-thread cutting
- D Facing off

(1)

4.6 Which ONE of the following is the purpose of lubrication?

- A To reduce friction
- B To reduce wear
- C To prevent corrosion
- D All of the above

(1)

4.7 SAE 20W50 oil, as illustrated in FIGURE 4.7 below, is used for ...



FIGURE 4.7

- A engine lubrication.
- B gearbox lubrication.
- C differential lubrication.
- D automatic lubrication.

(1)

4.8 ONE Pascal can be expressed as ...

- A 1 kg acting on 1 m².
- B 1 N acting on 1 m².
- C 1 kg acting on 1 mm².
- D 1 N acting on 1 mm².

(1)

- 4.9 FIGURE 4.9 below shows three gears meshing. What is the purpose of idler gear **B**?

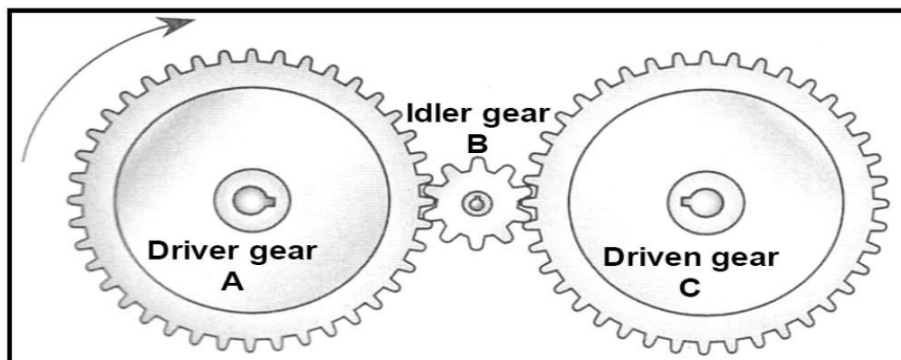


FIGURE 4.9

- A Rotates the driven gear in the opposite direction to the driver gear
 - B Rotates the driven gear in the same direction as the driver gear
 - C Decreases the final rotation frequency
 - D Increases the final rotation frequency
- (1)
- 4.10 The minimum diameter of a screw thread is measured at the ... of the screw thread.
- A root
 - B crest
 - C axis
 - D thread angle
- (1)
- 4.11 Identify the exploded pump type shown in FIGURE 4.11 below

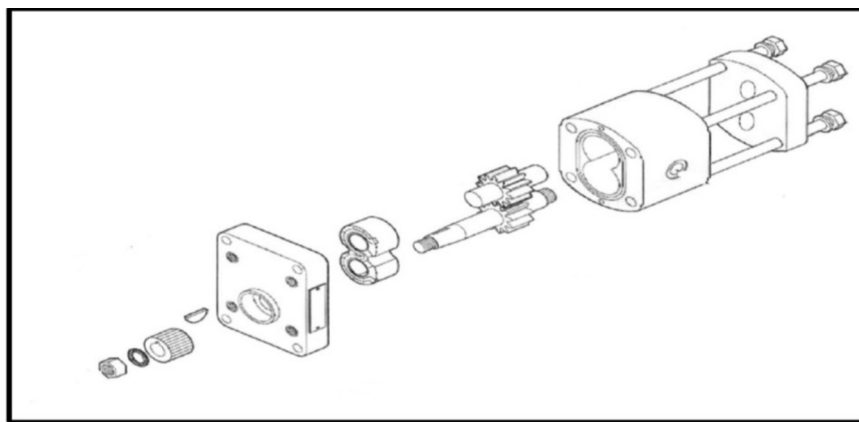


FIGURE 4.11

- A Vane pump
 - B Radial piston pump
 - C Centrifugal pump
 - D Gear pump
- (1)

4.12 Which ONE of the following is NOT an advantage of the belt drive?

- A Produce less noise and vibration
- B Simple and cheap
- C Lubrication is easy
- D All of the above

(1)

4.13 Unless otherwise stated, what is the clearance angle normally used to calculate the leading and following tool angles of a square thread cutting tool?

- A 60°
- B 6°
- C 30°
- D 3°

(1)

4.14 Identify the hydraulic symbol, shown in FIGURE 4.14 below.

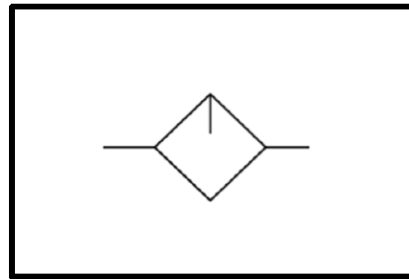


FIGURE 4.14

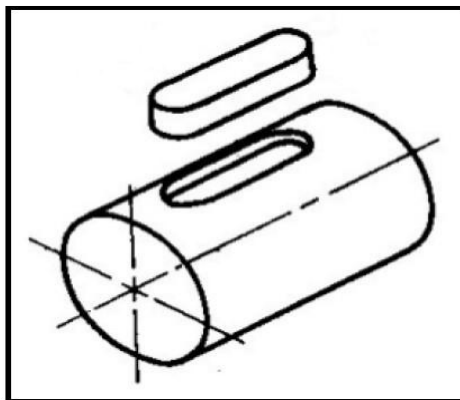
- A Hydraulic motor
- B Lubricator
- C Accumulator
- D Pump

(1)

[14]

QUESTION 5: TERMINOLOGY (LATHE AND MILLING MACHINE) (SPECIFIC)

- 5.1 Calculate the tailstock set-over required for turning a taper of 7° (included angle) on a centre lathe if the taper is 320 mm long. (3)
- 5.2 FIGURE 5.2 below shows a shaft and a key. The length of the key is 126 mm. Answer the questions that follow.

**FIGURE 5.2**

- 5.2.1 Identify the type of key. (1)
- 5.2.2 Determine the diameter of the shaft. (2)
- 5.2.3 Determine the thickness of the key. (2)
- 5.2.4 Determine the width of the key. (2)
- 5.3 State ONE advantage of EACH of the following milling processes:
- 5.3.1 Down cut milling (1)
- 5.3.2 Up cut milling (1)
- 5.4 Use neatly labelled sketches to show the difference between gang milling and straddle milling. (6)

[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

6.1 A spur gear has 25 teeth and a module of 2,5.

Calculate the following:

6.1.1 Dedendum (2)

6.1.2 The pitch-circle diameter (2)

6.1.3 The outside diameter (2)

6.1.4 The circular pitch of the teeth (2)

6.2 A spur gear with 97 teeth must be cut on a milling machine. The dividing head has a ratio of 40 : 1.

By means of calculations, determine:

6.2.1 The indexing that is needed (Choose 100 divisions) (4)

6.2.2 The change gears that are needed (5)

6.3 FIGURE 6.3 below shows a dovetail part. Calculate distances **Y** and **X**.

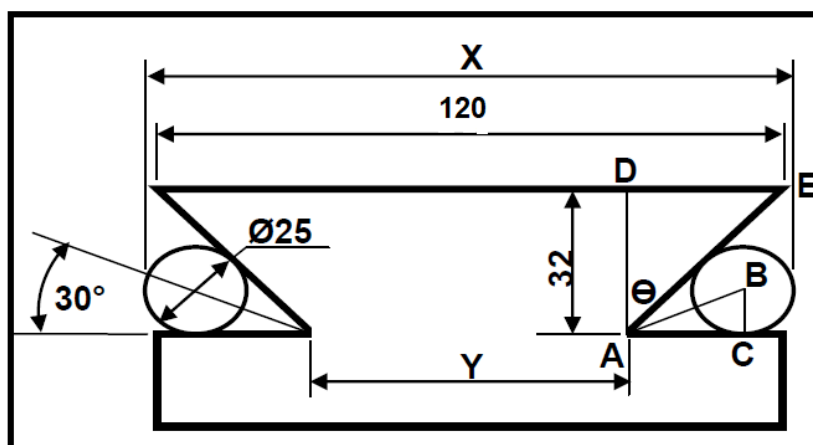
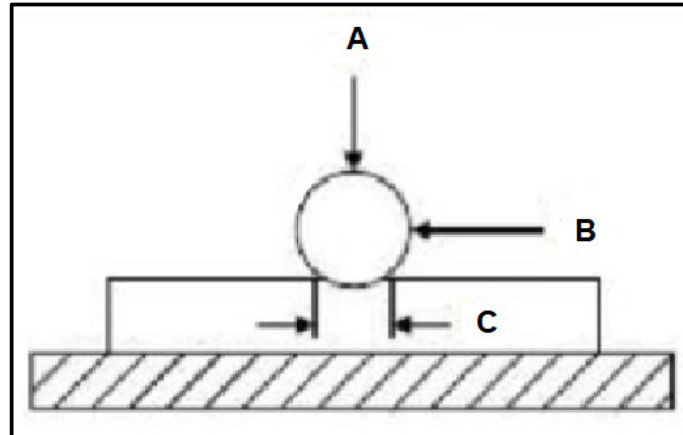


FIGURE 6.3

(11)
[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

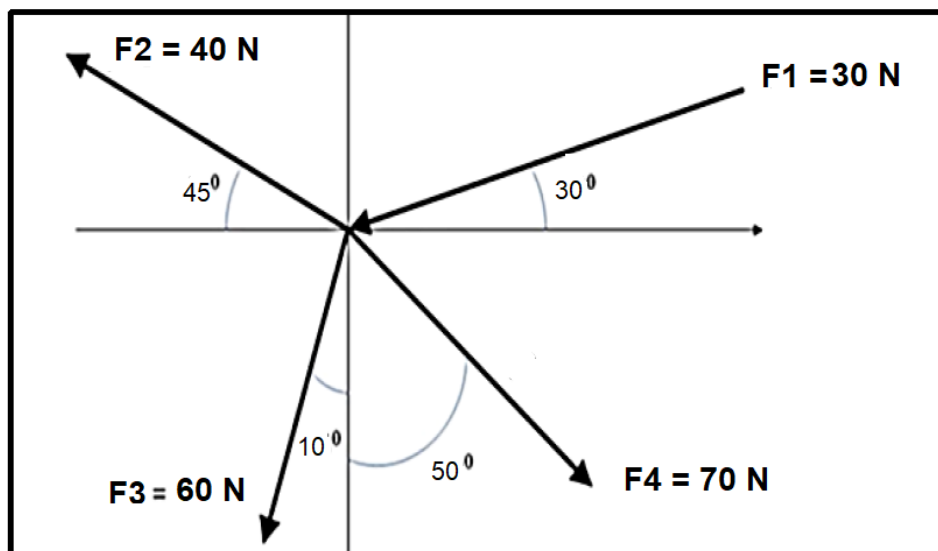
- 7.1 Explain the difference between *hardness* and *toughness* of materials. (4)
- 7.2 FIGURE 7.2 below illustrate the hardness testing process. Answer the questions that follow.

**FIGURE 7.2**

- 7.2.1 Identify the hardness testing process. (1)
- 7.2.2 Label parts **A**, **B** and **C**. (3)
- 7.3 Draw the screw thread micrometre reading of 6,80 mm. (5)
- [13]**

QUESTION 8: FORCES (SPECIFIC)

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

**FIGURE 8.1**

Calculate the following:

- 8.1.1 Sum of the horizontal components (5)
- 8.1.2 Sum of the vertical components (5)
- 8.1.3 Magnitude of the resultant (2)
- 8.1.4 Angle and the direction of the resultant (2)

8.2 A load of 60 kN causes a tensile stress of 30 MPa in a solid brass shaft. The original length of the shaft is 2 m and Young's modulus of elasticity for brass is 90 GPa.

Determine the following by means of calculations:

- 8.2.1 Diameter of the shaft (5)
- 8.2.2 Strain (3)
- 8.2.3 Change in length (3)

- 8.3 FIGURE 8.3 below shows a uniform beam that is supported by two vertical supports, **RL** and **RR**. Two vertical point loads are exerted onto the beam, as well as a uniformly distributed load of 5 kN/m, over a length of 4 m of the beam.

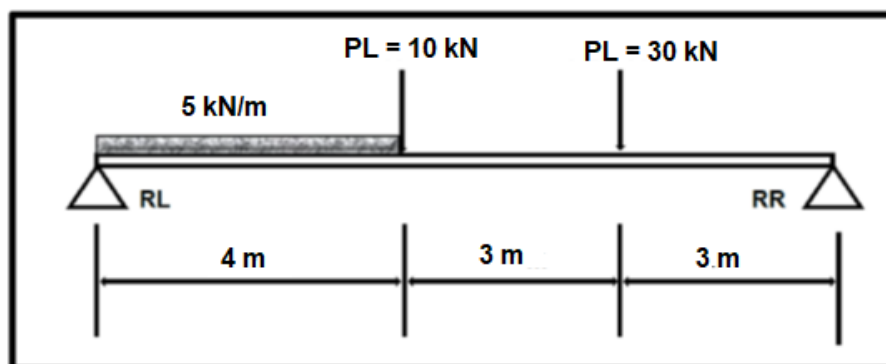


FIGURE 8.3

Calculate the:

- 8.3.1 Uniformly distributed load on the beam (2)
- 8.3.2 Magnitude of the reaction force at **RL** (3)
- 8.3.3 Magnitude of the reaction force at **RR** (3)

[33]

**QUESTION 9: MAINTENANCE (SPECIFIC)**

- 9.1 Name TWO sub-groups that preventative maintenance can be divided into. (2)
- 9.2 Name THREE aspects that need to be done during the preventative maintenance of a chain drive system. (3)
- 9.3 State THREE maintenance measures for cutting fluid in a centre lathe or milling machine. (3)
- 9.4 Define the term *viscosity*. (2)
- 9.5 List TWO advantageous characteristics for using nylon in engineering for the manufacturing of a large variety of components. (2)
- 9.6 Name ONE use of EACH of the following materials:
- 9.6.1 Teflon (1)
- 9.6.2 Glass fibre (1)
- 9.7 State whether the following statements are TRUE or FALSE:
- 9.7.1 PVC is created from natural materials, salt and oil and can be modified to suit any application. (1)
- 9.7.2 Polyester resins are used to strengthen PVC. (1)
- 9.7.3 Bakelite is used for its electrical and heat conductive properties. (1)
- 9.7.4 Vesconite machines easy on lathes and milling machines. (1)

[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1 Explain what is meant by the pitch of a screw thread. (2)

10.2 FIGURE 10.2 below shows a square thread.

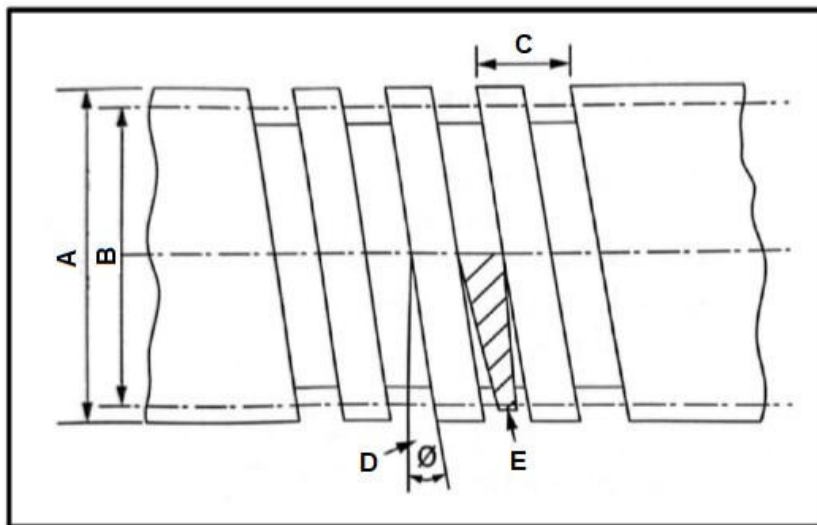


FIGURE 10.2

Label parts **A–E**. (5)

10.3 A three-start square screw thread with a 6 mm pitch needs to be cut on a lathe. The outside diameter of the thread is 78 mm and the clearance angle 3° .

Calculate the following:

10.3.1 Lead of the thread (2)

10.3.2 Mean diameter (2)

10.3.3 Helix angle of the screw thread (3)

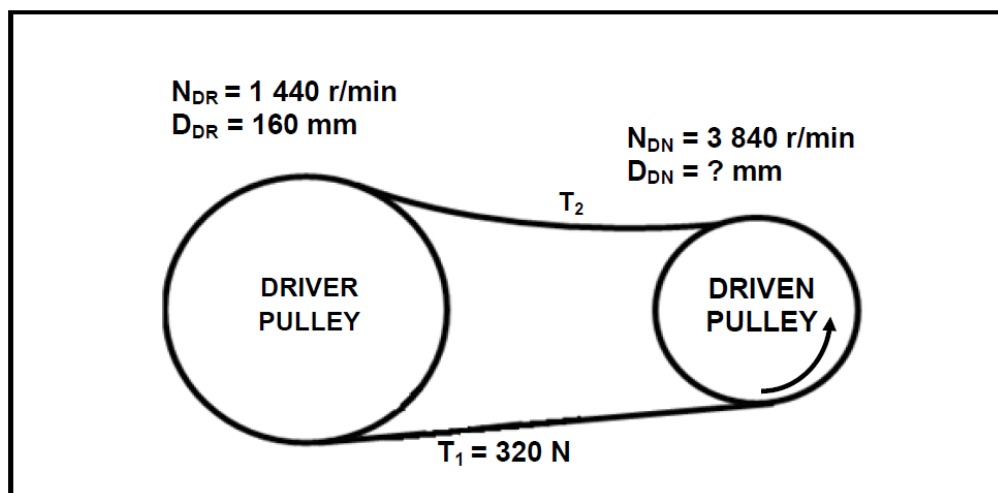
10.3.4 Leading tool angle (2)

10.3.5 Following tool angle (2)

[18]

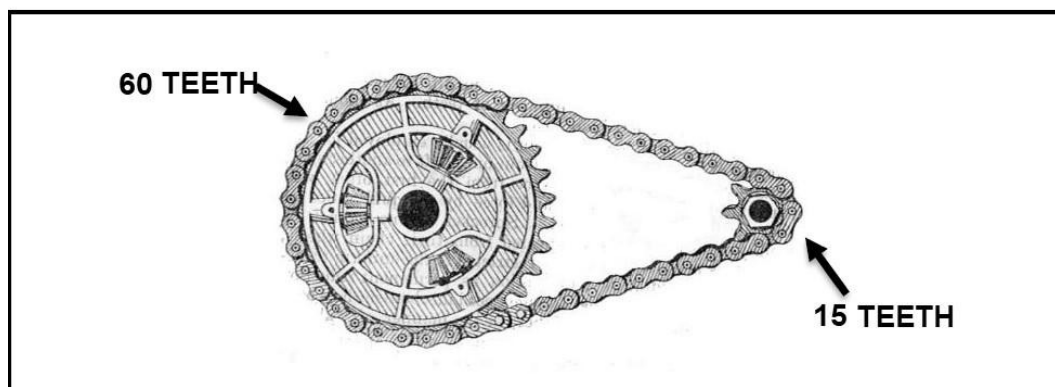
QUESTION 11: SYSTEMS AND CONTROL (SPECIFIC)

- 11.1 Describe the function of a belt in a belt and pulley drive system. (2)
- 11.2 A water pump must be driven at 3 840 r/min from a pulley with a diameter of 160 mm, which rotates at a speed of 1 440 r/min. The tensile force in the tight side of the belt is 320 N. The ratio between the tensile force in the tight side to the tensile force in the slack side is 2,5 : 1.

**FIGURE 11.2**

Determine the following by means of calculations:

- 11.2.1 The diameter of the pulley needed on the water pump (3)
- 11.2.2 Power transmitted (5)
- 11.3 Determine the speed ratio of a racing cycle that uses the chain and sprocket system as shown in FIGURE 11.3 below.

**FIGURE 11.3**

(3)

- 11.4 A hydraulic system is used to lift mechanical machines. The specifications of the system used are represented diagrammatically in FIGURE 11.4 below. The system is equipped with the necessary one-way control valves to prevent the fluid from flowing back after each stroke.

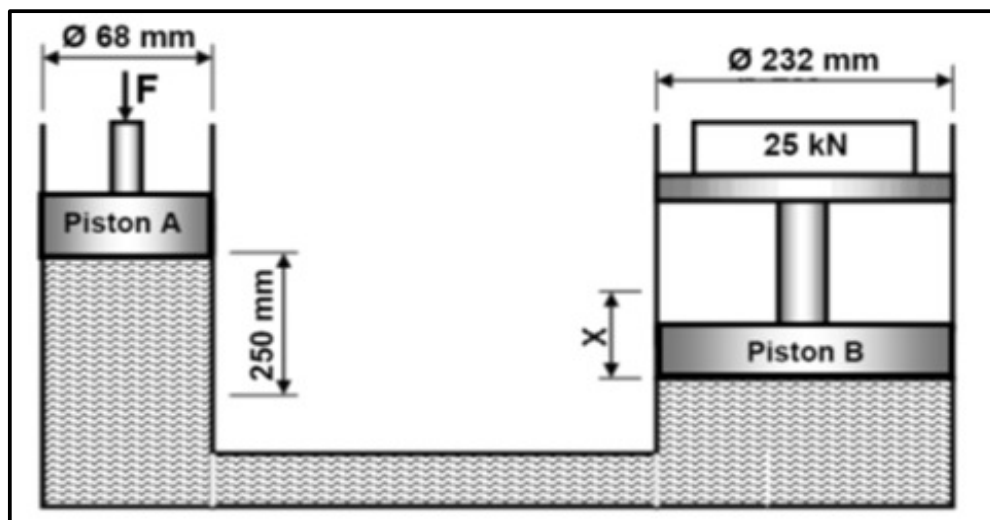


FIGURE 11.4

Determine the following by means of calculations:

- 11.4.1 The fluid pressure in the hydraulic system when in equilibrium. (5)
- 11.4.2 The force (F) that must be exerted onto piston **A** to lift the load of 25 kN on piston **B**. (5)
- 11.4.3 The distance X, in millimetres, that piston **B** will move if piston **A** completes 10 strokes. (5)

[28]

TOTAL: 200



FORMULA SHEET FOR MECHANICAL TECHNOLOGY (FITTING AND MACHINING)

1. BELT DRIVES

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

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

$$N_1 D_1 = N_2 D_2$$

$$\text{Power (P)} = \frac{2 \pi N T}{60}$$

$$\text{Ratio of tight side to slack side} = \frac{T_1}{T_2}$$

$$\text{Power} = \frac{(T_1 - T_2) \pi D N}{60} \quad \text{where } T_1 = \text{force in the tight side}$$

$$T_2 = \text{force in slack side}$$

$$T_1 - T_2 = \text{effective force (T}_e\text{)}$$

2. STRESS AND STRAIN

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} \quad \text{or} \quad (\sigma = \frac{F}{A})$$

$$\text{Strain } (\epsilon) = \frac{\text{change in length } (\Delta L)}{\text{original length } (L)}$$

$$\text{Young's modulus } (E) = \frac{\text{stress}}{\text{strain}} \quad \text{or} \quad (\frac{\sigma}{\epsilon})$$

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

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

$$\text{Safety factor} = \frac{\text{Break stress}}{\text{Safe working stress}}$$



3. HYDRAULICS

$$\text{Pressure (P)} = \frac{\text{Force (F)}}{\text{Area (A)}}$$

Volume = Cross-sectional area $\times$ stroke length

$$P_A = P_B$$

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

4. KEYS AND KEYWAYS

$$\text{Width of key} = \frac{\text{Diameter of shaft}}{4}$$

$$\text{Thickness of key} = \frac{\text{Diameter of shaft}}{6}$$

Length of key = $1,5 \times$ Diameter of shaft

Standard taper for taper key: 1 in 100 or 1:100



5. GEAR DRIVES

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

$$N_1 T_1 = N_2 T_2$$

$$\text{Gear ratio} = \frac{\text{Product of the number of teeth on driven gears}}{\text{Product of the number of teeth on driving gears}}$$

$$\frac{N_{\text{input}}}{N_{\text{output}}} = \frac{\text{Product of the number of teeth on driven gears}}{\text{Product of the number of teeth on driving gears}}$$

$$\text{Torque} = \text{force} \times \text{radius}$$

$$\text{Torque transmitted} = \text{gear ratio} \times \text{input torque}$$

$$\text{Module (m)} = \frac{\text{Pitch-circle diameter (PCD)}}{\text{Number of teeth (T)}}$$

$$\text{Pitch-circle diameter (PCD)} = \frac{\text{circular pitch (CP)} \times \text{number of teeth (T)}}{\pi}$$

$$\text{Outside diameter (OD)} = \text{PCD} + 2 \text{ module}$$

$$\text{Addendum (a)} = \text{module (m)}$$

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

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

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

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

$$\text{Add}_c = m + \frac{Tm}{2} \left(1 - \cos \frac{90^\circ}{T} \right)$$

$$t_c = Tm \sin \frac{90^\circ}{T} \quad \text{or} \quad t_c = \text{PCD} \sin \frac{90^\circ}{T}$$



6. SCREW THREADS

Pitch diameter = Outside diameter - $\frac{1}{2}$ pitch

Pitch circumference = $\pi \times$ pitch diameter

Lead = pitch $\times$ number of starts

Height of screw thread = $0,866 \times p$ where p = pitch of the screw thread

Depth of screw thread = $0,613 \times p$ where p = pitch of the screw thread

Number of turns = $\frac{\text{length}}{\text{lead}}$

Helix angle: $\tan \theta = \frac{\text{lead}}{\text{pitch diameter}}$

Leading tool angle = $90^\circ - (\text{helix} + \text{clearance angle})$

Following tool angle = $90^\circ + (\text{helix} - \text{clearance angle})$

7. CINCINNATI DIVIDING HEAD TABLE FOR THE MILLING MACHINE

Hole Circles											
Side 1	24	25	28	30	34	37	38	39	41	42	43
Side 2	46	47	49	51	53	54	57	58	59	62	66

Change Gears										
24 x 2	28	32	40	44	48	56	64	72	86	100

Simpl indexing = $\frac{40}{n}$ (where n = number of divisions)

Angular indexing = $\frac{n}{9^\circ}$

Change gears: $\frac{D_r}{D_n} = (A - n) \times \frac{40}{A}$ or $\frac{D_r}{D_n} = \frac{(A - n)}{A} \times \frac{40}{1}$
 (where A = chosen divisions) (where n = given divisions)

8. TAPERS

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

$$\text{Tailstock setover} = \frac{L(D - d)}{2 \times l} \quad (L = \text{Distance between centres})$$

$$\text{Tailstock setover} \quad \tan \frac{\theta}{2} = \frac{h}{l} \quad (l = \text{Taper Length})$$

9. DOVE TAILS

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

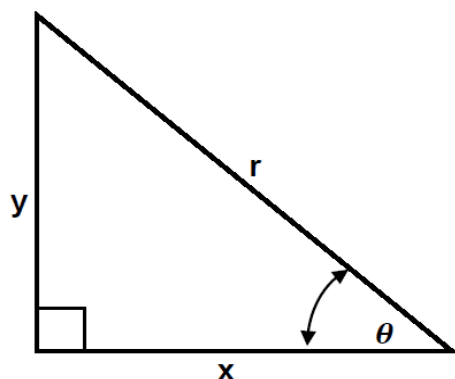
w = Minimum width of dovetail

W = Maximum width of dovetail

m = Distance between rollers

M = Distance over rollers

10. PYTHAGORAS' THEOREM AND TRIGONOMETRY



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

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

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

$$r^2 = x^2 + y^2$$

