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PES University, Bengaluru
(Established under Karnataka Act No. 16 of 2013)

UE21ME131A

MARCH 2022: END SEMESTER ASSESSMENT (ESA) B. TECH I SEMESTER

UE21ME131A – MECHANICAL ENGINEERING SCIENCE

Time: 3 Hrs	Answer All Questions	Max Marks: 100

1 a) The following particulars were obtained in a trial on a 4 stroke gas engine. — 8

Duration of trial = 1 hour
No. of revolutions = 14000
Net brake load = 1470 N
Mean effective pressure = 7.5 bar
Gas consumption = 20000 litres
Calorific value of gas = 21 kJ/litre
Cylinder diameter = 250 mm
Stroke = 400 mm
Sum of diameters of brake drum and rope = 1.27 m

Calculate (i) Indicated Power (ii) Brake Power (iii) Indicated thermal efficiency (iv) Mechanical efficiency

Solution:

(i) **Indicated Power**

We have, — 2

$$IP = \frac{nP_mLANk}{60000}$$

$$= \frac{1 \times 7.5 \times 10^5 \times 400 \times 10^{-3} \times \frac{\pi}{4} \times (250 \times 10^{-3})^2 \times \frac{14000}{60} \times \frac{1}{2}}{60000} = 28.63\ kW$$

(ii) **Brake Power**

We have,

$$BP = \frac{2\pi NT}{60000} = \frac{2 \times \pi \times \frac{14000}{60} \times 1470 \times \frac{1.27}{2}}{60000} = 22.86\ kW$$ — 2

(iii) **Indicated Thermal Efficiency**

We have,

$$\eta_{Ith} = \frac{IP}{m_f \times CV} = \frac{28.63}{\frac{20000}{3600} \times 21} = 24.54\%$$ — 2

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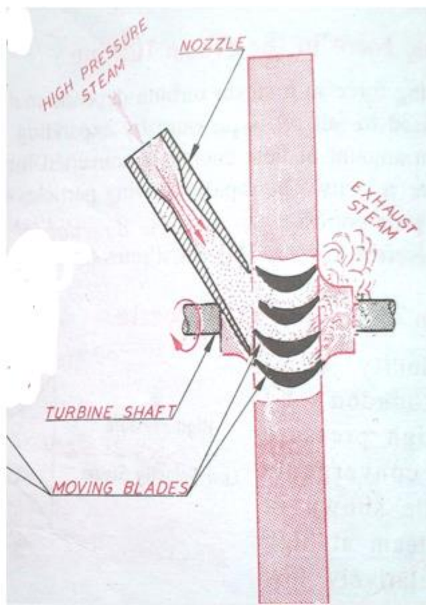
		(iv) **<u>Mechanical Efficiency</u>** We have, $$\eta_{mech} = \frac{BP}{IP} = \frac{22.86}{28.63} = 79.85\%$$	2
1	b)	Explain the working principle of a single stage De – Laval steam turbine with a neat sketch. Show the variation of pressure and velocity across the nozzle and turbine. <u>Solution</u>: The following figure shows the schematic representation of a single stage De – Laval steam turbine.  The turbine consists of a series of curved blades fixed on the circumference of a single wheel called rotor. The rotor in turn is connected to a shaft. In operation, the high pressure, low velocity steam generated in a boiler is made to flow through a convergent – divergent nozzle. As the steam passes through the nozzle, expansion takes place and the pressure of the steam decreases. This drop in pressure of the steam results in increase in velocity of steam. The high velocity jet of steam coming out of the nozzle is directed towards the moving blades of the turbine. The steam flowing over the blades undergoes a change in its velocity and direction thereby resulting in change of momentum. The force due to the change of momentum is the impulse force that acts in the direction normal to the blade, thereby pushing the blade in its direction. Since a number of blades are fixed on the wheel, each blade comes in contact with the high velocity jet of steam. As a result, the wheel rotates continuously at high speeds. Thus, the kinetic energy of steam is converted into mechanical work.	6 2 3

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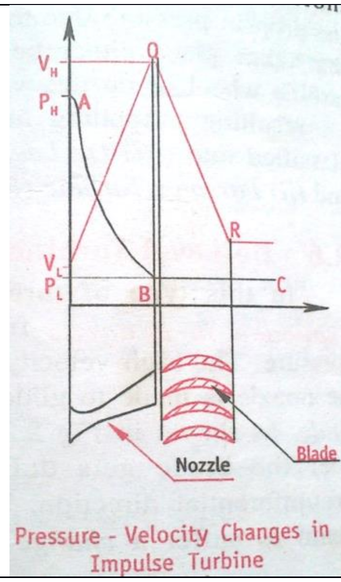

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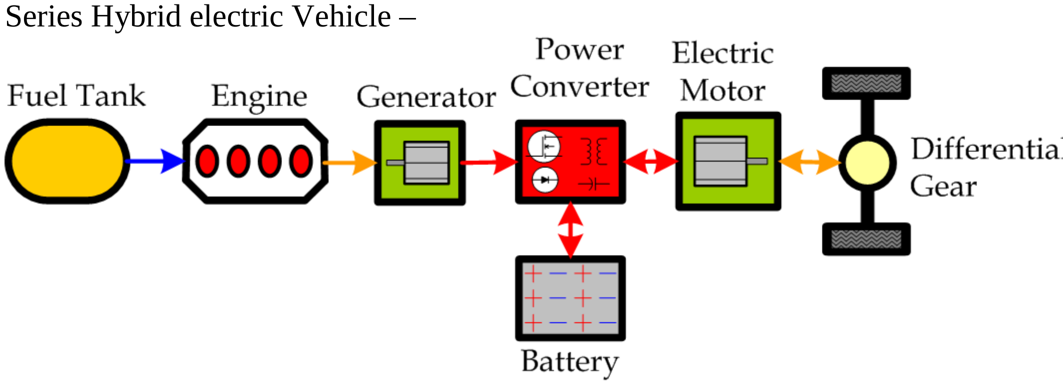
1 c) Describe the way in which series hybrid electric vehicle and parallel hybrid electric vehicle are propelled, with corresponding block diagram representations. 6

<u>Solution</u>:

Series Hybrid electric Vehicle –



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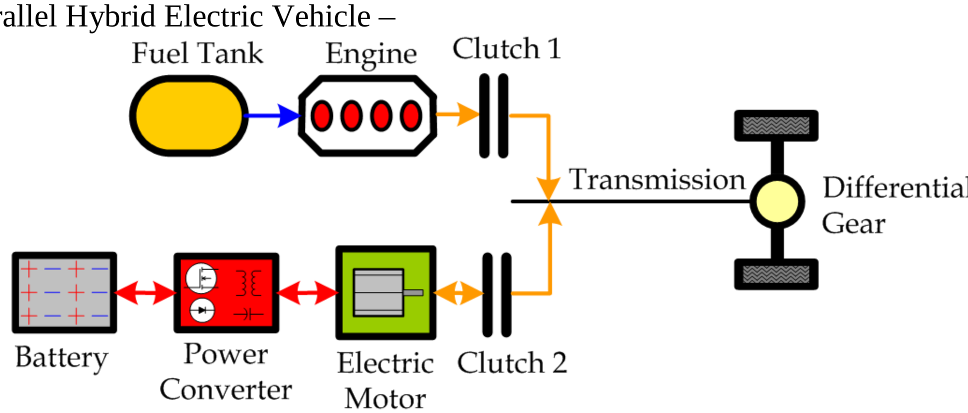
In case of series hybrid system, the mechanical output is first converted into electricity using a generator. The converted electricity either charges the battery or can bypass the battery to propel the wheels via the motor and mechanical transmission. Conceptually, it is an ICE assisted Electric Vehicle (EV). 2

Parallel Hybrid Electric Vehicle –



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		The parallel HEV allows both ICE and electric motor (EM) to deliver power to drive the wheels. Since both the ICE and EM are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by ICE alone, by EM only or by both ICE and EM. The EM can be used as a generator to charge the battery by regenerative braking or absorbing power from the ICE when its output is greater than that required to drive the wheels.	2
2	a)	A flat belt runs on a pulley of 1m diameter and transmits 7.5 kW at a speed of 200 rpm. Taking angle of lap as 170° and coefficient of friction as 0.2, determine the necessary width of the belt if the ratio of maximum tension to width of the belt is not to exceed 196 N/cm.	6
		<u>Solution</u>:	
		We have,	
		$Power = P = (T_1 - T_2)v \Rightarrow 7500 = (T_1 - T_2) \times \frac{\pi \times 1 \times 200}{60}$ $\Rightarrow 7500 = (T_1 - T_2)10.47$ $\Rightarrow (T_1 - T_2) = 716.33 - - - - - - - - -(1)$	2
		Also, we have,	
		$\frac{T_1}{T_2} = e^{\mu\theta} \Rightarrow \frac{T_1}{T_2} = e^{0.2 \times \frac{\pi \times 170}{180}} \Rightarrow \frac{T_1}{T_2} = 1.81 - - - -(2)$	2
		Solving (1) and (2), we get,	
		T_2 = 884.36 N and T_1 = 1600.69 N	1
		Therefore, necessary width of the belt = b = T_1/196 = 1600.69/196 = 8.17 cm	1

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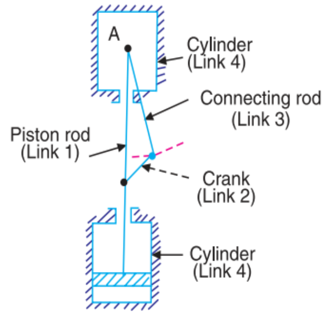
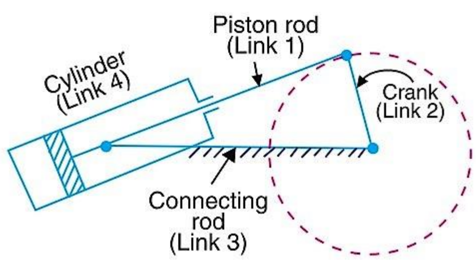
2	b)	i) Define inversion of a mechanism. ii) Describe with neat sketches, the inversions obtained when the cylinder and connecting rod respectively are fixed in a single slider crank chain mechanism.	7 (1+6)
		<u>Solution</u>:	
		(i) The method of obtaining different mechanisms by fixing different links of a kinematic chain is called as inversion of a mechanism.	1
		(ii) Pendulum pump mechanism can be obtained by fixing the cylinder in a single slider crank chain. The following figure shows the schematic representation of the pendulum pump mechanism.	
		 	1
		When the crank (link 2) rotates, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 at A and the piston attached to the piston rod (link 1) reciprocates. e.g., The duplex pump which is used to supply feed water to boilers.	2
		Oscillating cylinder engine mechanism can be obtained by fixing the connecting rod in a single slider crank chain. The following figure shows the schematic representation of the oscillating cylinder engine mechanism.	
		 	1
		When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at A. It is used in hoisting engine mechanisms.	2

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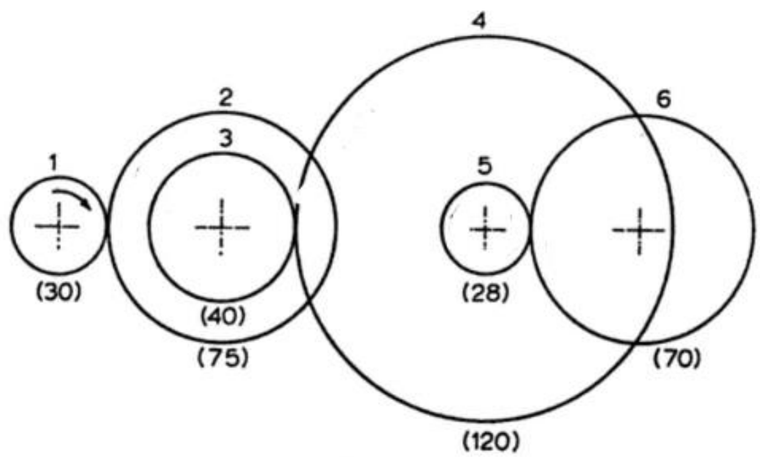
2 c) i) A certain gear box in an automobile initially contains a pair of spur gears for transmitting power between two shafts. Suggest a suitable alternative type of gears for the following scenarios encountered by the gear box, with suitable justifications. 7 (2+5)

a) Spur gears are generating heavy noise as there is involvement of high speed.

b) Due to a layout change, the shafts which were initially parallel, are now made intersecting at right angles.

(ii) In a compound gear train, shown in the following figure, the power is transmitted from a motor shaft to output shaft. The motor shaft is connected to gear 1 whereas the output shaft is connected to gear 6. The motor shaft is rotating at 1125 rpm in the clockwise direction. Determine the direction and speed of output shaft. The number of teeth on each gear are given below.

Gear	1	2	3	4	5	6
No. of teeth	30	75	40	120	28	70



Solution:

i) a) In this scenario, spur gears have to be replaced by helical gears. As there is gradual engagement in case of helical gears, they are suitable for high speed applications with less noise. 1

b) In this scenario, spur gears have to be replaced by bevel gears as they can suitably transmit power between shafts intersecting at 90 degrees. 1

ii) We have,

$$\frac{N_1}{N_6} = \frac{T_6}{T_5} \times \frac{T_4}{T_3} \times \frac{T_2}{T_1} = \frac{70 \times 120 \times 75}{28 \times 40 \times 30} = 18.75$$ 4

Therefore, N_6 = 1125/18.75 = 60 rpm 1

Direction: Anti - clockwise

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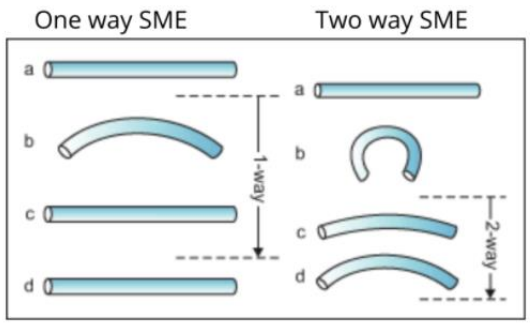
3 a) Explain one way and two way shape memory effects with neat diagrammatic representations. 6

Solution:

The following figure shows the schematic representation of one way and two way shape memory effect.



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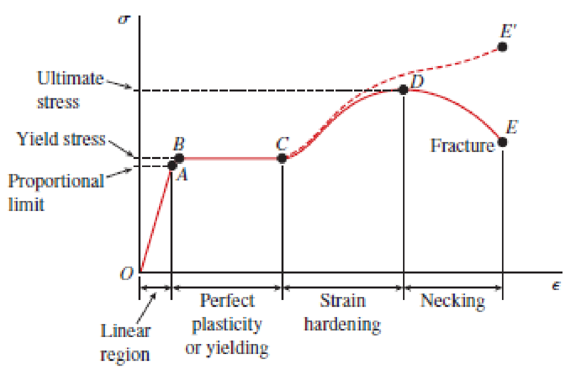
One way SME - A deformation imparted to the material in the low temperature martensite phase is fully recovered upon heating as the material completely transforms to the high temperature austenite phase. On subsequent cooling, the material returns completely to the martensite phase, but there is no further change in the shape of the material. Because the shape change occurs only during heating, this transformation is called the one-way shape memory effect. 2

Two way SME - In the two-way effect, the material 'remembers' both a high and a low temperature shape. Consequently, the material can continuously cycle between the two shapes as the temperature is raised and lowered, without the need for an external stress. 2

3 b) Explain stress – strain diagram of a mild steel specimen subjected to tensile test, with a proper description of all salient points and regions of the diagram. 8

Answer:

A stress-strain diagram for a typical mild steel specimen in tension is shown in Fig. below. Strains are plotted on the horizontal axis and stresses on the vertical axis.



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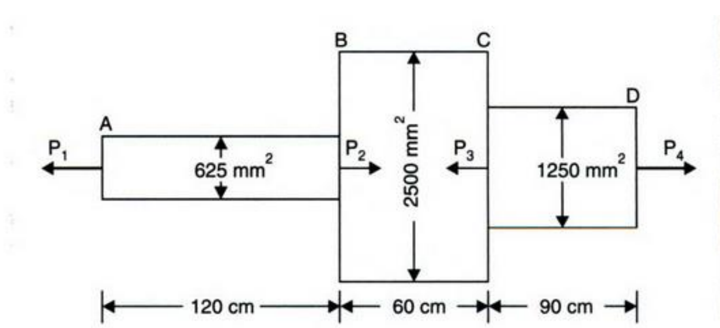
		The diagram begins with a straight line from the origin O to point A, which means that the relationship between stress and strain in this initial region is not only linear but also proportional. Beyond point A, the proportionality between stress and strain no longer exists; hence the stress at A is called the **proportional limit**. The slope of the straight line from O to A is called the modulus of elasticity. With an increase in stress beyond the proportional limit, the strain begins to increase more rapidly for each increment in stress. Consequently, the stress-strain curve has a smaller and smaller slope, until, at point B, the curve becomes horizontal. Beginning at this point, considerable elongation of the test specimen occurs with no noticeable increase in the tensile force (from B to C). This phenomenon is known as yielding of the material, and point B is called the **yield point**. The corresponding stress is known as the yield stress of the steel. In the region from B to C, the material becomes perfectly plastic, which means that it deforms without an increase in the applied load. After undergoing the large strains that occur during yielding in the region BC, the steel begins to strain harden. During strain hardening, the material undergoes changes in its crystalline structure, resulting in increased resistance of the material to further deformation. Elongation of the test specimen in this region requires an increase in the tensile load, and therefore the stress-strain diagram has a positive slope from C to D. The load eventually reaches its maximum value, and the corresponding stress (at point D) is called the **ultimate stress**. When a test specimen is stretched, lateral contraction occurs. The resulting decrease in cross-sectional area is too small to have a noticeable effect on the calculated values of the stresses up to about point C, but beyond that point the reduction in area begins to alter the shape of the curve. In the vicinity of the ultimate stress, the reduction in area of the bar becomes clearly visible and a pronounced **necking** of the bar occurs. Finally, the specimen undergoes **fracture** at point E.	1 1 2 2
3	c)	A member ABCD is subjected to point loads P_1 = 45 kN, P_2 = 365 kN, P_3 = 450 kN and P_4 = 130 kN as shown in the following figure. Determine the total elongation of the member, assuming the modulus of elasticity to be 2.1×10^5 N/mm^2.  	6

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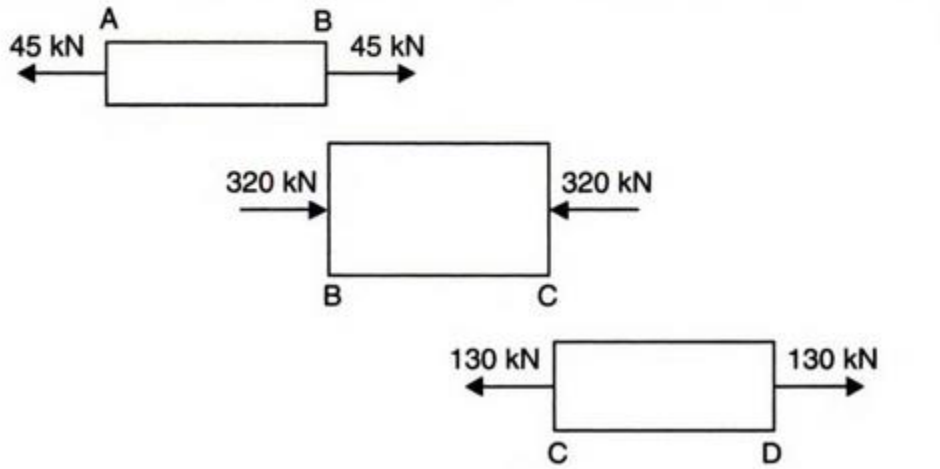
Solution:

Free body diagrams –



Therefore P_{AB} = 45 kN (tensile), P_{BC} = 320 kN (compressive) and P_{CD} = 130 kN (tensile) 3

We have, 1

$$\delta_{AB} = \frac{P_{AB}L_{AB}}{A_{AB}E_{AB}} = \frac{45 \times 10^3 \times 120 \times 10^{-2}}{625 \times 10^{-6} \times 2.1 \times 10^{11}} = 0.411\ mm$$

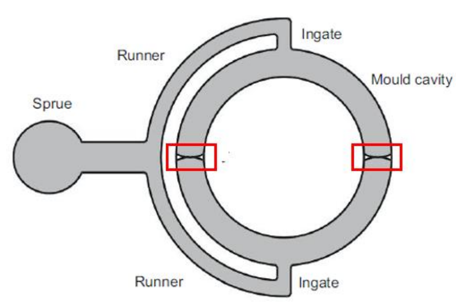
$$\delta_{BC} = \frac{P_{BC}L_{BC}}{A_{BC}E_{BC}} = \frac{320 \times 10^3 \times 60 \times 10^{-2}}{2500 \times 10^{-6} \times 2.1 \times 10^{11}} = 0.366\ mm$$ 1

$$\delta_{CD} = \frac{P_{CD}L_{CD}}{A_{CD}E_{CD}} = \frac{130 \times 10^3 \times 90 \times 10^{-2}}{1250 \times 10^{-6} \times 2.1 \times 10^{11}} = 0.446\ mm$$ 1

Therefore, total elongation = 0.411-0.366+0.446 = 0.491 mm

4 a) i) What do you mean by a loose piece pattern? Explain with a simple sketch. 6 (3+3)

ii) The following figure highlights a particular type of casting defect. Identify and describe the defect with atleast one cause and one remedy for the same.



Solution:

i) Loose piece pattern is used when the contour of the part is such that withdrawing the pattern from the mould is not possible. Hence during moulding the obstructing part of the contour is held as a loose piece by a wire. After moulding is over, first the main pattern is removed and then the loose pieces are recovered through the gap generated by the main pattern. 2

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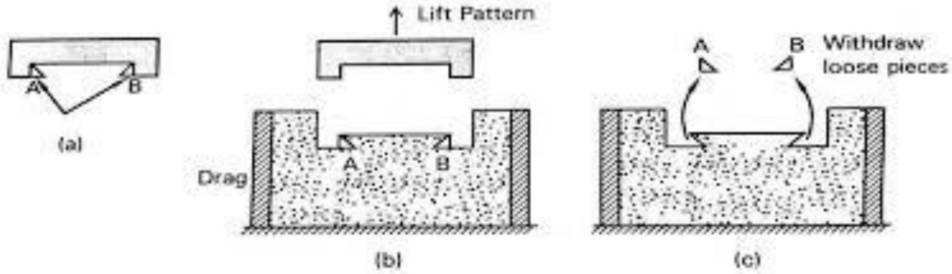


Loose piece pattern 1

ii) The given defect is called as "Cold Shut". When the molten metal enters into the mold from two gates and when these two streams of molten metal meet at a junction with low temperatures, then they do not fuse with each other and solidify, creating a type of crack with round edge. 1

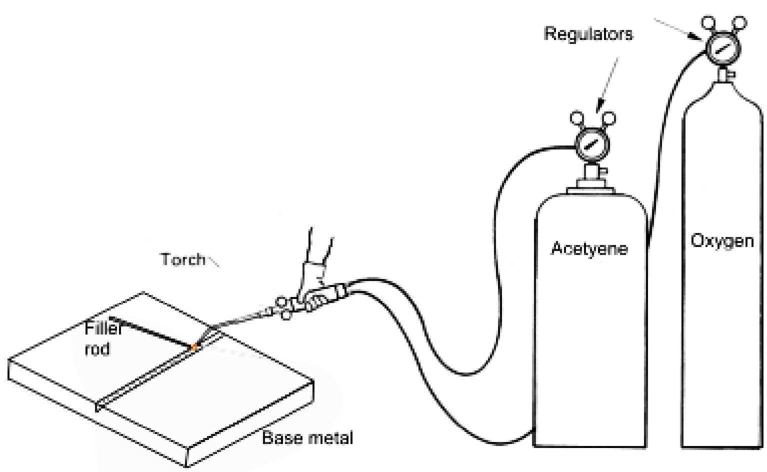
Causes (Any one):
Poor gating system
Low melting temperature 1
Lack of fluidity

Remedies (Any one):
Improved gating system 1
Proper pouring temperature

4 b) Explain the working principle of oxy – acytelene gas welding with a neat sketch. Describe the three types of flames used in this welding. 8

<u>Solution</u>:

The figure below shows the schematic of oxy – acytelene welding. In operation, the pressure regulators are adjusted to deliver suitable proportions of oxygen and acytelene gases to enter into the welding torch. The gases get mixed in the torch and are issued from the torch to burn in the atmosphere. The resulting flame at the torch tip has a temperature ranging from 3100 – 3500 degree Celsius and this heat is sufficient enough to melt the workpiece metals. Since a slight gap usually exists between the two workpieces, a filler metal may be used to supply the additional material to fill the gap. The molten metal of the filler metal combines with the molten metal of the workpiece and upon solidification, form a single piece of metal. 3



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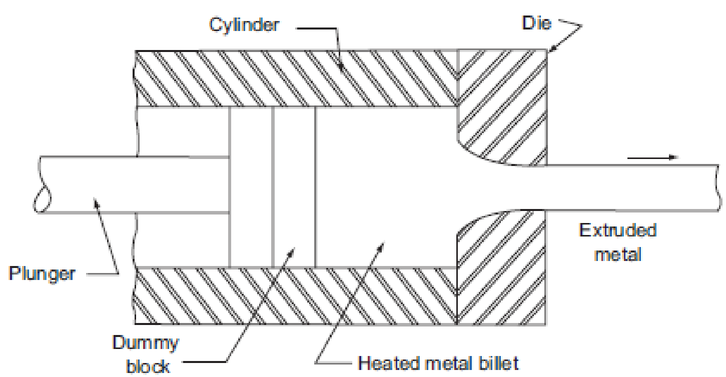
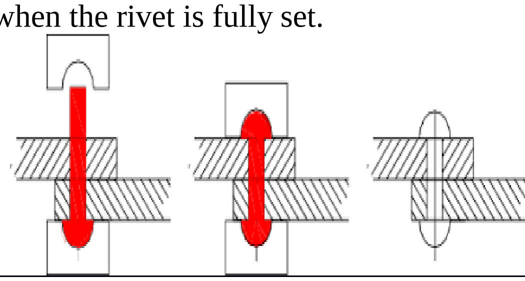
		The three types of flames produced during this welding process are – 1) Neutral flame – It is produced when approximately equal amounts of oxygen and acytelene are burnt at the torch tip. The flame has a nicely defined inner whitish cone surrounded by a sharp blue flame. 2) Oxidising flame – If, after the neutral flame has been established, the supply of oxygen is further increased, the result will be an oxidising flame. The oxidising flame appears similar to neutral flame but with a shorter inner white cone and the outer envelope being narrow and brighter in colour. 3) Reducing flame – If the volume of oxygen supplied to neutral flame is reduced, the resulting flame will be a carburising flame or reducing flame. It can be recognised by acytelene feather which exists between the inner cone and the outer envelope.	1 1 1
4	c)	Explain the working principles of extrusion and riveting with simple sketches. <u>Solution</u>: Extrusion - Extrusion is the process of confining the metal in a closed cavity and then allowing it to flow from only one opening so that the metal will take the shape of the opening. A typical extrusion process is presented in Fig. below. The equipment consists of a cylinder or container into which the heated metal billet is loaded. On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening.  Riveting - Riveting is a forging process that may be used to join parts together by way of a metal part called a rivet. First, the two metal sheets to be joined are held in proper relationship and then the holes are drilled through them. The diameter of the hole is kept slightly more than the shank diameter of the rivet. The rivet is then passed through the hole in such a way that the pre – formed head rests against an anvil. Next, the tail is forged to form another head. This is achieved by exerting the pressure on the die bar that covers the buck – tail. The clearance between the shank and hole is filled in when the rivet is fully set. 	6 (3+3) 2 1 2 1

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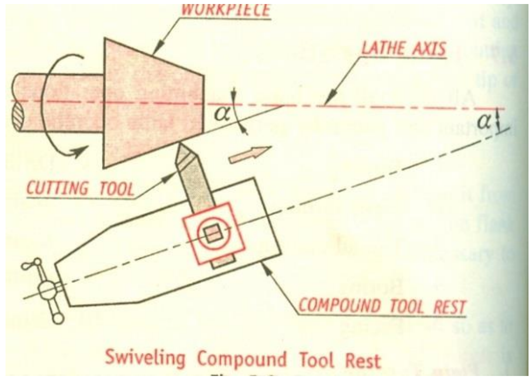
5 a) Explain with neat sketches, the working principles of — 8 (5+3)

a) Taper turning by swiveling the compound rest

b) Slab milling

a) <u>Taper turning by swiveling the compound rest</u>

The following figure shows the process of taper turning by swiveling the compound rest method.



Swiveling Compound Tool Rest

2

In operation, the compound rest supporting the cutting tool is swiveled to the desired angle at which the taper is to be produced. This angle, called half taper angle (α) is calculated using the equation given below –

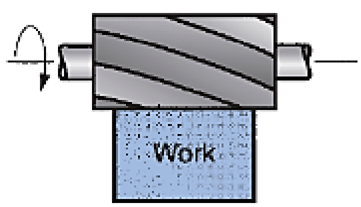
Half taper angle = $\alpha = tan^{-1}(D-d/2L_t)$

where D = larger diameter of taper; d = smaller diameter of taper; L_t = length of taper

The compound rest has a circular base graduated in degrees. The rotation of the compound rest to the calculated taper angle, will cause the tool to be fed at that angle, thereby producing the corresponding taper on the workpiece. 3

b) <u>Slab milling</u>

Plain milling also called surface milling or slab milling is the operation of producing a plain horizontal surface with a milling cutter whose axis is parallel to the surface of the work piece being machined. The cutter called plain or slab milling cutter is mounted on the arbor of a horizontal milling machine to carry out the machining operation. The cutter has straight or helical teeth formed on the periphery of a cylindrical surface. 2



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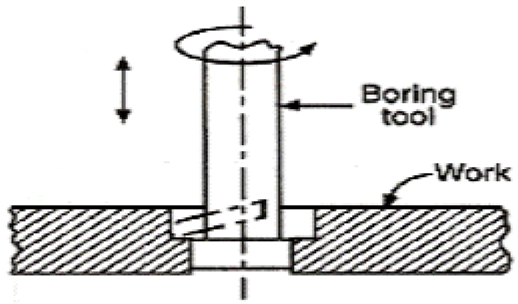
5 b) A hole of 181.5 mm has to be drilled on a flat plate. The available twist drill is only of 181 mm size. 8 (4+4)

i) Suggest a suitable operation for the machinist to enlarge the hole to required size, after drilling the hole of 181 mm diameter. Explain the same with a neat sketch.

ii) Further, the hole prepared in (i) has to be modified to accommodate a cylindrical headed cap screw in it. Suggest the operation to be carried out by the machinist for the aforementioned purpose. Explain the same with a neat sketch.
Note: Reamer of 181.5 mm is not available.

Solution:

i) The machinist should perform boring operation in order to achieve the hole of size equal to 181.5 mm. Boring operation is schematically represented in the following figure.

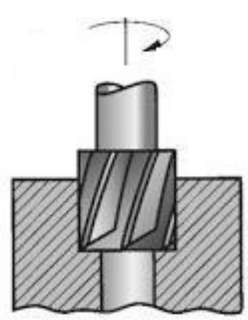


Boring

2

Boring is the operation of enlarging a previously drilled hole by means of an adjustable cutting tool having only one cutting edge. The operation is performed when a drill bit of the required dimension is not available. In such cases, a hole is drilled first to the nearest dimension and then a single point cutting tool is fastened and adjusted to a boring bar to enlarge the size of the existing hole to the required dimension. Additionally, it also corrects the hole location, roundness errors etc. The spindle is rotated at lower speeds during this operation. 2

ii) The machinist should perform Counter boring which is a process to increase the size of the hole at one end only through a small depth. The cutting tool will have a pilot to guide the tool. Speed for counter boring must be two- third of the drilling speed. 2



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5	c)	Differentiate between fixed and programmable automation. <u>Solution</u>: a) Fixed automation – Fixed automation is a system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration The typical features of fixed automation are: High initial investment for custom-engineered equipment High production rates Relatively inflexible in accommodating product changes b) Programmable automation – System involving automated production systems that are programmable are used in low and medium- volume production. The parts or products are typically made in batches. To produce each new batch of a different product, the system must be reprogrammed with the set of machine instructions that correspond to the new product. Some of the features that characterize programmable automation include: High investment in general-purpose equipment Low production rates relative to fixed automation Flexibility to deal with changes in product configuration	4 2 2