basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

**SENIOR CERTIFICATE EXAMINATIONS/
NATIONAL SENIOR CERTIFICATE EXAMINATIONS**

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

2021

MARKS: 200

TIME: 3 hours

This question paper consists of 17 pages and a 5-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	14
5	Terminology (Lathe and Milling Machine)	18	15
6	Terminology (Indexing)	28	24
7	Tools and Equipment	13	12
8	Forces	33	31
9	Maintenance	18	15
10	Joining Methods	18	15
11	Systems and Control (Drive Systems)	28	24
	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 A.

1.1   Which Act promotes non-discrimination in the workplace?

       A   Employment Relations Act
       B   Employment Equity Act
       C   Employment Conditions Act
       D   Employment Health and Safety Act   (1)

1.2   Which statement below is CORRECT in terms of the recommendations for the application of first aid? Do NOT …

       A   remove anything that is stuck to the wound.
       B   check the pulse of the patient.
       C   cool the patient's wound with cold water.
       D   pay attention to blood loss or breathing difficulties.   (1)

1.3   Workshops with more than five workers must be equipped with a first-aid box. Which Act determines the content of the first-aid box?

       A   Employment Relations Act, 1998 (Act 56 of 1998)
       B   Employment Equity Act, 1998 (Act 55 of 1998)
       C   Occupational Health and Safety (OHS) Act, 1993 (Act 85 of 1993)
       D   Labour Relations Act, 1995 (Act 66 of 1995)   (1)

1.4   Which test can be done to determine the ductility of a metal?

       A   Sound test
       B   Hardness test
       C   Bending test
       D   Machining test   (1)

1.5   What is the purpose of case hardening during the heat-treatment process? To produce a …

       A   tough case over a hard core
       B   hard case over a thin core
       C   hard case over a hard core
       D   hard case over a tough core   (1)

1.6   Which process causes severe scaling of a work piece during the heat treatment of ferrous metals?

       A   Normalising
       B   Annealing
       C   Tempering
       D   Hardening   (1)

   **[6]**

QUESTION 2: SAFETY (GENERIC)

2.1 First aid is a basic treatment to help an injured person and usually occurs in three stages. Name the THREE stages. (3)

2.2 State TWO safety precautions when using a drill press after it has already been switched on. (2)

2.3 Why must the electrode holder of an arc welding machine be isolated? (1)

2.4 State TWO disadvantages of the process workshop layout. (2)

2.5 State TWO advantages of the product workshop layout. (2)
[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 All heat-treatment processes involve the heating and cooling of metals according to a time-temperature cycle. Describe this cycle. (3)

3.2 Name any THREE types of quenching mediums used during the heat-treatment processes. (3)

3.3 Give ONE reason why steel is annealed. (1)

3.4 Carbon steel is classified into three groups. Name the THREE groups. (3)

3.5 In FIGURE 3.5 below the iron-carbon equilibrium diagram is shown. Label the diagram as indicated, from **A** to **D**. Write down only the answer next to the letter (A–D) in the ANSWER BOOK.
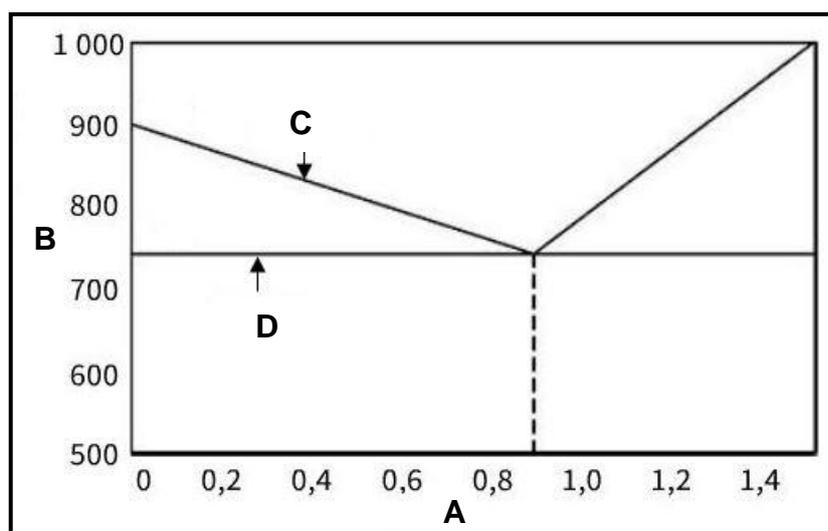
FIGURE 3.5 (4)
[14]

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.

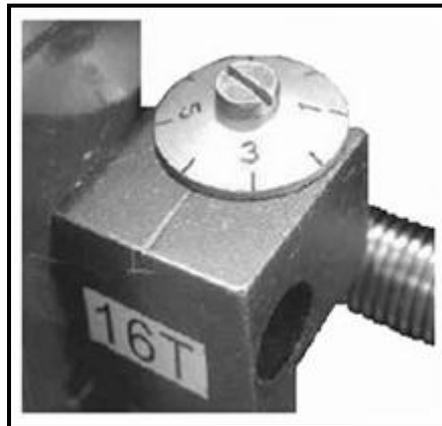4.1   Identify the lathe component shown in FIGURE 4.1.

FIGURE 4.1

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

4.2   Identify the CORRECT statement about using a centre lathe:

    A   Do not leave the machine while it is in motion.
    B   Remove cutting while the machine is in motion.
    C   Take measurements while the machine is in motion.
    D   Adjust guards while the machine is in motion.   (1)

4.3   What is meant by the term *absolute programming* when using a CNC milling machine?

    A   Taking the distance of one point to the next on the work piece
    B   Using dimensions with all points of reference being taken from a common point
    C   The sequence of programming for selecting cutting tools
    D   The location of each operation in coordinate format   (1)

4.4   Tool change takes place automatically between processes on a CNC milling machine, when the …

    A   machine is switched on.
    B   work piece has been set up completely.
    C   tool change has been programmed.
    D   tool have to be replaced by the operator.   (1)

4.5   What type of material is the indenter of a Brinell hardness tester made of?

          A   Brass
          B   Graphite
          C   Copper
          D   Carbide   (1)

4.6   Identify the type of tester in FIGURE 4.6.

FIGURE 4.6

          A   Tensile tester
          B   Beam tester
          C   Equilibrium tester
          D   Hardness tester   (1)

4.7   What is meant by the term *tensile stress*?

          A   An external tensile force acts on a matter.
          B   An external force is present when an internal tensile load is applied.
          C   An internal force present when an external tensile load is applied
          D   An internal tensile force present when an external compression load is
                 applied.   (1)

4.8   Identify the type of stress caused in the rivet in FIGURE 4.8.
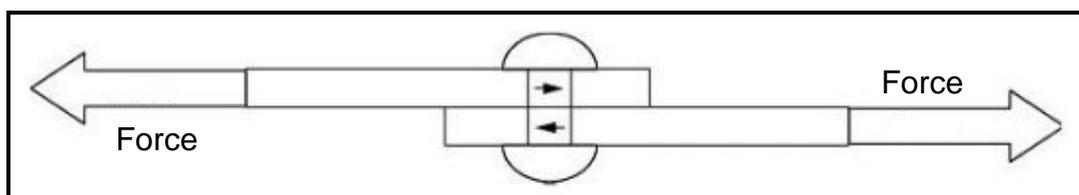
FIGURE 4.8

          A   Shear stress
          B   Compressive stress
          C   Tensile stress
   D   Form stress   (1)

4.9   Vesconite is best suited for …

A   the lathe chuck.
B   bearings and bushes.
C   lead screws.
D   the coating of a frying pan.   (1)

4.10   What is polyvinyl chloride (PVC) used for?

A   Compressor pistons
B   Cutting tools
C   Water pipes
D   Grinding wheels   (1)

4.11   Which statement best describes the metric square thread?

The metric square thread is a screw thread of which … are approximately equal.

A   the length of the screw thread, the thickness of the screw thread and the space between the threads
B   the width of the screw thread, the depth of the screw thread and the space between the threads
C   only the width of the screw thread and the depth of the screw thread
D   only the depth of the screw thread and the space between the threads   (1)

4.12   Multiple-start screw threads are used when …

A   great strength is required.
B   quick travel is required.
C   great strength and quick travel is required.
D   slow travel is required.   (1)

4.13   A Joule is defined as the work done when a force of …

A   1 N is exerted over a distance of 1 m in the direction of the force.
B   1 N is exerted over a distance of 1 m in the opposite direction of the force.
C   10 N is exerted in the direction of the force.
D   10 N is exerted over a distance of 1 m in the direction of the force.   (1)

4.14   In FIGURE 4.14 a symbol of a hydraulic component is shown. Identify the symbol.
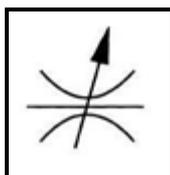
FIGURE 4.14

A   Fixed-flow control valve
B   Directional control valve
C   Filter
D   Adjustable-flow control valve   (1)
[14]

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

5.1   State THREE disadvantages of cutting a taper on a centre lathe using the compound slide method.   (3)

5.2   FIGURE 5.2 shows a taper with an included angle of 10° which should be machined between two centres. Answer the questions that follow.
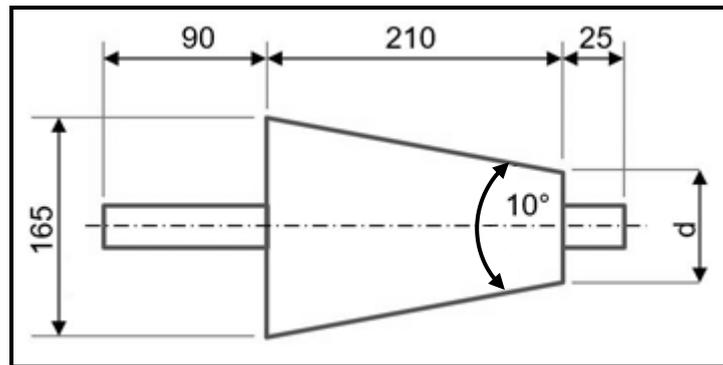
FIGURE 5.2

5.2.1   Calculate the small diameter of the taper.   (4)

5.2.2   Calculate the set-over of the tailstock.   (3)

5.3   Calculate the following dimensions for a parallel key suitable for a 55 mm diameter shaft.

5.3.1   Width   (2)

5.3.2   Thickness   (2)

5.3.3   Length   (2)

5.4   State TWO advantages of up-cut milling.   (2)

[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

6.1 Thabo is a machinist and is tasked to cut a spur gear with a pitch-circle diameter of 136 mm and a module of 4.

Calculate the following:

6.1.1 Number of teeth (2)

6.1.2 Dedendum (2)

6.1.3 Outside diameter (2)

6.1.4 Circular pitch (2)

6.2 FIGURE 6.2 shows a drawing of a dovetail. Answer the questions that follow.
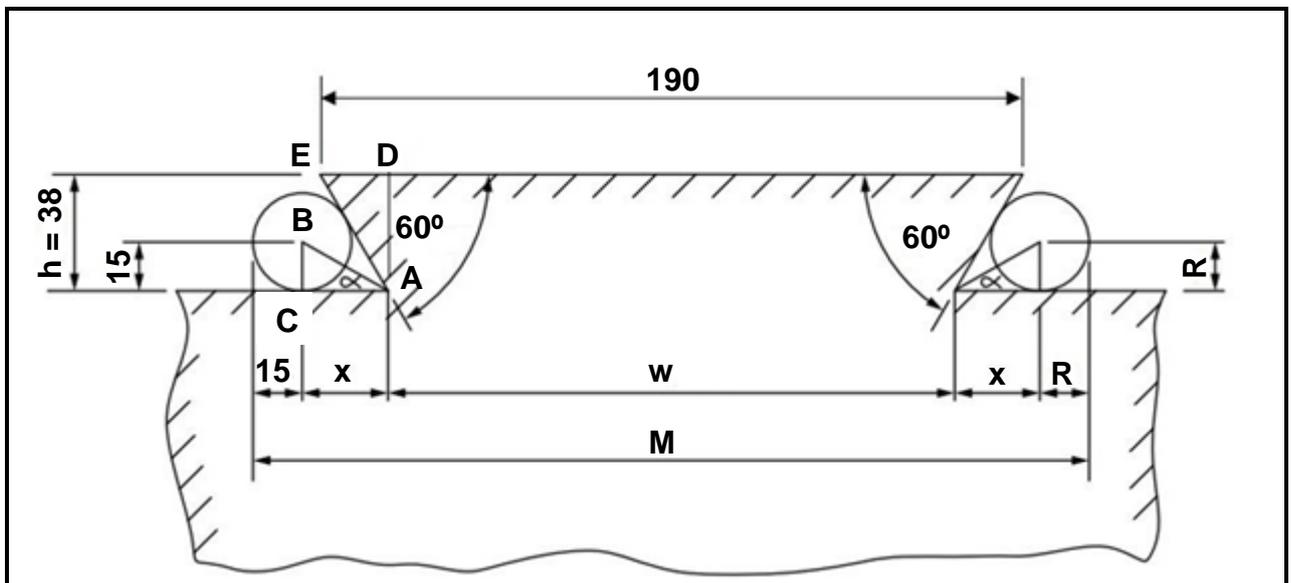
FIGURE 6.2

Calculate the following:

6.2.1 Minimum width of the dovetail (w) (6)

6.2.2 Distance over the precision rollers (M) (6)

6.3 Amanda is a machinist and is required to mill a spur gear with 163 teeth. The dividing head she is using 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 needed. (5)

[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

7.1   Determine the depth micrometer reading shown in FIGURE 7.1.
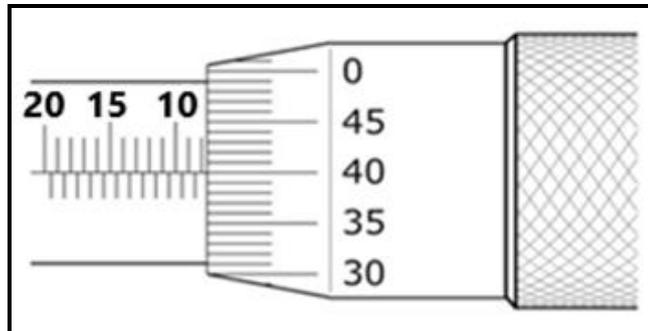
FIGURE 7.1   (2)

7.2   Explain step by step how you will conduct a Brinell hardness test to determine the hardness of steel.   (6)

7.3   State THREE aspects that are determined when a tensile test is conducted on a material.   (3)

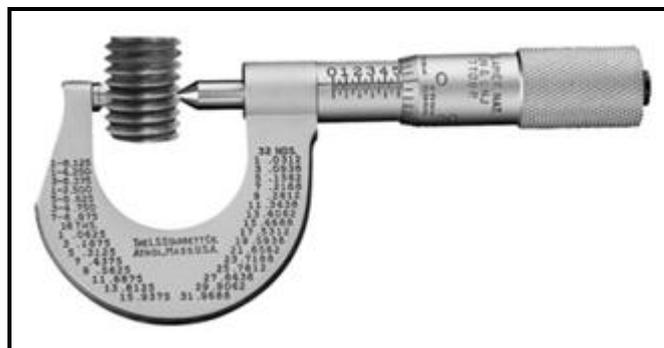7.4   FIGURE 7.4 shows a precision measuring instrument. Answer the questions that follow.

FIGURE 7.4

7.4.1   Identify the instrument in FIGURE 7.4.   (1)

7.4.2   State the function of the instrument.   (1)
[13]

QUESTION 8: FORCES (SPECIFIC)

8.1   FIGURE 8.1 shows a system of forces with four forces acting on the same point.
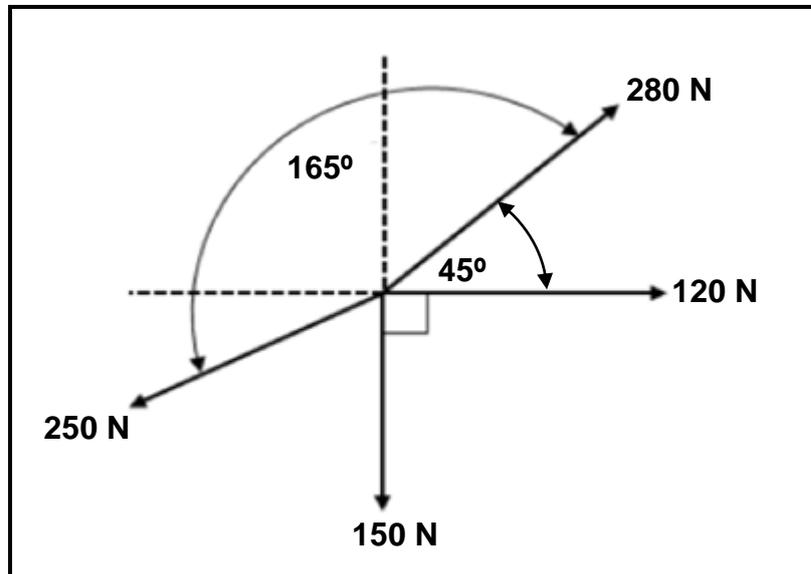
FIGURE 8.1

Calculate the following:

8.1.1   Sum of the horizontal components (HC)   (4)

8.1.2   Sum of the vertical components (VC)   (4)

8.1.3   Magnitude of the equilibrium force   (3)

8.1.4   Direction of the equilibrium force   (3)

8.2 FIGURE 8.2 shows a beam supported by two vertical supports, **A** and **B**. Two vertical point loads of 345 N and 165 N, and a uniformly distributed load of 95 N/m, are exerted onto the beam.
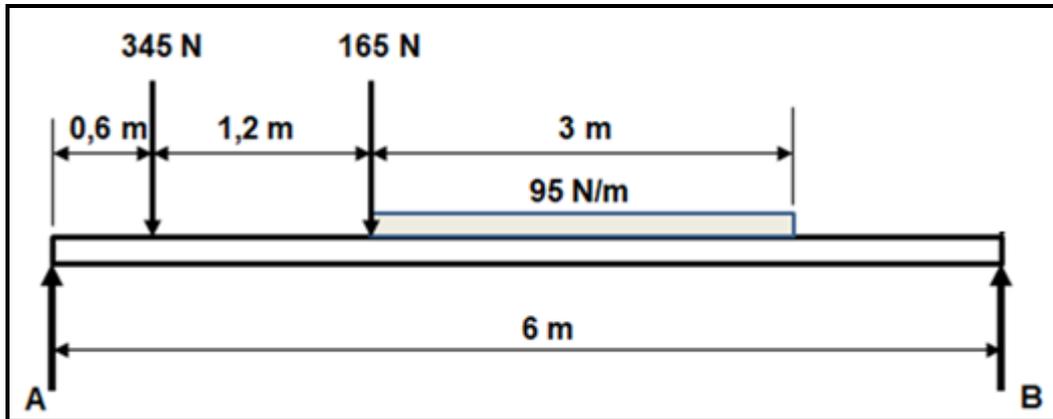
FIGURE 8.2

Calculate the magnitude of the reactions at supports **A** and **B**. (8)

8.3 A tensile force of 50 kN is applied to a brass bush. The outside diameter of the brass bush is 58 mm and the inside diameter is 42 mm. The original length of the brass bush was 68 mm.

Calculate the following:

8.3.1 Resistance area of the bush (2)

8.3.2 Stress in the material in MPa (3)

8.3.3 Strain (final length of the bush is 68,975 mm) (3)

8.3.4 Young's modulus of elasticity for the material (3)

[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

9.1   State TWO consequences of a lack of preventative maintenance of mechanical drive systems.   (2)

9.2   Give TWO reasons for the malfunctioning of chain drives.   (2)

9.3   State TWO procedures that can be followed to reduce the wear on a gear drive system.   (2)

9.4   State TWO properties of EACH of the following materials:

    9.4.1   Polyvinyl chloride (PVC)   (2)

    9.4.2   Carbon fibre   (2)

    9.4.3   Bakelite   (2)

9.5   Classify the following materials as thermoplastic composites or thermo-hardened (thermosetting) composites:

    9.5.1   Vesconite   (1)

    9.5.2   Glass fibre   (1)

    9.5.3   Carbon fibre   (1)

9.6   Name ONE use of EACH of the following materials:

    9.6.1   Teflon   (1)

    9.6.2   Carbon fibre   (1)

    9.6.3   Nylon   (1)
[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1   A two-start square threaded bar needs to be manufactured. The lead of the thread is 40 mm and the crest diameter is 85 mm. The clearance angle must be 3°.

Calculate the following:

10.1.1   Mean diameter   (4)

10.1.2   Helix angle of the thread   (4)

10.1.3   Leading tool angle   (2)

10.1.4   Following tool angle   (2)
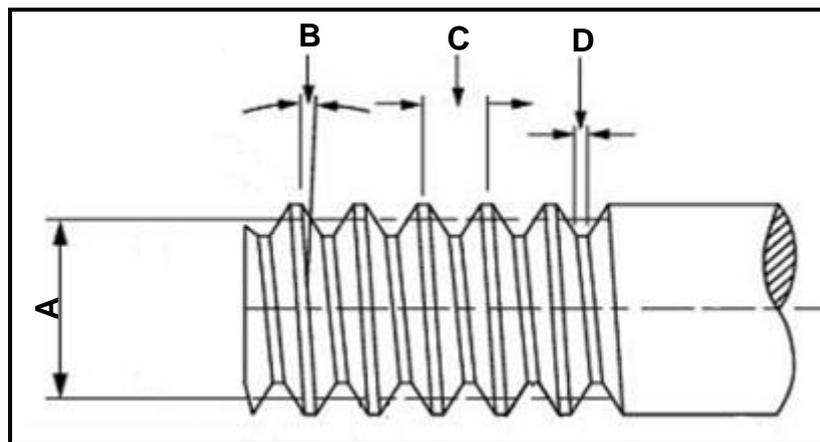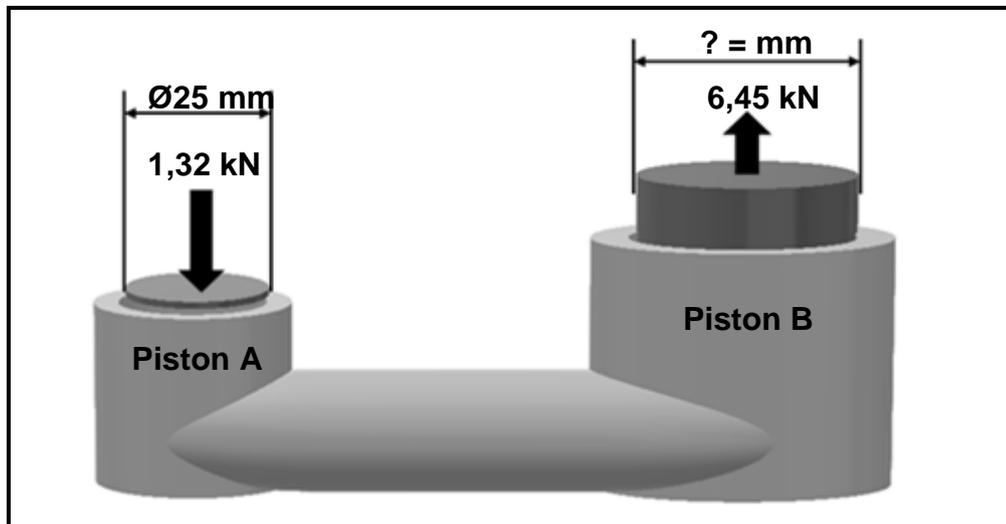
10.2   FIGURE 10.2 shows an metric V-screw thread.

FIGURE 10.2

Label **A–D**.   (4)

10.3   State TWO uses of a square thread.   (2)

[18]

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

11.1   FIGURE 11.1 shows a hydraulic system with piston **A** with a diameter of 25 mm. A force of 1,32 kN is exerted onto piston **A**. The system also has piston **B**, with a force of 6,45 kN. 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 in millimetres of piston **B**   (6)

11.2   State TWO advantages of a *chain drive* when compared to a *belt drive*.   (2)

11.3   State TWO functions of a reservoir in a hydraulic system.   (2)

11.4   State ONE application of a hydraulic system.   (1)

11.5　　FIGURE 11.5 shows a belt drive system with a driven pulley of 255 mm rotating at 85 r/min. The diameter of the driver pulley is 95 mm. Answer the questions that follow.
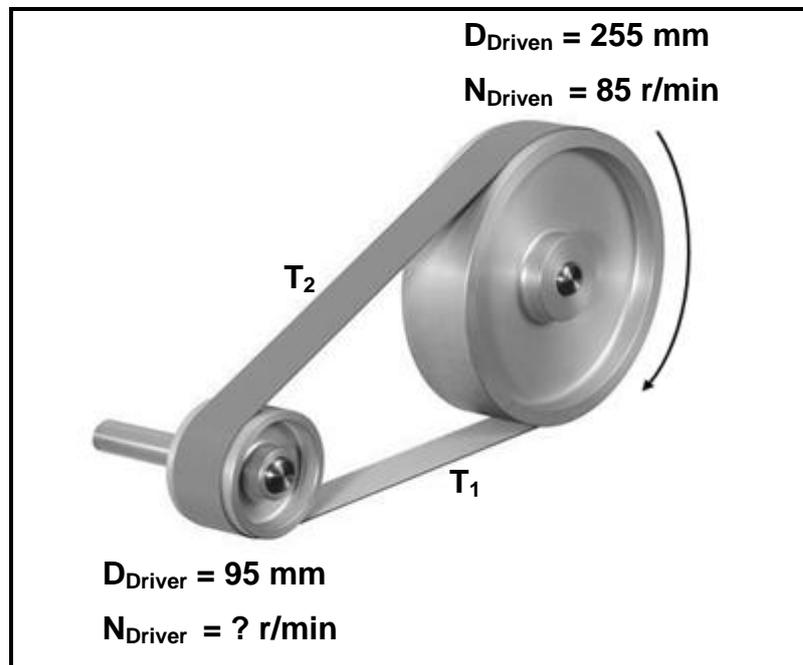

FIGURE 11.5

Calculate the following:

11.5.1　　The rotational frequency of the driver pulley　　　　　　　　(3)

11.5.2　　The speed ratio　　　　　　　　(3)

11.6   FIGURE 11.6 shows a gear drive system. Gear **A** on the shaft of the motor has 30 teeth that mesh with gear **B** with 40 teeth on the countershaft. On the countershaft is another gear, **C**, with 20 teeth that mesh with gear **D** with 60 teeth on a second countershaft. The second countershaft has gear **E** with 50 teeth that mesh with gear **F** with 70 teeth. Gear **F** is connected to the output shaft. Answer the questions that follow.
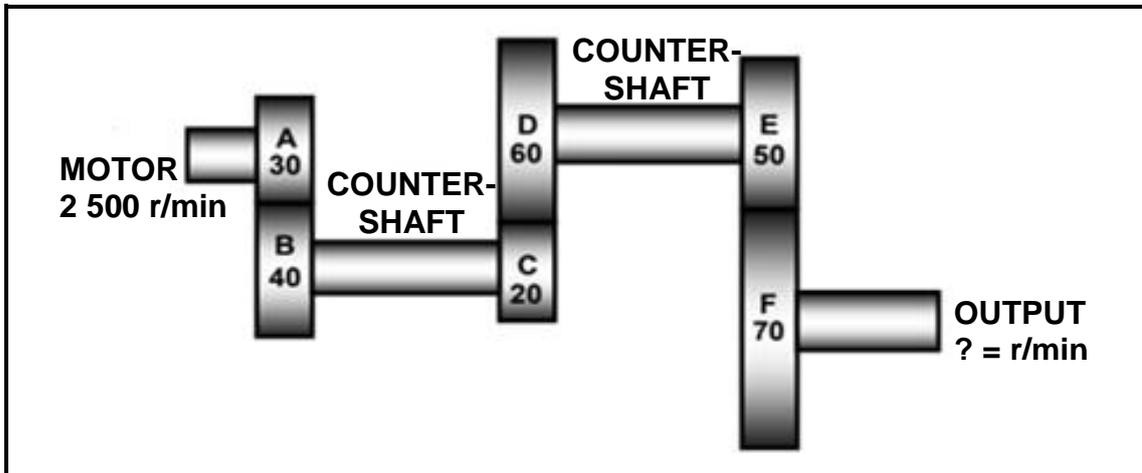

FIGURE 11.6

Calculate the following:

11.6.1   The rotation frequency of the output shaft if the motor rotates at 2 500 r/min   (4)

11.6.2   The gear ratio between the input shaft and the output shaft of the system   (3)

[28]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY: FITTING AND MACHINING

1. BELT DRIVES

1.1 Belt speed $= \dfrac{\pi DN}{60}$

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

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

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

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

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

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

1.8 Power $(P) = \dfrac{(T_1 - T_2)\pi DN}{60}$

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 $= \dfrac{T_1}{T_2}$

1.10 Power $(P) = \dfrac{2\pi NT}{60}$

1.11 Width $= \dfrac{T_1}{\text{Permissable tensile force}}$

1.12 $N_{DR} \times D_{DR} = N_{DN} \times D_{DN}$

2. STRESS AND STRAIN

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

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

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

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

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

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

3. HYDRAULICS

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

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

3.3 $\text{Work done} = \text{Force} \times \text{Distance}$

3.4 $P_A = P_B$

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

4. GEAR DRIVES

4.1   Power $(P) = \dfrac{2\pi N T}{60}$

4.2   Gear ratio $= \dfrac{\text{Product of teeth on driven gear}}{\text{Product of teeth on driver gear}}$ OR   Speed ratio $= \dfrac{N_{Input}}{N_{output}}$

4.3 $\dfrac{N_{input}}{N_{output}} = \dfrac{\text{Product of the number of teeth on driven gears}}{\text{Product of the number of teeth on driver gears}}$

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

4.5   Torque = Force × Radius

4.6   Torque transmitted = Gear ratio × Input torque

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

4.8   Pitch circle diameter $= \dfrac{\text{Circlular pitch} \times \text{Number of teeth}}{\pi}$ OR $PCD = \dfrac{CP \times T}{\pi}$

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

4.10   Addendum = Module   OR $a = m$

4.11   Dedendum $(b) = 1,157(m)$ OR   Dedendum $(b) = 1,25(m)$

4.12   Cutting depth $(h) = 2,157(m)$ OR   Cutting depth $(h) = 2,25(m)$

4.13   Clearance $(c) = 0,157(m)$ OR   Clearance $(c) = 0,25(m)$

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

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

5. PULLEYS

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

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

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

6. KEYWAYS

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

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

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

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 $= \dfrac{40}{n}$ (n = number of divisions)

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

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 distance of dovetail
W = Maximum width distance of dovetail
m = Distance between rollers
M = Distance over rollers

9.   TAPERS

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

9.2 $\tan \dfrac{\theta}{2} = \dfrac{L(D-d)}{2 \times l}$ $(L = \text{Distance between centres})$

10.   SCREW THREADS

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

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 : $\text{Tan}\theta = \dfrac{\text{Lead}}{\pi \times D_m}$

10.7   Leading angle = 90° − (Helix angle + Clearance angle)

10.8   Following angle = 90° + (Helix angle − Clearance angle)