basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

NOVEMBER 2023

MARKS: 200

TIME: 3 hours

This question paper consists of 19 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 9,81 m/s^2 or 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 Who is responsible for safe working conditions in the workplace?

A Workers' union
B Employer
C Employee
D Department of Labour (1)

1.2 Identify the Act that seeks to protect the worker from physical injuries in the workplace:

A Occupational Health and Safety Act (OHSA), 1993 (Act 85 of 1993)
B Labour Relations Act (LRA), 1995 (Act 66 of 1995)
C Employment Equity Act (EEA), 1998 (Act 55 of 1998)
D Basic Conditions of Employment Act (BCEA), 1997 (Act 75 of 1997) (1)

1.3 Which safety precaution must be applied when arc welding?

A Wet the work piece before welding to prevent overheating.
B Do not let oil and grease come into contact with the oxygen fittings.
C Use completely insulated electrode holders.
D Ensure that you always open the acetylene valve slowly. (1)

1.4 Identify the test shown in FIGURE 1.4 below.

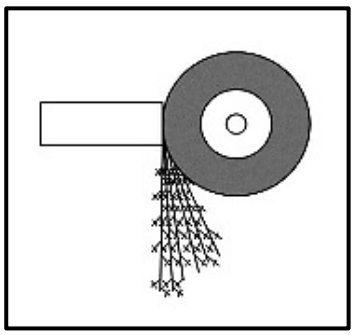


FIGURE 1.4

A Sound test
B Ultrasonic test
C Spark test
D Cutting test (1)

1.5 Which heat-treatment process relieves the internal stresses produced by machining, forging and welding?

A Normalising
B Case hardening
C Tempering
D Hardening (1)

1.6 FIGURE 1.6 below shows the changes in metal structures during the annealing process. What change is indicated at **Y**?

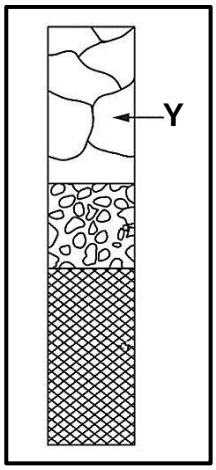


FIGURE 1.6

A Recovery
B Grain growth
C Recrystallisation
D Grain crystallisation (1)
[6]

QUESTION 2: SAFETY (GENERIC)

2.1 State TWO checks that must be done on injured persons before removing them from a danger zone. (2)

2.2 Name TWO safety devices fitted to power guillotines. (2)

2.3 State TWO safety precautions that must be conducted on a grinding wheel before it is fitted to a bench grinder. (2)

2.4 Name TWO safety devices fitted to gas-welding equipment. (2)

2.5 State TWO advantages of a workshop with a process layout. (2)
[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 Give ONE reason why the lengths of metals are normally marked or colour-coded at the ends. (1)

3.2 State ONE property of metals that can be determined by EACH of the following tests:

3.2.1 Sound test (1)

3.2.2 Bending test (1)

3.2.3 Machining test (1)

3.3 Why is metal soaked in heat when performing heat-treatment processes? (2)

3.4 State TWO methods of conducting case hardening. (2)

3.5 Explain how steel is annealed during heat-treatment processes. (3)

3.6 Name TWO quenching mediums that rapidly cool metal after heat-treatment processes. (2)

3.7 Which heat-treatment process follows the hardening process of a metal? (1)
[14]

QUESTION 4: MULTIPLE-CHOICE (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 your ANSWER BOOK, e.g. 4.15 E.

4.1 Identify the type of tool in FIGURE 4.1 below.

FIGURE 4.1

A Vernier height gauge
B Screw-cutting dial gauge
C Centre gauge
D Thread-pitch gauge (1)

4.2 Which ONE of the following is an advantage of cutting tapers on a lathe, using the compound slide method?

A Tapers with large angles can be cut.
B The automatic feed of the machine can be used.
C Long tapers can be cut.
D It causes the operator to become fatigued. (1)

4.3 Which part(s) of the dividing head is used to set the distances between the holes on the index plate?

A Sector arms
B Crank handle
C Index plates
D Change gears (1)

4.4 Identify the part of a CNC milling machine in FIGURE 4.4 below.

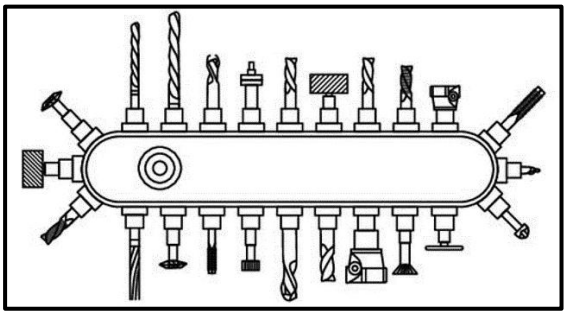


FIGURE 4.4

A Tool chuck
B Turret
C Tool magazine
D Tool shelf (1)

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

A Moment hardness tester
B Tensile hardness tester
C Brinell hardness tester
D Rockwell hardness tester (1)

4.6 Identify part **A** of the screw thread micrometer shown in FIGURE 4.6 below.

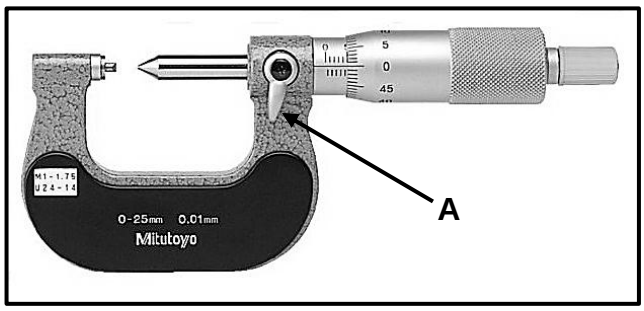


FIGURE 4.6

A Ratchet
B Lock
C Thimble
D Anvil (1)

4.7 What does the term *stress* mean?

A It is an indication of the reluctance of a body to move.
B It is the internal resistance in a body to an external load.
C It is an external force acting upon matter.
D It is the change in length of a material under a load. (1)

4.8 FIGURE 4.8 below shows the different stages of a pop rivet during the riveting process. Identify the type of force that is exerted onto the casing of the pop rivet.

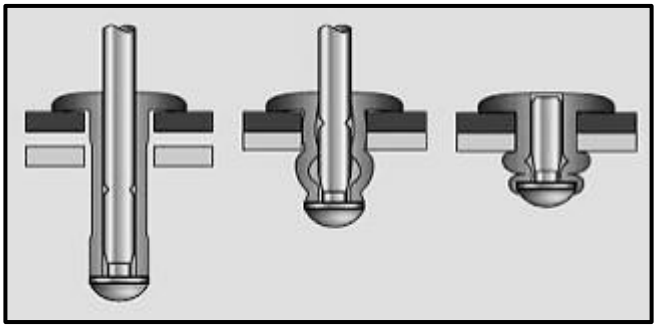


FIGURE 4.8

A Compressive force
B Shear force
C Tensile force
D Pushing force (1)

4.9 … is used to strengthen fibreglass when used for boats and motor vehicle bodies.

A Pigment
B Glass
C Polyester resin
D Glue (1)

4.10 Identify the material that bushes are made of:

A PVC
B Fibreglass
C Wood
D Vesconite (1)

4.11 What is the included angle of a metric V-screw thread?

A 90°
B 60°
C 29°
D 55° (1)

4.12 Identify the type of screw thread that produces a faster movement:

A Multiple-start screw thread
B V-screw thread
C Square thread
D Acme screw thread (1)

4.13 Identify the type of gear system in FIGURE 4.13 below.

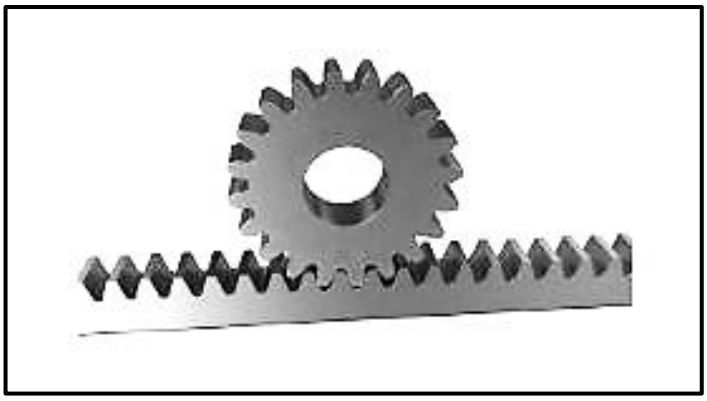


FIGURE 4.13

A Spur gear system
B Helical gear system
C Rack and pinion gear system
D Worm gear system (1)

4.14 Pneumatics uses compressed … to operate equipment.

A oil
B water
C nitrogen
D air (1)

[14]

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

5.1 State TWO disadvantages of cutting tapers on a centre lathe machine using the compound slide method. (2)

5.2 FIGURE 5.2 below shows a diagram of a taper with an included angle of 8°, which should be machined between two centres.

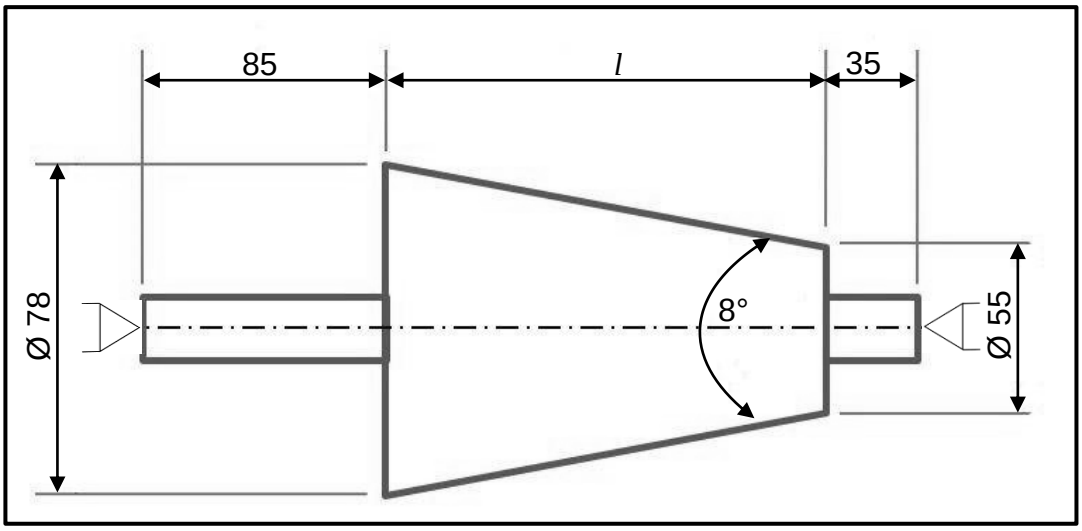


FIGURE 5.2

5.2.1 Calculate the length of the taper. (4)

5.2.2 Calculate the set-over of the tailstock required to cut the taper in FIGURE 5.2. (4)

5.3 Calculate the following dimensions for a parallel key suitable for a 83 mm diameter shaft that must be used in an industrial lathe machine:

5.3.1 Width (2)

5.3.2 Thickness (2)

5.3.3 Length (2)

5.4 Label **A** and **B** in FIGURE 5.4 below showing the straddle milling process.

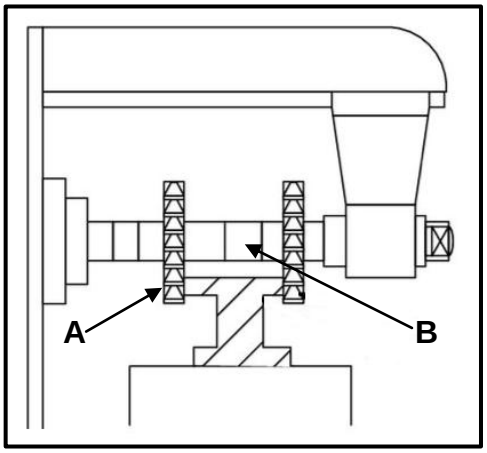


FIGURE 5.4

(2)
[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

6.1 A machinist in a milling workshop is tasked to cut a spur gear with 180 teeth and a module of 2,5.

Calculate the following:

6.1.1 Pitch-circle diameter (2)

6.1.2 Dedendum (2)

6.1.3 Outside diameter (2)

6.2 FIGURE 6.2 below shows an external dovetail component for a machine vice.

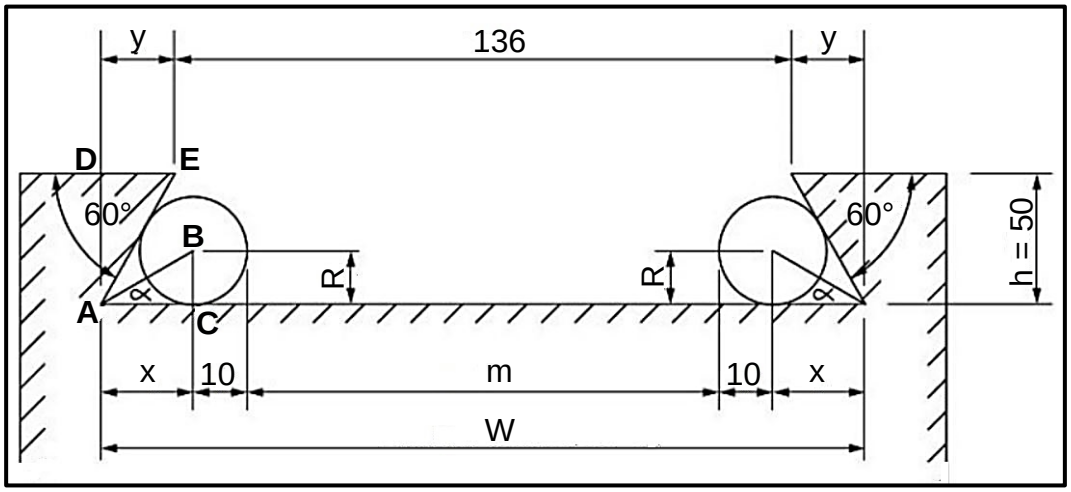


FIGURE 6.2

Calculate the following:

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

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

6.3 A spur gear with 89 teeth must be cut on a milling machine with the use of a dividing head. The dividing head has a ratio of 40 **:** 1.

HINT: Use A = 90 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 Describe any TWO constraints/disadvantages that can be experienced during the practical application of balancing a work piece on a lathe when using a face plate. (2)

[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

7.1 What instrument will be used to measure the diameter of the indentation on the test material when using a Brinell hardness tester? (1)

7.2 State TWO methods to determine the Brinell hardness number. (2)

7.3 State ONE of the functions of a moment tester. (1)

7.4 Describe the working principle of a tensile tester. (3)

7.5 What is the difference between a *depth micrometer* and a *screw-thread micrometer* with regard to the scales on the barrels of the instruments? (1)

7.6 State THREE ways how to assess the hardness of metals. (3)

7.7 Mr Patterson is using a depth micrometer to measure a hole. The measurement reading on the micrometer is 5,94 mm and a 50–75 mm interchangeable rod is used. What will be the CORRECT depth measurement of the hole? (2)

[13]

QUESTION 8: FORCES (SPECIFIC)

8.1 FIGURE 8.1 indicates a system of forces with three pulling forces and one pushing force acting onto the same point.

HINT: Draw and complete the diagram in FIGURE 8.1. Show ALL the horizontal and vertical components before you do the calculation.

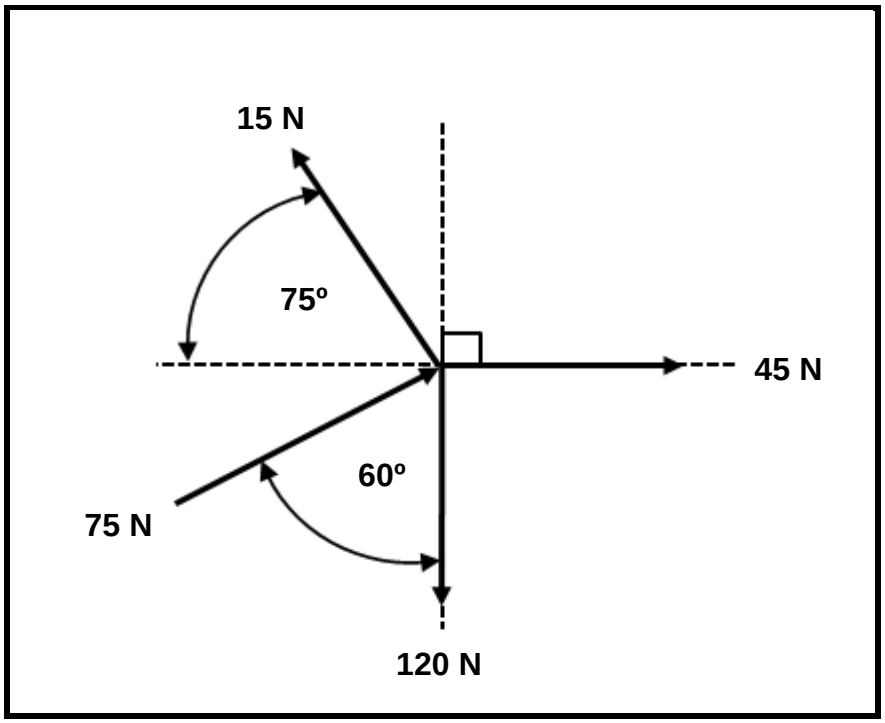


FIGURE 8.1

Calculate the following:

8.1.1 Sum of the horizontal components (4)

8.1.2 Sum of the vertical components (4)

8.1.3 Resultant (2)

8.1.4 Angle and direction of the resultant (4)

8.2 FIGURE 8.2 below shows a uniform beam that is supported by two vertical supports, **A** and **B**. TWO vertical point loads are exerted onto the beam. Calculate the magnitude of the reaction forces in **A** and **B**.

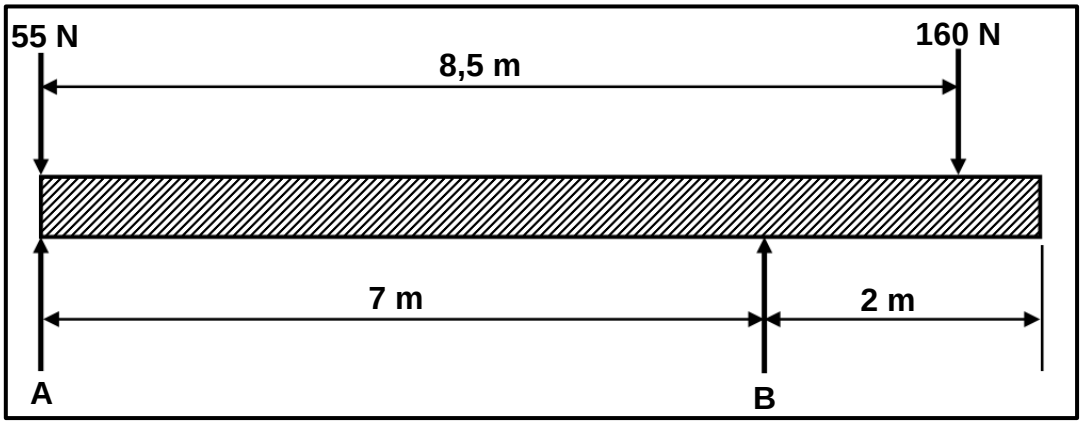


FIGURE 8.2 (9)

8.3 A mild steel tie bar has a diameter of 20 mm and is 4 m in length. The maximum stress in the steel is 640 MPa and Young's modulus of elasticity for mild steel is 200 GPa. The safety factor is 3.

Calculate the following:

8.3.1 The maximum load the tie bar may carry in kN (6)

8.3.2 The safe working stress in MPa (4)
[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

9.1 Preventative maintenance can be divided into two subgroups. Name the TWO subgroups. (2)

9.2 State THREE advantages of belt drives compared to gear drives. (3)

9.3 Name THREE types of belt drives. (3)

9.4 Which material is commonly used for non-stick coatings on frying pans? (1)

9.5 State TWO uses of EACH of the following composites:

9.5.1 Polyvinyl chloride (PVC) (2)

9.5.2 Bakelite (2)

9.5.3 Fibreglass (2)

9.6 State whether EACH of the following materials is a thermo-hardened or a thermoplastic composite:

9.6.1 Carbon fibre (1)

9.6.2 Nylon (1)

9.6.3 Bakelite (1)
[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1 Draw a cross-sectional view of a square screw thread. Label the crest and the root of the screw thread. (3)

10.2 A two-start square screw thread needs to be cut on a lathe. The lead of the thread is 25 mm and the crest diameter is 70 mm. The clearance angle must be 3°.

Calculate the following:

10.2.1 Pitch diameter (4)

10.2.2 Helix angle of the screw thread (4)

10.2.3 Leading tool angle (2)

10.2.4 Following tool angle (2)

10.3 Label parts **A**–**C** of the V-screw thread shown in FIGURE 10.3 below.

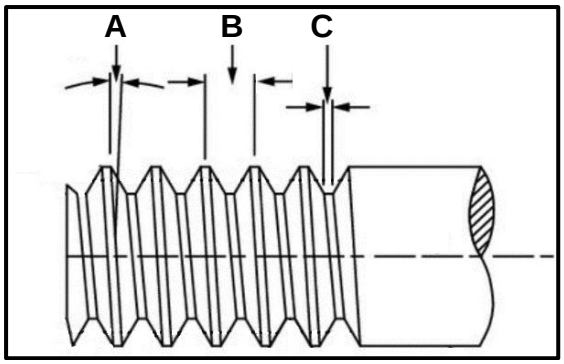


FIGURE 10.3

(3)
[18]

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

11.1 FIGURE 11.1 below shows a hydraulic system.

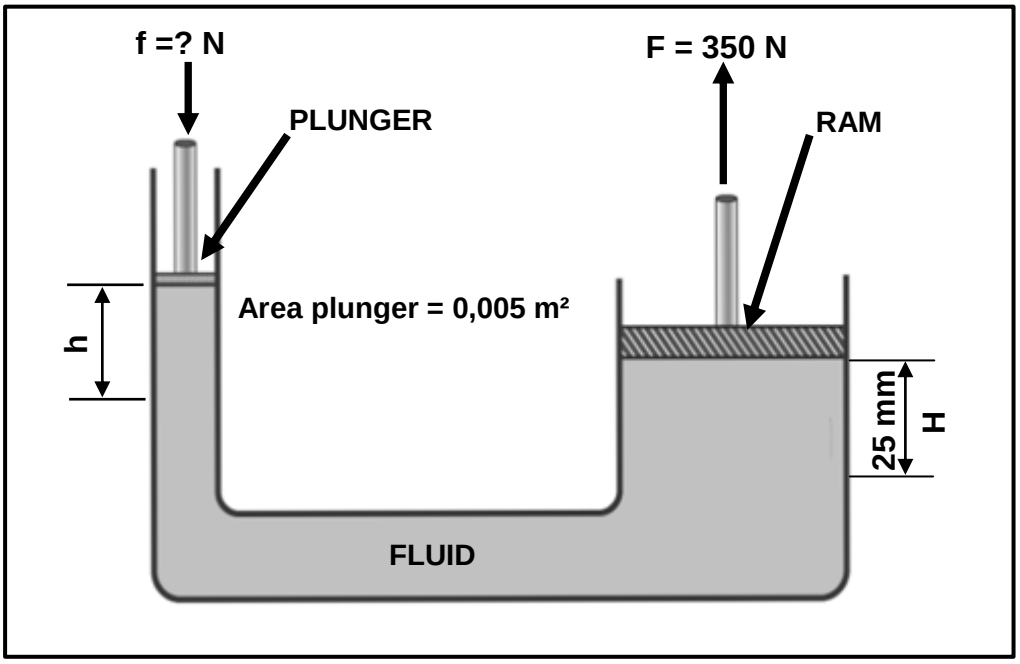


FIGURE 11.1

Calculate the following:

11.1.1 The area of the ram if the diameter of the cylinder is 110 mm (2)

11.1.2 Force applied on the small piston (plunger) (3)

11.1.3 The displacement **h** of the small piston (plunger) in mm (3)

11.2 What is the purpose of using pressure gauges in a hydraulic system? (2)

11.3 State ONE advantage of applying pneumatics in a system. (1)

11.4 An electrical motor with a driver pulley of 75 mm diameter rotates at 25 r/sec. The motor drives a pulley of 350 mm diameter by means of a flat belt.

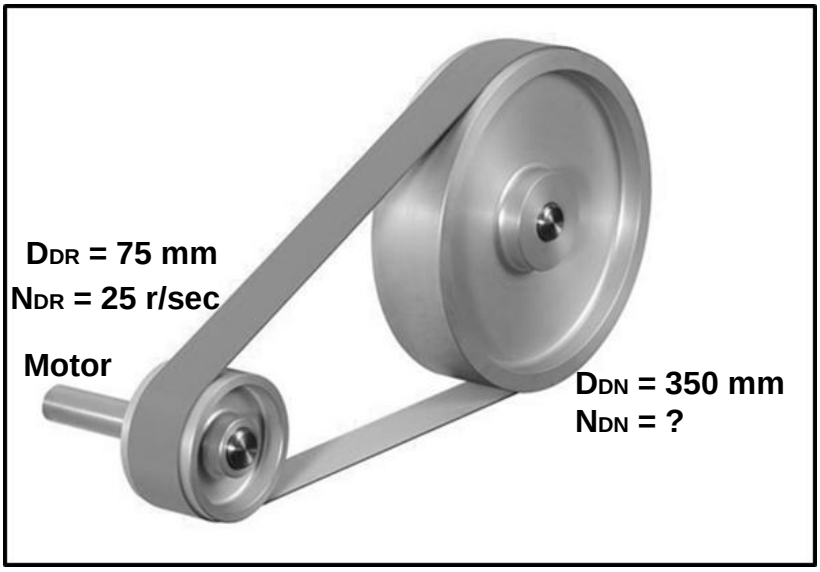


FIGURE 11.4

Calculate the following:

11.4.1 The rotational frequency of the driven pulley in r/sec (4)

11.4.2 The belt speed in $m.s^{-1}$ (2)

11.5 What protects a V-belt against sudden loads so that it cannot get damaged? (1)

11.6 FIGURE 11.6 below shows a gear drive system on the shaft of an electric motor.

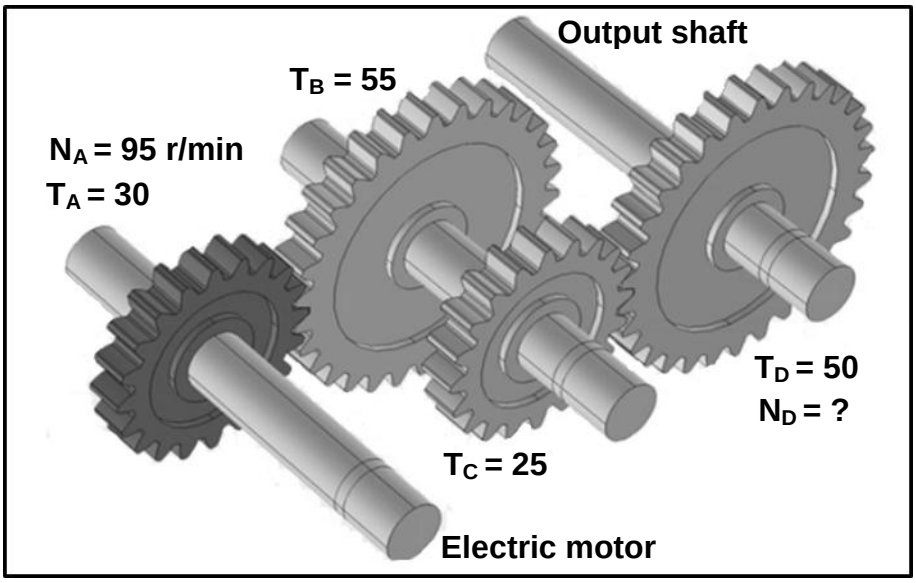


FIGURE 11.6

Calculate the following:

11.6.1 The rotation frequency of the output shaft in r/min (4)

11.6.2 The power transmitted if the torque in the system is 120 Nm. Show the CORRECT unit with the final answer. (3)

11.7 A fitter applies a force of 300 N on a ring spanner. What must the length of the ring spanner be to generate a torque of 135 Nm? (3)

[28]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY: FITTING AND MACHINING

1. BELT DRIVES

1.1 *Belt speed* = $\frac{\pi DN}{60}$

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

1.3 *Belt mass = Area × Length × Density* *(A = thickness × width)*

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

1.5 *Belt length (flat) = [(D + d) × 1,57] + (2 × centre distance)*

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

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

1.8 *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 *Ratio between tight side and slack side* = $\frac{T_1}{T_2}$

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

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

2. STRESS AND STRAIN

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

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

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

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

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

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

3. HYDRAULICS

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

3.2 *Volume = Area × Stroke length (l or s)*

3.3 *Work done = Force × Distance*

3.4 $P_A = P_B$

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

4. GEAR DRIVES

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

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

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

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

4.5 $Torque = Force \times Radius$

4.6 $Torque\ transmitted = Gear\ ratio \times Input\ torque$

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

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

OR

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

4.9 $Outside\ diameter\ (OD) = PCD + 2(m)$

4.10 $Addendum = Module$ OR $a = m$

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

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

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

4.14 $Circular\ pitch\ (CP) = m \times \pi$

4.15 $Working\ depth\ (WD) = 2 \times m$ OR $Working\ depth\ (WD) = 2 \times a$

5. PULLEYS

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

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

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

6. KEYWAYS

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

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

6.3 *Length (L) = 1,5 × D*
Where:
D = Diameter of shaft

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

7. CINCINNATI DIVIDING HEAD TABLE FOR 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											
Gears	*24 x 2*	*28*	*32*	*40*	*44*	*48*	*56*	*64*	*72*	*86*	*100*

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

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

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

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

10. SCREW THREADS

10.1 *Mean diameter = Outside diameter – (½ × Pitch)* *OR* $D_m = OD - \frac{P}{2}$

10.2 *Effective diameter (D_{eff}) = Pitch diameter (D_p) = Mean diameter (D_m)*

10.3 *Lead = Pitch × Number of starts*

10.4 *Height of screw thread = 0,866 × Pitch (P)*

10.5 *Depth of screw thread = 0,613 × Pitch (P)*

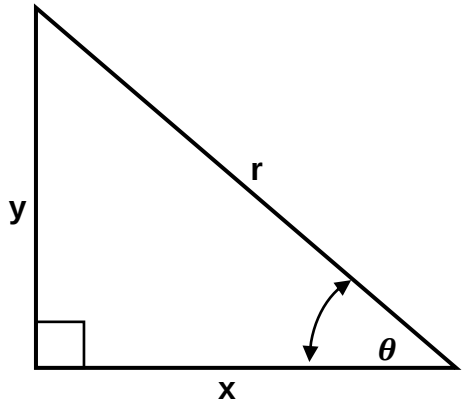
10.6 *Helix angle: Tan* $\theta = \frac{Lead}{\pi \times D_m}$

10.7 *Leading angle = 90° – (Helix angle + Clearance angle)*

10.8 *Following angle = 90° + (Helix angle – Clearance angle)*

10.9 $D_P = D_N - (0{,}866 \times P)$

11. PYTHAGORAS' THEOREM AND TRIGONOMETRY



11.1 $Sin\ \theta = \frac{y}{r}$

11.2 $Cos\ \theta = \frac{x}{r}$

11.3 $Tan\ \theta = \frac{y}{x}$

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