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

UE21ME131B

JULY 2022: END SEMESTER ASSESSMENT (ESA) B. TECH II SEMESTER

UE21ME131B – MECHANICAL ENGINEERING SCIENCE

Time: 3 Hrs	Answer All Questions	Max Marks: 100

1 a) The following observations were recorded during a trial of a four-stroke, single-cylinder oil engine. **8**

Duration of trial = 30 minutes
Oil consumption = 4 litres
Calorific value of the oil = 43 MJ/kg
Specific gravity of the fuel = 0.8
Average area of the indicator diagram = 8.5 cm^2
Length of the indicator diagram = 8.5 cm
Spring constant = 5.5 bar/cm
Brake load = 150 kg
Spring balance reading = 20 kg
Effective brake wheel diameter = 1.5 m
Speed = 200 rpm
Cylinder diameter = 30 cm
Stroke = 45 cm

Calculate (i) Indicated power (ii) Brake power (iii) Brake specific fuel consumption in kg/kWh and (iv) Indicated thermal efficiency. 2

Solution:

(i) Indicated Power

We have, $P_m = \frac{Area\ of\ the\ indicator\ diagram \times Spring\ constant}{Length\ of\ the\ indicator\ diagram} = \frac{8.5\times5.5}{8.5} = 5.5\ bar$ 1

Now, $IP = \frac{nP_mLANk}{60000} = \frac{1\times5.5\times10^5\times45\times10^{-2}\times\frac{\pi}{4}\times(30\times10^{-2})^2\times200\times(\frac{1}{2})}{60000} = 29.16\ kW$ 1

(ii) Brake Power

We have, $BP = \frac{2\pi NT}{60000} = \frac{2\times\pi\times200\times(150-20)\times9.81\times(1.5/2)}{60000} = 20.03\ kW$ 2

(iii) Brake specific fuel consumption

We have, $BSFC = \frac{m_f\ in\ kg/h}{BP\ in\ KW} = \frac{\left[\left(\frac{4}{1000}\right)\times0.8\times1000\times2\right]}{20.03} = 0.3195\ kg/kWh$ 2

(iv) Indicated thermal efficiency

We have, $\eta_{ith} = \frac{IP}{m_f \times CV} = \frac{29.16}{\frac{\left(\frac{4}{1000}\right)\times 0.8\times 1000\times 2}{3600}\times 43\times 10^{3}} = 38.15\%$ **2**

1 b) Explain the functions of the following components – **6**

(i) Draft tube in a Francis turbine

(ii) Convergent - divergent nozzle in a De Laval turbine

(iii) Heat exchangers in a closed loop gas turbine

Answer:

(i) Draft tube in a Francis turbine - Draft tube is a diverging tube fitted at the exit of runner of turbine and used to utilize the kinetic energy available with water at the exit of runner. This draft tube at the end of the turbine increases the pressure of the exiting fluid at the expense of its velocity. This means that the turbine can reduce pressure to a higher extent without fear of back flow from the tail race. **2**

(ii) Convergent - divergent nozzle in a De Laval turbine – The high pressure low velocity steam generated in boiler is made to pass through the convergent – divergent nozzle of a De laval turbine, where the kinetic energy of the steam is increased at the expense of its enthalpy and the steam emerges out as a high velocity jet from the nozzle. **2**

(iii) Heat exchangers in a closed loop gas turbine – The high pressure gas coming out of the compressor is heated in the first heat exchanger, where the gas exhausted from the turbine is cooled in the second heat exchanger. **2**

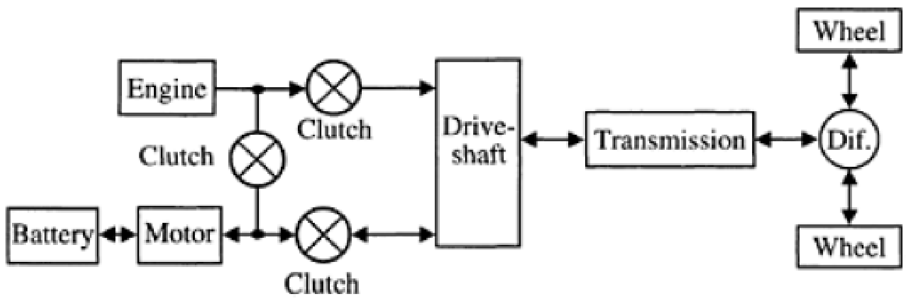
1 c) (i) List any two differences between flat plate type solar collector and concentrating type solar collector. **6 (2+4)**

(ii) A Toyota Prius car model has a compact design without an electrical generator and has a smaller traction motor. Describe the architecture used in the aforementioned hybrid vehicle model with a neat schematic diagram.

Answer:

(i) **2**

Concentrating collector	**Flat plate collector**
Only beam radiation	Both diffuse and beam radiation.
Tracking mechanism required.	Tracking mechanism not required.
More maintenance	Less maintenance
Can attain high temperature, due to concentration of solar radiation and less loss to surrounding.	Cannot attain high temperature as radiations are not concentrated and more loss to surrounding.

		(ii) A Toyota Prius car model uses parallel hybrid vehicle architecture. The parallel HEV as shown in the following figure allows both IC engine and electric motor to deliver power to drive the wheels. Since both the IC engine and electric motor are coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by IC engine alone, by electric motor only or by both IC engine and electric motor. The electric motor can be used as a generator to charge the battery by regenerative braking or absorbing power from the IC engine when its output is greater than that required to drive the wheels. 	2 2
2	a)	(i) Define (1) Successfully constrained motion (2) Flexible link (ii) Identify and sketch the mechanism used for the following applications – 1) Coupled wheels of a locomotive in which the rotary motion of one wheel is transmitted to the other wheel. 2) Reciprocating engine. **<u>Answer:</u>** (i) Successfully constrained motion - When the motion between the elements, forming a pair, is such that the constrained motion is not completed by itself, but by some other means, then the motion is said to be successfully constrained motion. Flexible link - A flexible link is one which is partly deformed in a manner not to affect the transmission of motion. For example, belts, ropes, chains and wires are flexible links and transmit tensile forces only. (ii) Coupled wheels of a locomotive in which the rotary motion of one wheel is transmitted to the other wheel – This application uses a **<u>double crank mechanism</u>**, which is an inversion of a four bar chain mechanism.	6 (2+4) 1 1 1

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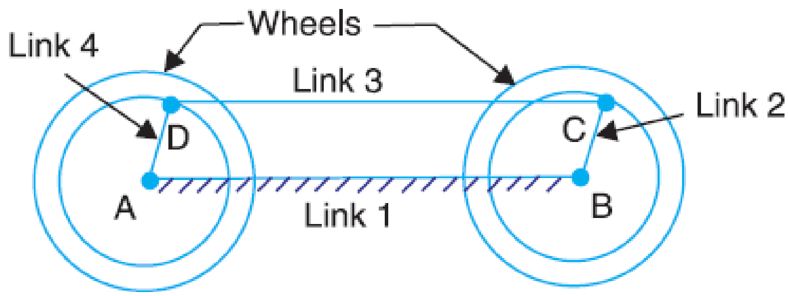

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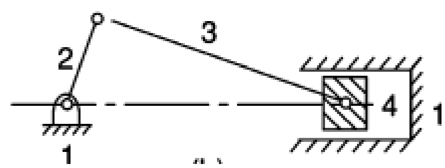
Reciprocating engine – This application uses a **<u>single slider crank mechanism with fixed cylinder link.</u>** 1



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2 b) An open belt running over two pulleys of 24 cm and 60 cm diameters, connects two parallel shafts 3 m apart and transmits 3.75 kW from the smaller pulley that rotates at 300 rpm. The coefficient of friction between the belt and the pulleys is 0.3. Determine 8

(i) initial belt tension

(ii) length of the belt required.

<u>Solution:</u>

We have,

$$P = 3.75 \times 1000 = (T_1 - T_2)v = (T_1 - T_2)\frac{\pi \times 24 \times 10^{-2} \times 300}{60}$$

$$=> (T_1 - T_2) = 994.72 - - - - (1)$$

2

We have,

$$\theta = 180^o - 2\,sin^{-1}\left[\frac{r_1 - r_2}{x}\right] = 180^o - 2\,sin^{-1}\left[\frac{30 - 12}{300}\right]$$

$$= 173.12\ degrees\ or\ 3.02\ radians$$

1

Now,

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3\times3.02} = 2.474 => T_1 = 2.474T_2 - - - (2)$$

1

Solving (1) and (2), we get, T_1 = 1669.56 N and T_2 = 674.84 N 1

(i) Initial belt tension = $T_0 = \frac{T_1+T_2}{2} = \frac{1669.56+674.84}{2} = 1172.2\ N$ 1

(ii) Length of the belt = $L_o = \pi(r_1 + r_2) + 2x + \frac{(r_1-r_2)^2}{x} = 733\ cm = 7.33\ m$ 2

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2	c)	(i) Axial thrust (force component acting along the axis of the shaft) is absent in case of double helical gears. Justify the statement. (ii) Determine the number of teeth for two toothed wheels to transmit a velocity ratio of 1/4 between two parallel shafts, the centre of which are at a distance of 675 mm. Take module = 15 mm. **Answer:** (i) A double helical gear has a pair of helical gears secured together, one with left hand helix and the other with right hand helix. The two opposite rows of teeth cancel their respective axial thrust component, as a result of which the aforementioned force will be eliminated in case of a double helical gear. (ii) We have, $\frac{N_2}{N_1} = \frac{T_1}{T_2} = \frac{d_1}{d_2} = \frac{1}{4} => 4d_1 = d_2 --- (1)$ Also, the centre distance, $r_1 + r_2 = \frac{d_1+d_2}{2} = 675 => d_1 + d_2 = 1350 --- (2)$ Solving (1) and (2), we get, d_1 = 270 mm and d_2 = 1080 mm. Now, $T_1 = d_1/m = 270/15 = 18$ $T_2 = d_2/m = 1080/15 = 72$	6 (2+4) 2 2 2
3	a)	(i) Spring steels are "**resilient**" while structural steels are "**tough**". Bring out the basic difference between the highlighted attributes of the aforementioned materials. (ii) Explain the behaviour of electro/magneto rheological fluids in the presence of the external field. **Answer:** (i) Resilience is the ability of the material to absorb energy within elastic limit, whereas toughness is the ability of the material to absorb energy within elastic and plastic range, before fracture. Resilience is essential in spring applications where toughness is required for components subjected to bending, twisting, stretching and impact loads. (ii) In the absence of a field, the fluid can freely flow across the electrodes in response to an applied pressure gradient, or can be sheared by a relative motion of the electrodes. On the application of the field, the fluid flow across the electrodes is impeded by the particle chains. A larger pressure gradient is required to break the chains and maintain the flow of the fluid. As a result, a larger force is required on the electrodes to produce a relative motion between them. The forming and breaking of the chains results in a significant change in the viscosity of the fluid.	6 (2+4) 2 3

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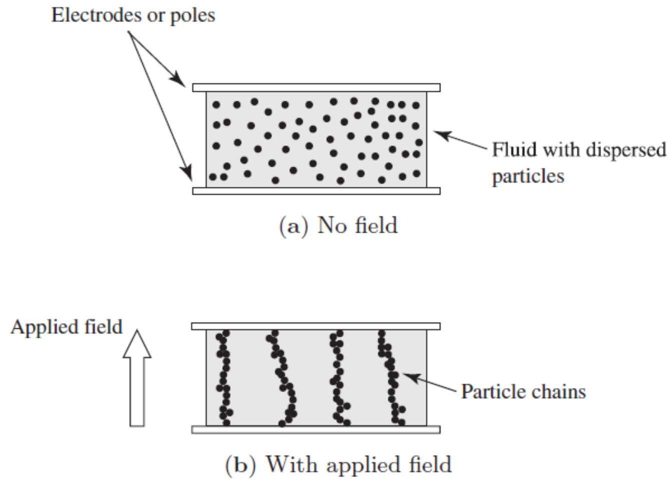

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3 b) The following figures show the stress strain curves of mild steel and aluminium specimens respectively, subjected to uniaxial tensile test. 8

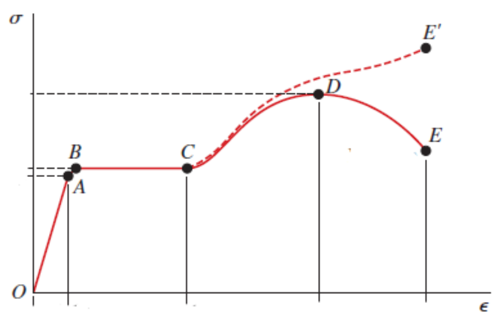

Fig.1: Stress Strain curve of Mild Steel

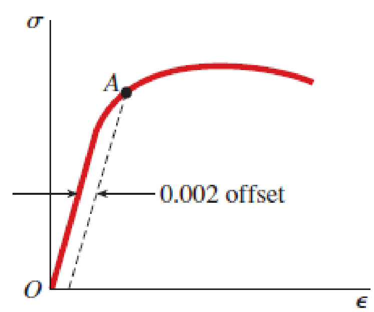

Fig.2: Stress Strain curve of Aluminium

Describe

(i) Region CD and point D of Fig.1

(ii) Point A of Fig.2

(iii) Region DE and point E of Fig. 1

(iv) Curve OABCE' of Fig. 1

Answer:

(i) Region CD and point D of Fig.1 – “**strain hardening**” region and ultimate stress. 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**. 2

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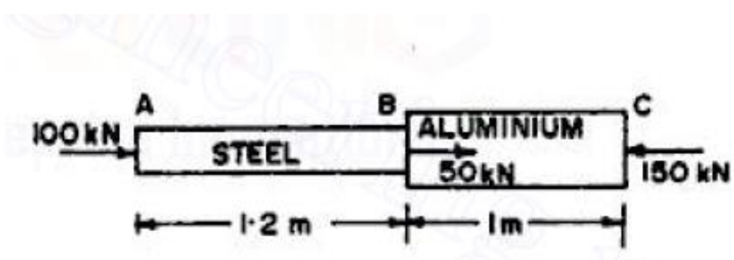
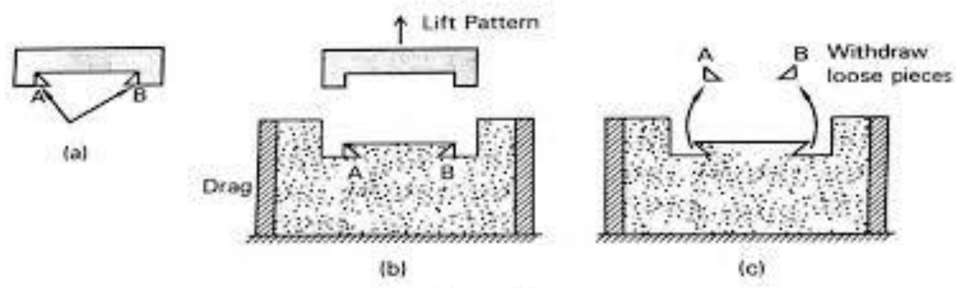
		(ii) Point A of Fig.2 – **offset yield stress**. When a material such as aluminum does not have an obvious yield point and yet undergoes large strains after the proportional limit is exceeded, an arbitrary yield stress may be determined by the offset method. A straight line is drawn on the stress-strain diagram parallel to the initial linear part of the curve but offset by some standard strain, such as 0.002 (or 0.2%). The intersection of the offset line and the stress-strain curve (point A in the figure) defines the yield stress. Because this stress is determined by an arbitrary rule and is not an inherent physical property of the material, it should be distinguished from a true yield stress by referring to it as the **offset yield stress**.	2
		(iii) Region DE and point E of Fig. 1 - "**Necking**" region and fracture point. When a test specimen is stretched, lateral contraction occurs, as previously mentioned. 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. The material finally undergoes **fracture** at point 'E'.	2
		(iv) Curve OABCE' of Fig. 1 – **True** stress strain curve. If the actual cross-sectional area at the narrow part of the neck is used to calculate the stress, the **true stress-strain curve** (the dashed line CE') is obtained. The total load the bar can carry does indeed diminish after the ultimate stress is reached (as shown by curve DE), but this reduction is due to the decrease in area of the bar and not to a loss in strength of the material itself. In reality, the material withstands an increase in true stress up to failure (point E').	2
3	c)	ii) A member ABC is formed by connecting a steel bar of 20 mm diameter to an aluminium bar of 30 mm diameter, and is subjected to forces as shown in the following figure. Determine the individual deformations of each portion and total deformation of the bar, taking E for aluminium as 0.7×10^5 N/mm^2 and that for steel as 2×10^5 N/mm^2. 	6
		<u>**Answer**</u>: Force on AB = P_{AB} = 100 kN $\delta_{AB} = \frac{P_{AB}L_{AB}}{A_{AB}E_{AB}} = \frac{100\times10^3\times1.2}{\frac{\pi}{4}\times(20\times10^{-3})^2\times2\times10^{11}} = 1.91\ mm\ (compressive)$	2
		Force on BC = 150 kN $\delta_{BC} = \frac{P_{BC}L_{BC}}{A_{BC}E_{BC}} = \frac{150\times10^3\times1}{\frac{\pi}{4}\times(30\times10^{-3})^2\times0.7\times10^{11}} = 0.303\ mm\ (compressive)$	2

		Total deformation = 1.91+0.303 = 2.213 mm (compression)	2
4	a)	(i) In a certain sand casting process of a component made of aluminium alloy, it was observed that the molten aluminium has picked up hydrogen gas from the furnace and the sand in the mould is also having less permeability due to over ramming. Describe the casting defect that would be caused in the above scenario. (ii) Explain loose piece pattern with a neat sketch. **<u>Answer:</u>** (i) **Pin hole porosity** is caused by hydrogen in the molten metal. This could have been picked up in the furnace or by the dissociation of water inside the mould cavity. As the molten metal gets solidified, it loses the temperature which decreases the solubility of gases and there by expelling the dissolved gases. The hydrogen while leaving the solidifying metal would cause very small diameter and long pin holes showing the path of escape. (ii) 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.  Loose piece pattern	6 (2+4) 2 3 1
4	b)	Explain the working principle of electric arc welding with a neat sketch. **<u>Answer:</u>** The following figure shows the electric arc welding process. In operation, an arc is struck by touching the tip of the electrode on the workpiece and instantaneously the electrode is separated by a small distance of 2 – 4 mm such that the arc still remains between the electrode and the workpiece. The temperature of the arc ranges from 5000 – 6000 degree Celsius. The high heat at the tip of the arc melts the workpiece metal forming a small molten metal pool. At the same time, the tip of the electrode also melts. The molten metal of the electrode is transferred into the molten metal of the workpiece in the form of globules of molten metal. The deposited metal fills the joint and bonds the joint to form a single piece of metal. The electrode is moved along the surface to be welded to complete the joint.	6 4

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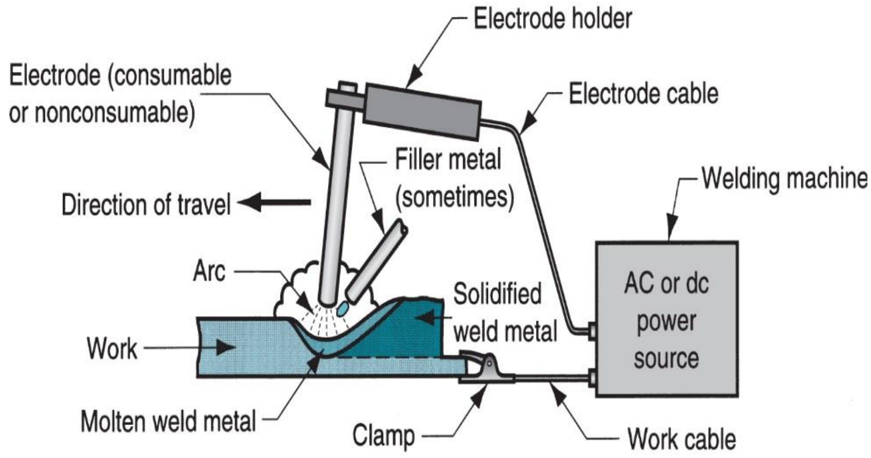

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4 c) (i) List any two differences between hot working and cold working processes.
(ii) Explain the working principles of forging and drawing with neat sketches. 8 (2+6)

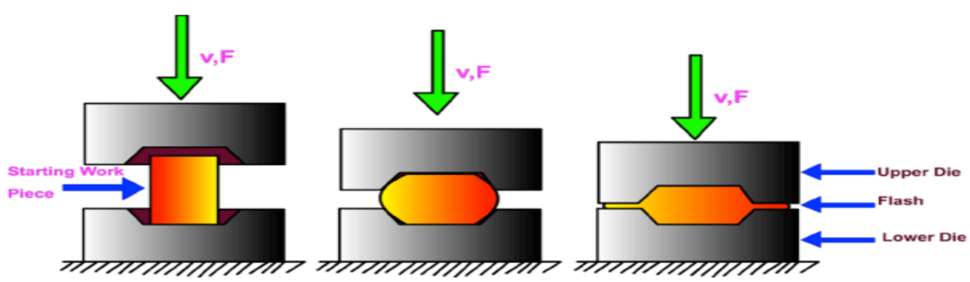
Answer:

(i)

Hot Working	**Cold Working**
Working above recrystallization temperature	Working below recrystallization temperature
Strain hardening is absent	Strain hardening is present
Poor surface finish	Good surface finish
Leads to dimensional inaccuracy due to thermal expansion	Better dimensional accuracy is achieved

2

(ii) Forging - Forging is the operation where the metal is heated and then a force is applied to manipulate the metal in such a way that the required final shape is obtained. Forging is generally a hot-working operation though cold forging is used sometimes. The types of forces applied can be manual hammering (smith forging), series of blows by drop hammers (drop forging), continuous squeezing type (press forging) etc. The press forging operation is schematically represented below. 2



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Drawing - A typical wire-drawing die is shown in Fig. below. The wire drawing die is of conical shape. The end of the rod or wire, which is to be further reduced is made into a point shape and inserted through the die opening. This end is then gripped on the other side with a gripper, which would then pull the wire through the die. The wire thus drawn is then coiled round a power reel. Rod and tube drawing is similar to wire drawing except for the fact that the dies are bigger because of the rod size being larger than the wire. In case of tube drawing, it requires a mandrel of the requisite diameter to form the internal hole. 2

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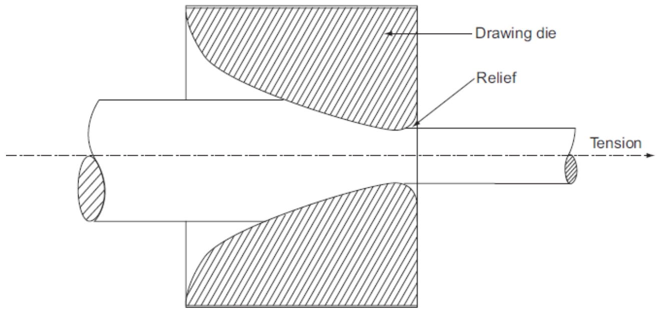
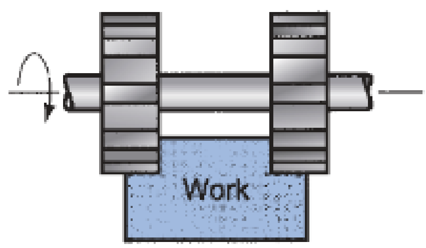
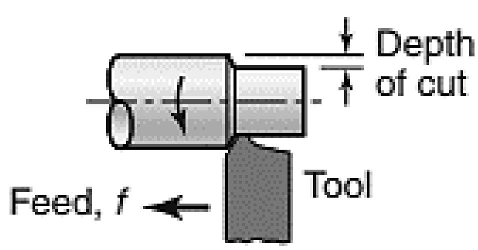
			1
5	a)	(i) What is the function of lead screw in a centre lathe machine? (ii) Explain the working principles of straddle milling and plain turning operations with neat sketches.	8 (2+6)
		Answer:	
		(i) Lead screw is a long threaded shaft geared to the headstock. Closing a split nut around the lead screw engages it with the carriage. The lead screw is used for cutting thread accurately and should be disengaged for other operations.	2
		(ii) Straddle milling – Straddle is a special form of gang milling where only side and face milling cutters are used. In gang milling a number of milling cutters are fastened to the arbor to suit the profile of the work piece to be machined.	2
			1
		Plain turning - Plain turning is by far the most commonly used operation in a lathe. In this the work held in the spindle is rotated while the tool is fed past the work piece in a direction parallel to the axis of rotation. The surface thus generated is the cylindrical surface as shown in Fig. below. It is usually done in two stages – rough turning and smooth or finish turning. Rough turning involves majority of material removal and it is usually done at high speeds while smooth turning is done at lesser speeds and it is involved in finishing the given job to required dimensions.	2
			1

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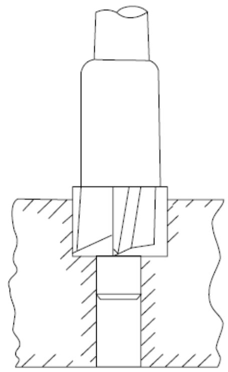
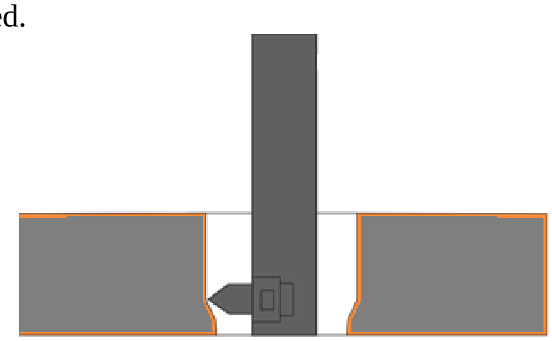
5	b)	Explain the working principles of counter boring and boring operations with neat sketches. **<u>Answer:</u>** Counter boring - In the counter boring operation, the hole is enlarged with a flat bottom to provide proper seating for the bolt head or a nut, which will be flush from the outer surface. The counter boring can be done by a tool with the cutting edges present along the side as well as the end, while a pilot portion is present for the tool to enter the already machined hole to provide the concentricity with the hole.  Boring - Boring is an operation of enlarging a hole. The single point cutting tool used for the boring operation is shown in Fig. below. Generally the single point tool bit is mounted in the boring bar of suitable diameter commensurate with the diameter to be bored. 	6 (3+3) 2 1 2 1
5	c)	(i) A flexible automated system is capable of producing a variety of parts (or products) with virtually no lost production time. Justify the statement. (ii) Explain open loop and closed loop control systems. **<u>Answer:</u>** (i) A flexible automated system is capable of producing a variety of parts (or products) with virtually no time lost for changeovers from one part style to the next. There is no lost production time while reprogramming the system and altering the physical setup. Consequently, the system can produce various combinations and schedules of parts or products instead of requiring that they be made in batches. **What makes flexible automation possible is that the differences between parts processed by the system arc not significant. It is a case of soft variety so that the amount of changeover required between styles is minimal**.	6 (2+4) 2

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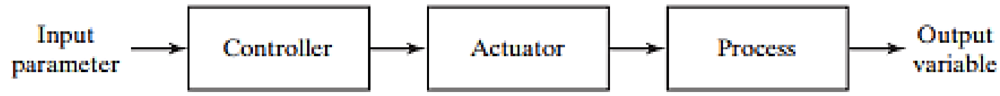
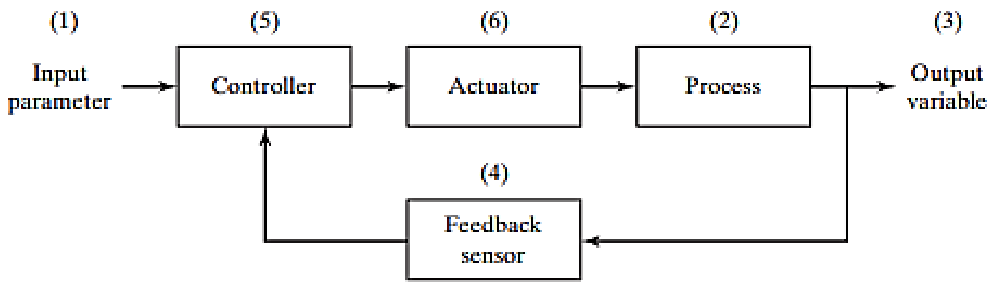
		(ii) A control system in which the control action is totally independent of the output of the system then it is called an **open-loop control system**. A manual control system is also an open-loop control system. The figure below shows a control system block diagram of an open-loop control system in which process output is totally independent of the controller action.	1
			1
		Control systems in which the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated is called a **closed-loop control system**. The figure below shows the block diagram of the closed loop control system in which feedback is taken from the output and fed into the input.	1
			1