Province of the
EASTERN CAPE
EDUCATION

NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2022

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

MARKS: **200**

TIME: **3 hours**

This question paper consists of pages 21, including a 4-page formula sheet.

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) (COMPULSORY)

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

1.1 What is the purpose of the Employment Equity Act (EEA No. 55 of 1998)?

A To create an environment of equality in the workplace.
B To promote non-discrimination in the workplace.
C Employer may not demote or promote an employee because of his/her HIV status.
D All of the above. (1)

1.2 Which ONE of the following options does NOT constitute the responsibility of the employer when applying first aid in the workplace?

A Provision of first aid equipment.
B Keeping record of daily activities in the workplace.
C Provision of first aid training.
D Provision of first aid service by qualified personnel. (1)

1.3 Which ONE of the following is an advantage of product workshop layout?

A Minimum material handling
B Low equipment cost
C Greater flexibility
D High production time (1)

1.4 Which ONE of the following is a reason why oil and grease must NOT come in contact with the oxygen fitting?

A It will extinguish the flame.
B It makes the oxygen fittings slippery.
C It will form a flammable mixture.
D It accumulates dust. (1)

1.5 Safety devices of a power-driven guillotine are used to prevent accidents during the cutting stroke of the machine. Which ONE of the following is NOT among the guillotine safety devices?

A Automatic sweep away
B Revolving warning light
C Pressure gauge
D Rear view mirror (1)

1.6 Which factor is important in the heat treatment of steel?

A Colour
B Temperature
C Length
D Shape (1)

[6]

QUESTION 2: SAFETY (GENERIC)

2.1 State THREE personal protective equipment (PPE) that must be worn, before an arc welding operation is carried out. (3)

2.2 State THREE safety measures that must be observed before using an arc welding machine. (3)

2.3 Give ONE reason why you must not force a drill bit into a workpiece during drilling operations. (1)

2.4 It is very important to clamp a small workpiece securely before drilling commences. Give ONE reason why it is important to do so. (1)

2.5 State TWO safety precautions that must be observed when handling gas cylinders. (2)

[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 State ONE test required to identify each of the following properties of metals.

3.1.1 Carbon content (1)

3.1.2 Ductility (1)

3.2 Metals are usually marked, or colour coded on the ends in order to know the carbon content or the type of steel they are. Why is it important to cut from the unmarked end of the metal? (1)

3.3 List the THREE types of case-hardening used in the metallurgical industry. (3)

3.4 Why is it impossible to use medium or high carbon steel in case-hardening? (1)

3.5 Briefly explain the heat treatment process of metal. (3)

3.6 State THREE factors that determine the hardness of steel during the heat treatments of metals. (3)

3.7 Give ONE property that can be achieved by annealing steel. (1)

[14]

QUESTION 4: MULTIPLE-CHOICE QUESTION (SPECIFIC)

Various options are provided as possible answers to the following questions. Choose the correct 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 FIGURE 4.1 below shows a rack and pinion as used in the movement of the saddle of a lathe.

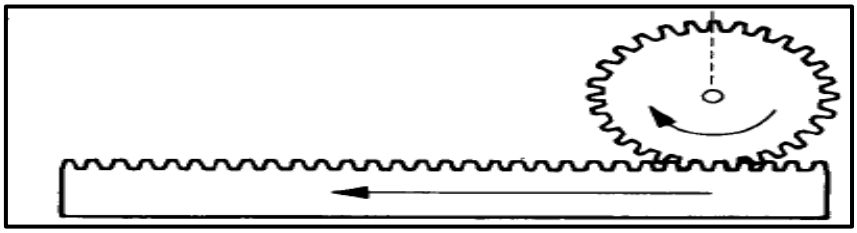


FIGURE 4.1

Choose the correct statement from those given below if the pinion is the driver gear.

A Converts linear motion to rotary motion
B Converts rotary motion to linear motion
C Converts reciprocating motion to reciprocating motion
D Converts linear motion to reciprocation motion (1)

4.2 Identify the type of milling operation shown in FIGURE 4.2.

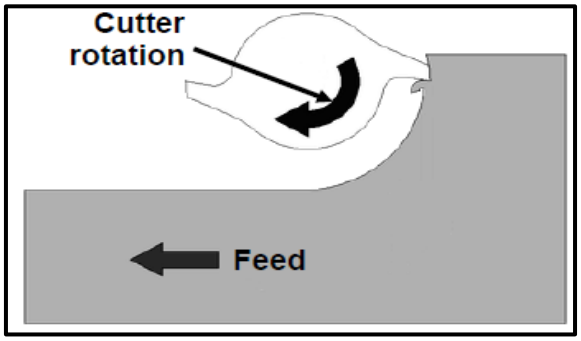


FIGURE 4.2

A Plain straight-tooth cutter
B Straight-tooth side-milling cutter
C Down-cutting
D Up-cutting milling (1)

4.3 Which ONE of the following is NOT a lathe component?

A Grinding wheel
B Feed shaft
C Cross slide dial
D Spindle-speed gear levers (1)

4.4 What does the abbreviation CNC stand for?

A Computer Numerical Control
B New Control Coding
C Company Numbers Control
D None of the above (1)

4.5 Calculate the strain when a tensile force causes a stress of 6 MPa in a workpiece. The material has an elasticity module of 3 GPa.

A 2×10^{-3}
B 500 MPa
C 1,8 x 10 mm
D 2×10^{3} (1)

4.6 The main reason for performing a hardness test on engineering materials is to determine the …

A elasticity of the material.
B resistance of the material against denting.
C corrosion of the material.
D fluidity of the metal. (1)

4.7 What does point 'B' denote in the stress/strain diagram in FIGURE 4.7?

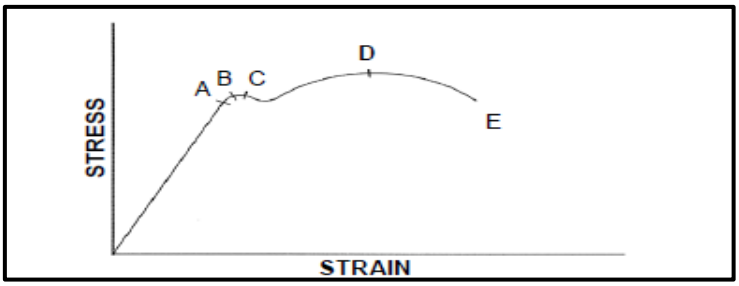


FIGURE 4.7

A Limit of proportionality
B Elastic limit
C Maximum stress
D Break stress (1)

4.8 Which ONE of the following is categorised as a mechanical drive?

A Screw drive
B Lead screw
C Gear drive
D White metal (1)

4.9 What will be the drill size for a M12 x 1,5 mm screw thread?

A 13,5 mm
B 1,5 mm
C 12 mm
D 10,5 mm (1)

4.10 A workpiece must have 13 gear teeth machined on its circumference. What type of indexing would you perform on this gear-blank?

A Angular indexing
B Simple indexing
C Rapid indexing
D New indexing (1)

4.11 If the module of a spur gear is 2,5 mm, what will be the addendum?

A 6 mm
B 3 mm
C 2,5 mm
D 9 mm (1)

4.12 What is the velocity ratio of the pulley system in FIGURE 4.12 below if the smaller pulley is the driver pulley?

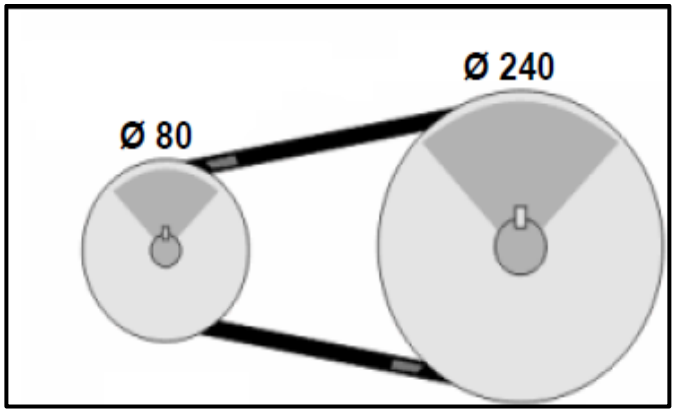


FIGURE 4.12

A 3 : 1
B 24 : 1
C 8 : 1
D 31 : 1 (1)

4.13 There are different types of machine processes in manufacturing. Which process would you use to cut an internal thread of a hole?

A Tapping
B Boring
C Slotting
D Spot facing (1)

4.14 Identify the symbol, shown in FIGURE 4.14 below, which relates to a pneumatic system.

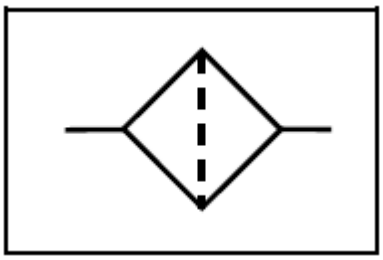


FIGURE 4.14

A Valve
B Filter
C Compressor
D Motor (1)

[14]

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

5.1 List the names of TWO types of steadies that are used when working on the centre lathe machine cutting a long work piece and STATE the ONE advantage of each. (2 x 2) (4)

5.2 Name TWO methods used to cut screw threads using a centre lathe. (2)

5.3 A circular shaft with an outside diameter of 85 mm must be machined with a two-start square thread of 12 mm pitch.

Calculate the following:

5.3.1 The lead of the thread (2)

5.3.2 The mean diameter of the thread (2)

5.3.3 The helix angle of the thread (2)

5.4 FIGURE 5.4 below shows a drawing of a keyway being cut with a 12 mm wide cutter on a 48 mm diameter shaft. Answer the following questions.

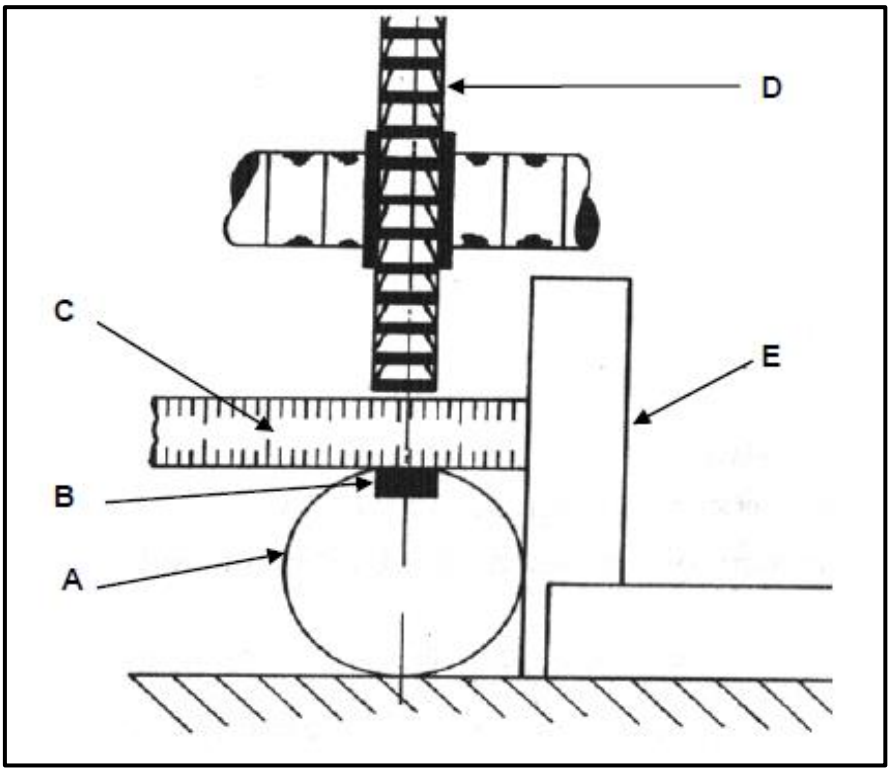


FIGURE 5.4

5.4.1 Identify the cutter used to cut the keyway. (1)

5.4.2 Label parts **A**–**E**. (5)

[18]

QUESTION 6: TERMINOLOGY (SPECIFIC)

6.1 With an aid of simple line diagrams, sketch the following milling methods:

6.1.1 Gang milling (2)

6.1.2 Straddle milling (2)

6.2 State ONE use of the following milling cutters.

6.2.1 T-slot milling cutter (1)

6.2.2 End mill cutter (1)

6.2.3 Slitting saw (1)

6.3 Define the term '*indexing*' as applied to milling processes. (1)

6.4 State the TWO milling methods. (2)

6.5 Calculate the differential indexing of a gear with 111 teeth, determining:

6.5.1 The indexing required. (**Hint**: Choose 120 divisions) (3)

6.5.2 The change gears required for the dividing head (4)

6.5.3 What is the meaning of the positive (+) sign and the negative (-) sign for the change of gears? (2)

6.6 The drawing in FIGURE 6.6 show two precision rollers placed in an internal dovetail. Use the given information to answer the question that follow.

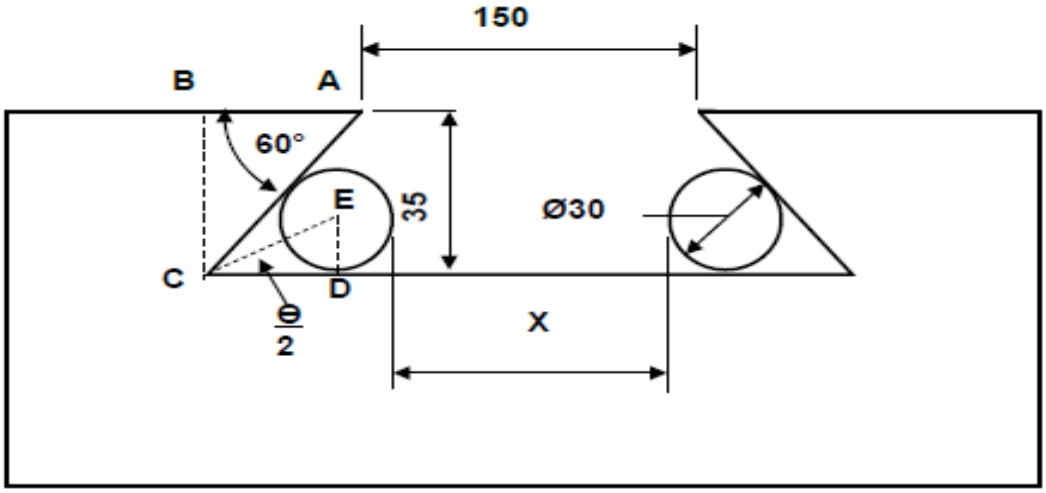


FIGURE 6.6

6.6.1 Calculate distance X between the rollers. (9)

[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

7.1 Explain how the following hardness tests are performed.

7.1.1 Brinell hardness tester (3)

7.1.2 Rockwell hardness tester (3)

7.2 What is *hardness*? (2)

7.3 Study the diagram shown in FIGURE 7.3 below and answer the questions that follow.

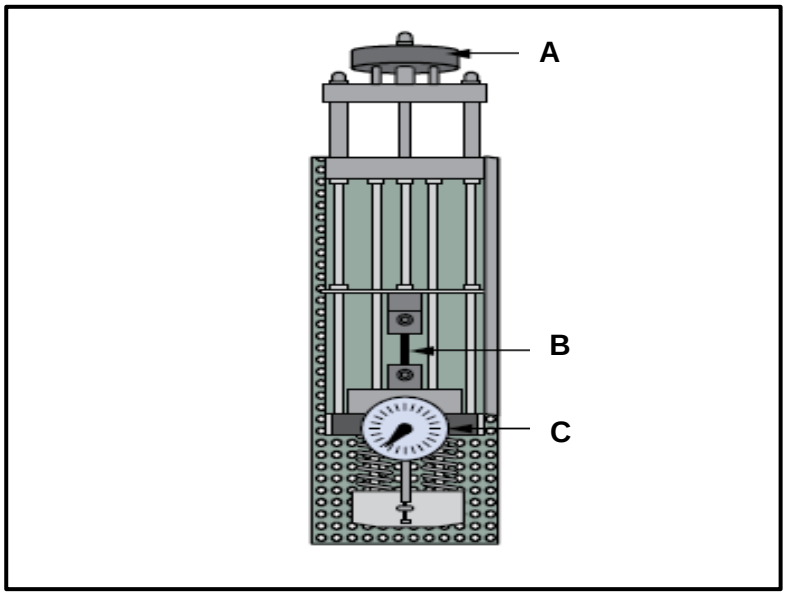


FIGURE 7.3

7.3.1 What is the name of the engineering apparatus in FIGURE 7.3? (1)

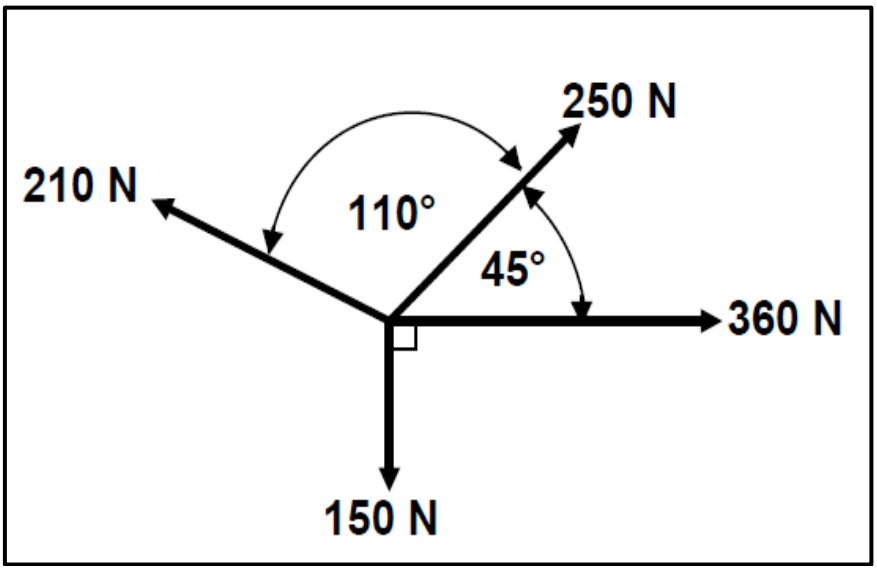
7.3.2 Label the parts **A–C**. (3)

7.4 Explain the function of a depth micrometre. (1)

[13]

QUESTION 8: FORCES (SPECIFIC)

8.1 FIGURE 8.1 below shows a system of forces with four concurrent applied forces.



Calculate the:

8.1.1 Sum of the horizontal components in magnitude and direction (3)

8.1.2 Sum of the vertical components in magnitude and direction (3)

8.1.3 Magnitude and direction of the resultant force and its equilibrant (6)

8.2 FIGURE 8.2 below shows a beam with two vertical applied point loads of 400 N and another 600 N and also a 50 N/m uniformly distributed load for a span of 6,5 m.

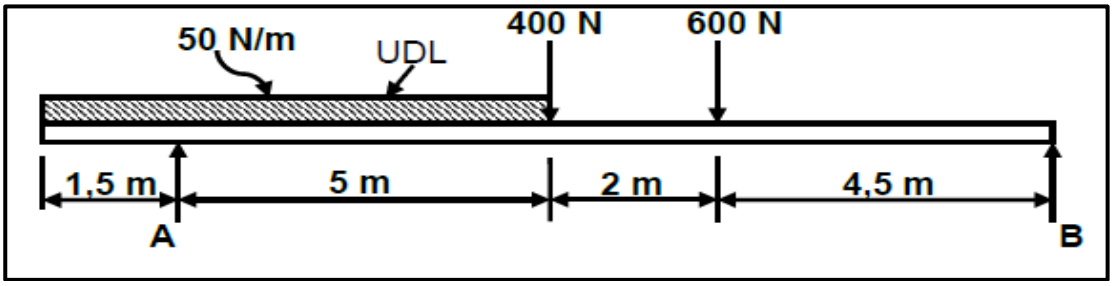


FIGURE 8.2

8.2.1 Calculate the magnitude of reactions R_A and R_B. (7)

8.3 A steel spoke of a bicycle wheel has a cross-sectional area of 2,2 mm^2 and a length of 300 mm. The nut of the spoke is tightened until the length increases by 0,2 mm.

Determine, by means of calculations, the tensile force in the spoke material. Take Young's elasticity modulus for the spoke material as 245 GPa. (9)

8.4 Study the stress/strain diagram.

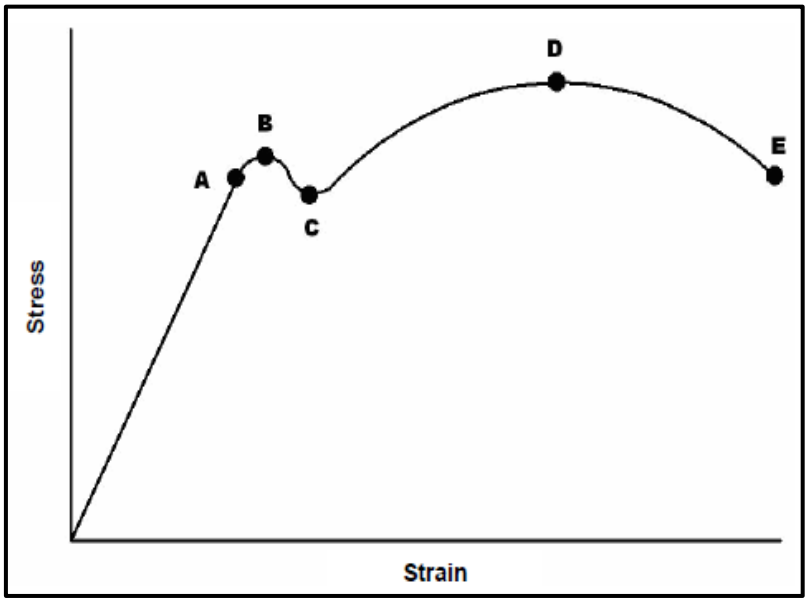


FIGURE 8.4

8.4.1 Explain the material behaviour at point **A**, **D** and **E**. (6)

[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

9.1 Classify the following materials as either thermoplastic composites or thermo hardened (thermosetting) composites:

9.1.1 Teflon PVC (1)

9.1.2 Vesconite (1)

9.1.3 Bakelite (1)

9.2 Why is it essential to use a cutting fluid on a milling machine or centre lathe? State TWO reasons. (2)

9.3 What are the possible consequences for failure to do maintenance? (3)

9.4 Give TWO reasons for using carbon fibre in the manufacturing of bicycle frames. (2)

9.5 In tabulated form compare ONE property and ONE use of the following plastic materials:

9.5.1 PVC (2)

9.5.2 Glass Fibre (2)

9.5.3 Nylon (2)

9.6 Name TWO aspects when preventative maintenance is conducted. (2)

[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1 A spur gear has 48 teeth and a module of 3.
Determine, by means of calculations, the following:

10.1.1 The pitch-circle diameter (2)

10.1.2 The addendum (1)

10.1.3 The clearance (2)

10.1.4 The dedendum (2)

10.1.5 The outside diameter of the gear (2)

10.1.6 Circular pitch (1)

10.2 Study FIGURE 10.2 below and answer the question that follows.

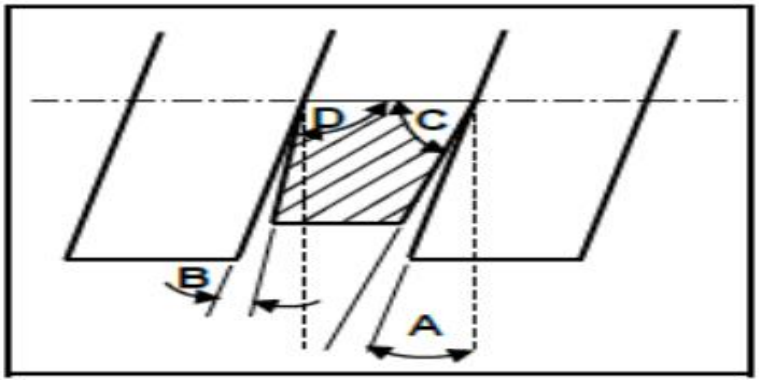


FIGURE 10.2

Label parts **A–D**. (4)

10.3 Why would a multi-start thread be preferred mostly to a single start thread? (2)

10.4 What does the abbreviation ISO stand for? (2)

[18]

QUESTION 11: SYSTEMS AND CONTROL (SPECIFIC)

11.1 Define the term *pressure*. (2)

11.2 A hydraulic system is used to lift a lathe. The specifications of the system are presented diagrammatically in FIGURE 11.2.

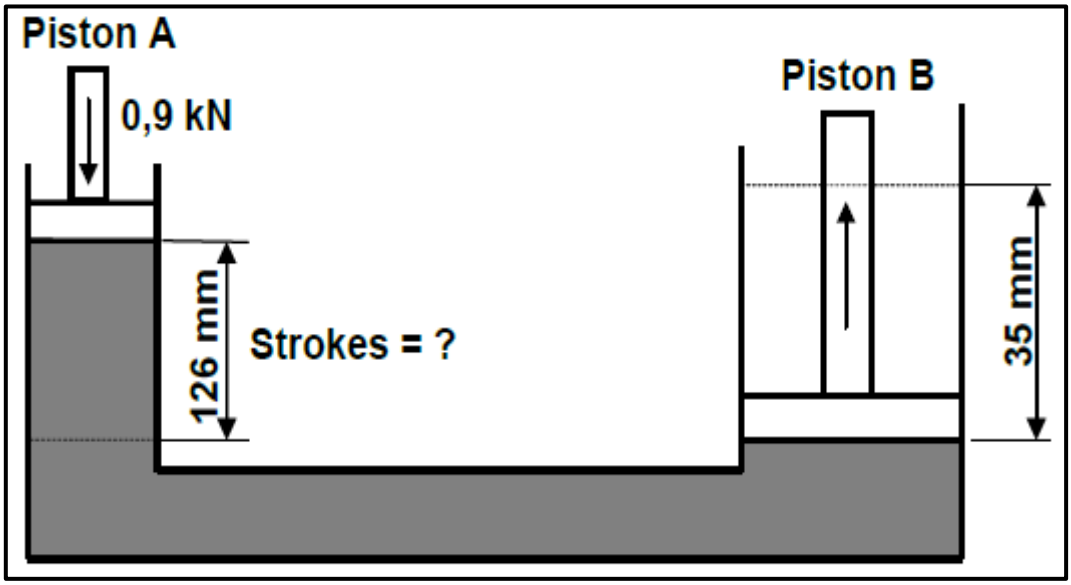


FIGURE 11.2

Calculate the following:

11.2.1 The fluid pressure in the hydraulic system when the system is in equilibrium. (4)

11.2.2 The number of strokes by piston A needed to lift piston B, 35 mm. The system has been equipped with the necessary one-way valves to supply adequate hydraulic fluid and pressure during the process. (9)

11.3 Define what is meant by *hydraulics*. (2)

11.4 A power saw's motor has a pulley, 130 mm in diameter, that turns at 1 205 rpm. The speed at which the driven pulley drives the saw blades is 385 rpm.

Calculate the diameter of the driven pulley. (2)

11.5 Make neat, freehand sketches of the ISO symbols representing the following pneumatic components:

11.5.1 Cylinder (1)

11.5.2 Accumulator (1)

11.5.3 Electric motor (1)

11.6 FIGURE 11.6 below shows a gear-drive system. A driver gear on the shaft of an electric motor has 24 teeth and meshes with a gear on a counter shaft with 40 teeth. On this counter shaft is another driver gear with 20 teeth that meshes with a gear with 48 teeth on a second counter shaft. The second counter shaft has a driver gear with 42 teeth which drives a gear with 90 teeth on the output shaft.

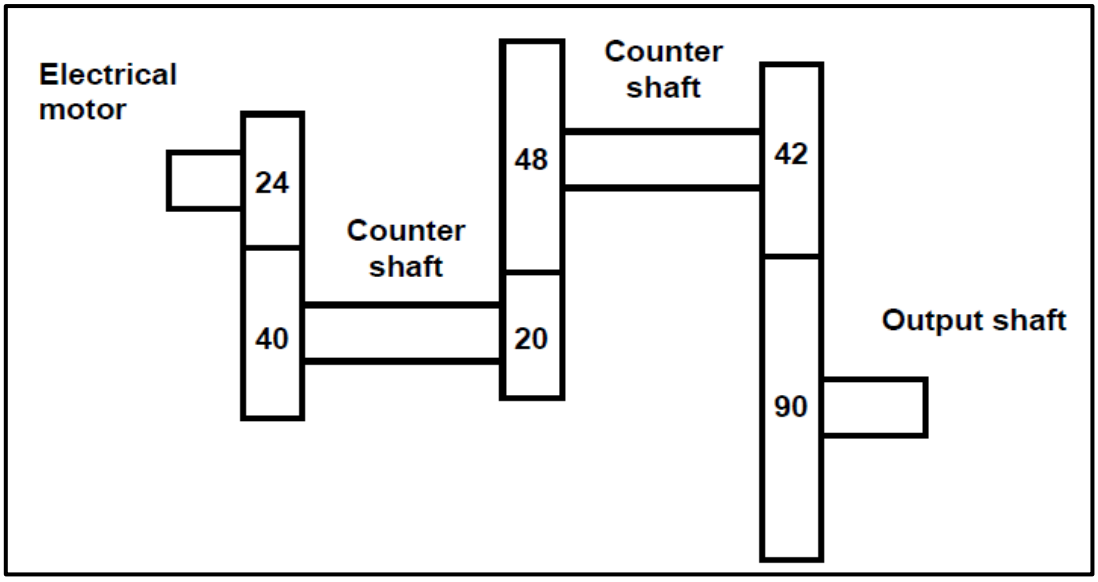


FIGURE 11.6

Calculate the:

11.6.1 Rotation frequency of the output shaft on the electric motor if the electric motor shaft rotates at 1 440 r/min (3)

11.6.2 Velocity ratio between the input and output shaft (2)

11.6.3 In which direction will the driven shaft rotate if the driver gear rotates anti-clockwise? (1)

[28]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY (FITTING AND MACHINING)

1. BELT DRIVES

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

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

$$N_1 D_1 = N_2 D_2$$

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

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

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

where T_1 = force in the tight side

T_2 = force in slack side

$T_1 - T_2$ = effective force (T_e)

2. STRESS AND STRAIN

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

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

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

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

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

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

3. HYDRAULICS

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

$$\text{Volume} = \text{Cross-sectional area} \times \text{stroke length}$$

4. KEYS AND KEYWAYS

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

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

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

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

5. GEAR DRIVES

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

$$N_1T_1 = N_2T_2$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6. SCREW THREADS

Pitch diameter = Outside diameter – ½pitch

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

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

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

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

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

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

$$\text{Simple indexing} = \frac{40}{n} \quad (\text{where n = number of divisions})$$

$$\text{Angular Indexing} = \frac{n}{9°}$$

$$\text{Change gears: } \frac{Dr}{Dn} = (A - n) \times \frac{40}{A} \quad \text{or} \quad \frac{Dr}{Dn} = \frac{(A - n)}{A} \times \frac{40}{1}$$

(where A = chosen divisions) (where n = given divisions)