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Internal Assessment Test III

Sub:	Mechatronics				Sub Code:	17ME754	Branch:	ME
Date:	27/01/2022	Duration:	90 min's	Max Marks: 50	Sem / Sec:	7^{th} B		OBE

Answer any 5 Questions.		MARKS	CO	RBT
1.	What is a mechanical actuator? List the various types of mechanical actuators.	10	CO3	L1
2.	Explain the construction of a ratchet and pawl mechanism.	10	CO3	L2
3	Draw and explain the types of belts used in belt drives for power transmission.	10	CO3	L2
4.	With the help of neat sketch explain the working of DC motor.	10	CO3	L2
5.	Sketch and explain the working of stepper motor.	10	CO3	L2
6.	Define the following and state any two applications of it: Relay, ii) Solenoid, iii) MOSFETS iv) Diodes	10	CO5	L2
7.	Explain the method of transmitting the power between two shafts.	10	CO5	L2

CI **CCI** **HOD**

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Scheme of Evaluation

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		MARKS	CO	RBT
1.	What is a mechanical actuator? List the various types of mechanical actuators.	**4+6**	CO3	L1
2.	Explain the construction of a ratchet and pawl mechanism.	**5+5**	CO3	L2
3	Draw and explain the types of belts used in belt drives for power transmission.	**5+5**	CO3	L2
4.	With the help of neat sketch explain the working of DC motor.	**4+4+2**	CO3	L2
5.	Sketch and explain the working of stepper motor.	**5+5**	CO3	L2
6.	Define the following and state any two applications of it: Relay, ii) Solenoid, iii) MOSFETS iv) Diodes	**2*2.5**	CO5	L2
7.	Explain the method of transmitting the power between two shafts.	**5+5**	CO5	L2

Solutions:

What is a mechanical actuator? List the various types of mechanical actuators.

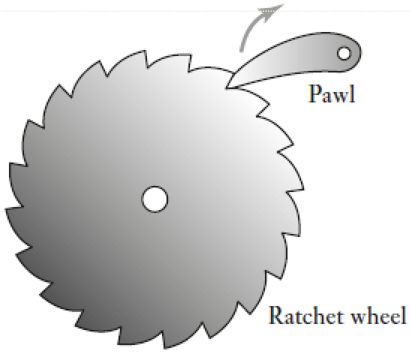
Mechanical actuators are devices which can be considered to be motion converters in that they transform motion from one form to some other required form. They might, for example, transform linear motion into rotational motion, or motion in one direction into a motion in a direction at right angles, or perhaps a linear reciprocating motion into rotary motion, as in the internal combustion engine where the reciprocating motion of the pistons is converted into rotation of the crank and hence the drive shaft.

Mechanical elements can include the use of linkages, cams, gears, rack and pinion, chains, belt drives, etc. For example, the rack-and-pinion can be used to convert rotational motion to linear motion. Parallel shaft gears might be used to reduce a shaft speed. Bevel gears might be used for the transmission of rotary motion through 90°. A toothed belt or chain drive might be used to transform rotary motion about one axis to motion about another. Cams and linkages can be used to obtain motions which are prescribed to vary in a particular manner.

Explain the construction of a ratchet and pawl mechanism.

Ratchets can be used to lock a mechanism when it is holding a load. Figure 8.21 shows a ratchet and pawl. The mechanism consists of a wheel, called a ratchet, with saw-shaped teeth which engage with an arm called a pawl. The arm is pivoted and can move back and forth to engage the wheel. The shape of the teeth is such that rotation can occur in only one direction. Rotation of the ratchet wheel in a clockwise direction is prevented by the pawl and can only take place when the pawl is lifted. The pawl is normally spring loaded to ensure that it automatically engages with the ratchet teeth.

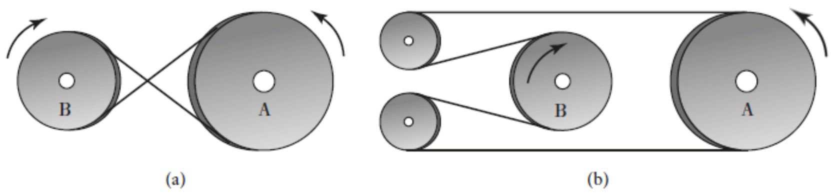
Thus a winch used to wind up a cable on a drum may have a ratchet and pawl to prevent the cable unwinding from the drum when the handle is released.



Draw and explain the types of belts used in belt drives for power transmission.

Belt drives are essentially just a pair of rolling cylinders with the motion of one cylinder being transferred to the other by a belt (Figure 8.22). Belt drives use the friction that develops between the pulleys attached to the shafts and the belt around the arc of contact in order to transmit a torque. Since the transfer relies on frictional forces then slip can occur. The transmitted torque is due to the differences in tension that occur in the belt during operation. This difference results in a tight side and a slack side for the belt. The belt drive shown in Figure 8.22 gives the driven wheel rotating in the same direction as the driver wheel. Figure 8.23 shows two types of reversing drives. With both forms of drive, both sides of the belt come into contact with the wheels and so V-belts or timing belts cannot be used.

Figure 8.23 Reversed belt drives: (a) crossed belt, (b) open belt.



Types of belts

The four main types of belts (Figure 8.24) are outlined below.

1 *Flat*

The belt has a rectangular cross-section. Such a drive has an efficiency of about 98% and produces little noise. They can transmit power over long distances between pulley centres. Crowned pulleys are used to keep the belts from running off the pulleys.

2 *Round*

The belt has a circular cross-section and is used with grooved pulleys.

3 V-belts

V-belts are used with grooved pulleys and are less efficient than flat belts but a number of them can be used on a single wheel and so give a multiple drive.

4 *Timing*

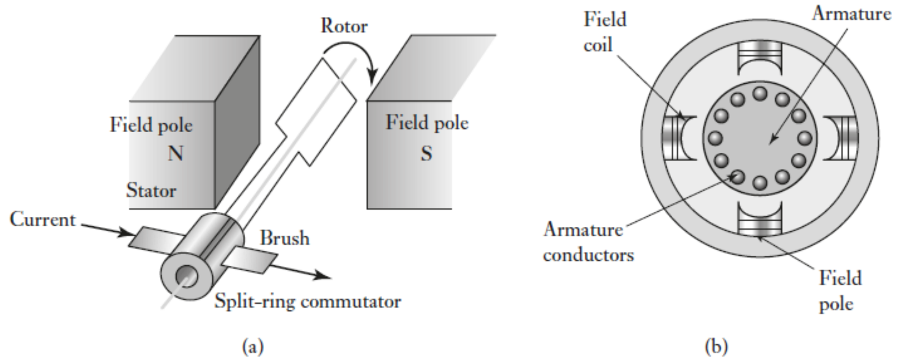
Timing belts require toothed wheels, having teeth which fit into the grooves on the wheels. The timing belt, unlike the other belts, does not stretch or slip and consequently transmits power at a constant angular velocity ratio. The teeth make it possible for the belt to be run at slow or fast speeds.

With the help of neat sketch explain the working of DC motor.

Electric motors are frequently used as the final control element in positional or speed control systems. Motors can be classified into two main categories: d.c. motors and a.c. motors, most motors used in modern control systems being d.c. motors. It is possible to divide d.c. motors into two main groups, those using brushes to make contact with a commutator ring assembly on the rotor to switch the current from one rotor winding to another and the brushless type. With the brush type of motor, the rotor has the coil winding and the stator can be either a permanent magnet or an electromagnet. With the brushless type, the arrangement is reversed in that the rotor is a permanent magnet and the stator has the coil winding.

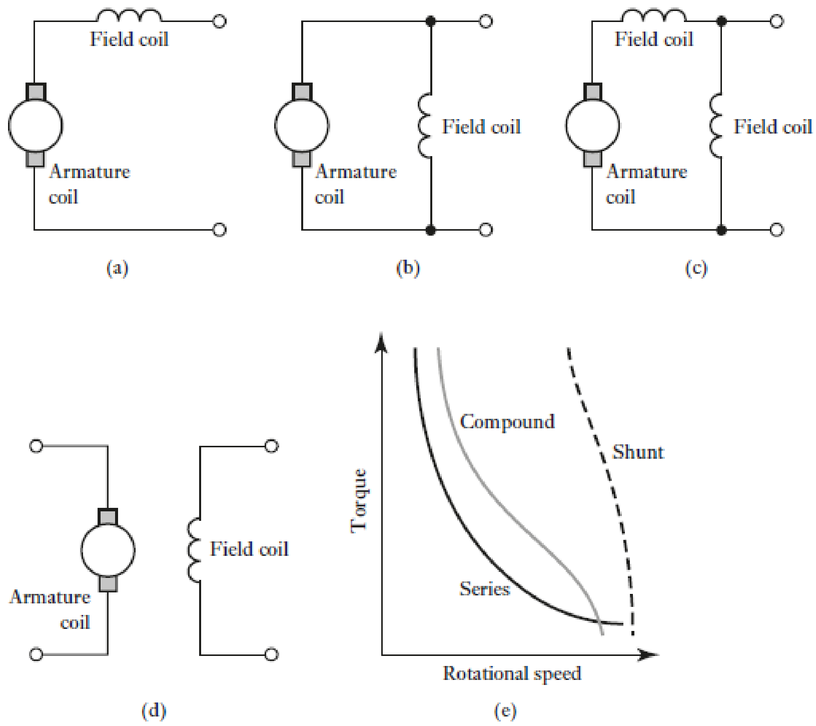
A brush-type d.c. motor is essentially a coil of wire which is free to rotate, and so termed the rotor, in the field of a permanent magnet or an electromagnet, the magnet being termed the stator since it is stationary (Figure 9.15(a)). When a current is passed through the coil, the resulting forces acting on its sides at right angles to the field cause forces to act on those sides to give rotation. However, for the rotation to continue, when the coil passes through the vertical position the current direction through the coil has to be reversed and this is achieved by the use of brushes making contact with a split-ring commutator, the commutator rotating with the coil.

Figure 9.15 A d.c. motor: (a) basics, (b) with two sets of poles.



In the conventional d.c. motor, coils of wire are mounted in slots on a cylinder of magnetic material called the armature. The armature is mounted on bearings and is free to rotate. It is mounted in the magnetic field produced by field poles. These may be, for small motors, permanent magnets or electromagnets with their magnetism produced by a current through the field coils. Figure 9.15(b) shows the basic principle of a four-pole d.c. motor with the magnetic field produced by current-carrying coils. The ends of each armature coil are connected to adjacent segments of a segmented ring called the commutator with electrical contacts made to the segments through carbon contacts called brushes. As the armature rotates, the commutator reverses the current in each coil as it moves between the field poles. This is necessary if the forces acting on the coil are to remain acting in the same direction and if the rotation is to continue. The direction of rotation of the d.c. motor can
be reversed by reversing either the armature current or the field current.

Figure 9.17 Direct current motors: (a) series, (b) shunt, (c) compound, (d) separately wound, (e) torque–speed characteristics.



Direct current motors with field coils are classified as series, shunt, compound and separately excited according to how the field windings and armature windings are connected (Figure 9.17).
1 Series wound motor (Figure 9.17(a))
With the series-wound motor, the armature and field coils are in series and thus carry the same current. Such d.c. motors are used where large starting torques are required. With light loads there is a danger that a series-wound motor might run at too high a speed.
2 Shunt-wound motor (Figure 9.17(b))
With the shunt-wound motor, the armature and field coils are in parallel. It provides the lowest starting torque and a much lower no-load speed and has good speed regulation. The field coil is wound with many turns of fine wire and so has a much larger resistance than the armature coil. Thus, with a constant supply voltage, the field current is virtually constant.
3 Compound motor (Figure 9.17(c))

The compound motor has two field windings, one in series with the armature and one in parallel. The aim is to get the best features of the series- and shunt-wound motors, namely a high starting torque and good speed regulation.

4 Separately excited motor (Figure 9.17(d))

The separately excited motor has separate control of the armature and field currents and can be considered to be a special case of the shunt wound motor.

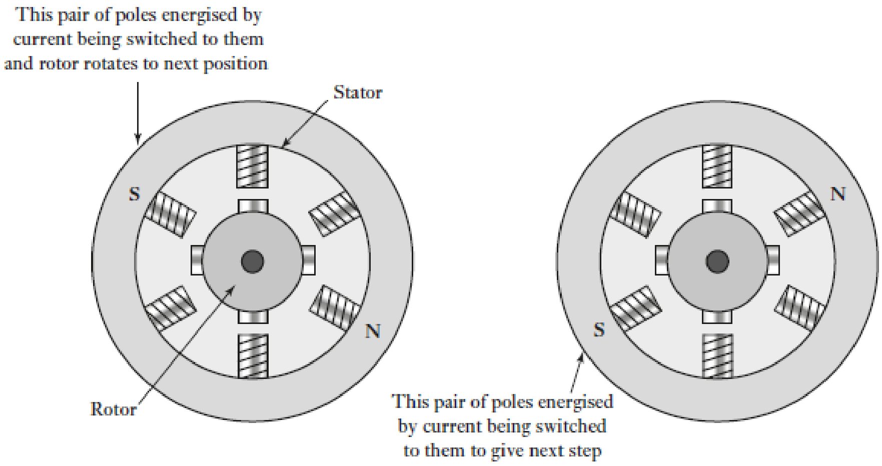
Sketch and explain the working of stepper motor.

The stepper motor is a device that produces rotation through equal angles, the so-called steps, for each digital pulse supplied to its input. Thus, for example, if with such a motor 1 pulse produces a rotation of 6° then 60 pulses will produce a rotation through 360°. There are a number of forms of stepper motor.

1 Variable reluctance stepper

Figure 9.24 shows the basic form of the variable reluctance stepper motor. With this form the rotor is made of soft steel and is cylindrical with four poles, i.e. fewer poles than on the stator. When an opposite pair of windings has current switched to them, a magnetic field is produced with lines of force which pass from the stator poles through the nearest set of poles on the rotor. Since lines of force can be considered to be rather like elastic thread and always trying to shorten themselves, the rotor will move until the rotor and stator poles line up. This is termed the position of minimum reluctance. This form of stepper generally gives step angles of 7.5° or 15°.

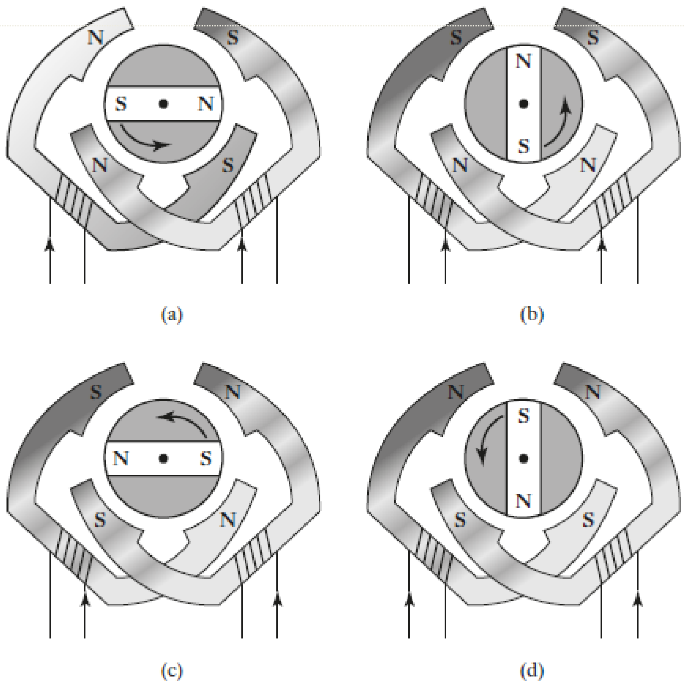
Figure 9.24 Variable reluctance stepper motor.



2 Permanent magnet stepper

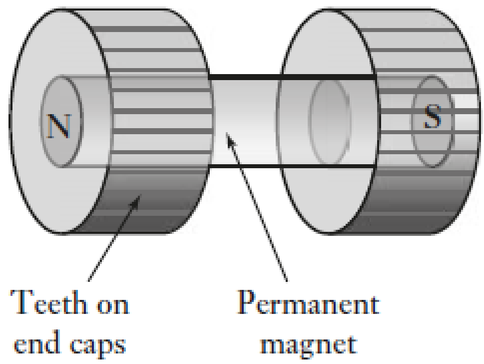
Figure 9.25 shows the basic form of the permanent magnet motor. The motor shown has a stator with four poles. Each pole is wound with a field winding, the coils on opposite pairs of poles being in series. Current is supplied from a d.c. source to the windings through switches. The rotor is a permanent magnet and thus when a pair of stator poles has a current switched to it, the rotor will move to line up with it. Thus for the currents giving the situation shown in the figure, the rotor moves to the 45° position. If the current is then switched so that the polarities are reversed, the rotor will move a further 45° in order to line up again. Thus by switching the currents through the coils, the rotor rotates in 45° steps. With this type of motor, step angles are commonly 1.8°, 7.5°, 15°, 30°, 34° or 90°.

Figure 9.25 Permanent magnet two-phase stepper motor with 90° steps. (a), (b), (c) and (d) show the positions of the magnet rotor as the coils are energised in different directions.



3 Hybrid stepper

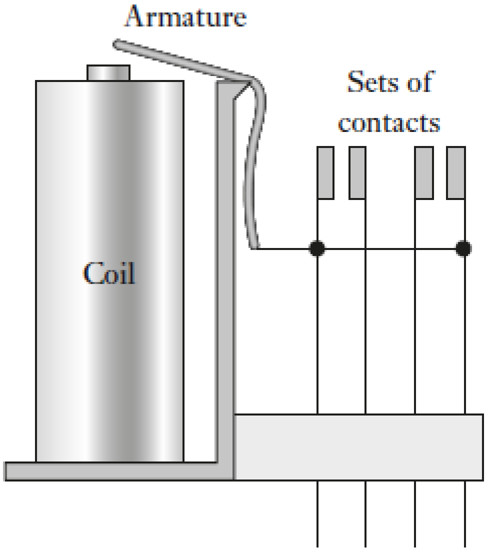
Hybrid stepper motors combine the features of both the variable reluctance and permanent magnet motors, having a permanent magnet encased in iron caps which are cut to have teeth (Figure 9.26). The rotor sets itself in the minimum reluctance position in response to a pair of stator coils being energised. Typical step angles are 0.9° and 1.8°. If a motor has n phases on the stator and m teeth on the rotor, the total number of steps per revolution is nm. Such stepper motors are extensively used in high-accuracy positioning applications, e.g. in computer hard disk drives.



Define the following and state any two applications of it:

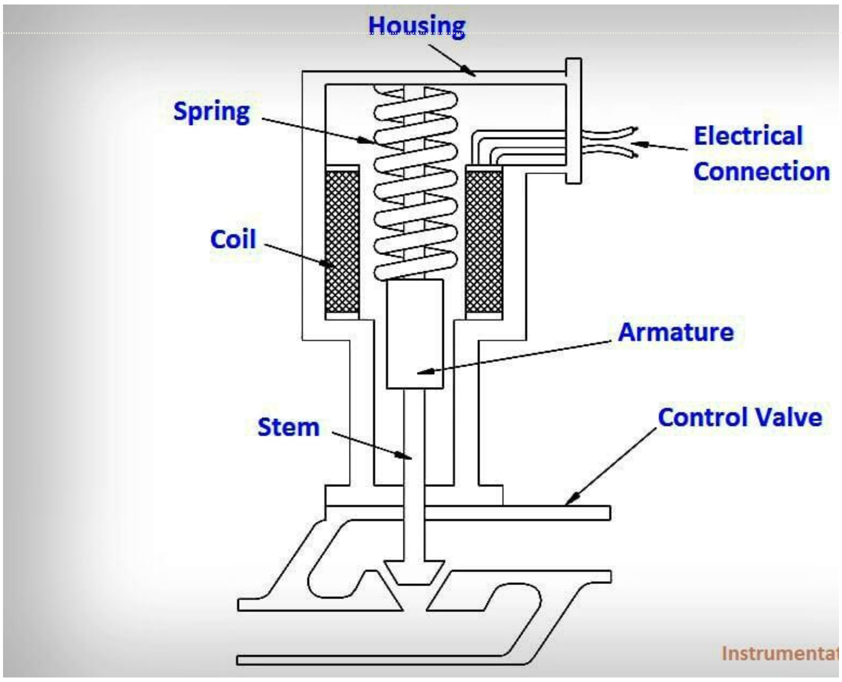
iv) RELAY, ii) SOLENOID, iii) Diodes, iv) MOSFETS

i)Relays are electrically operated switches in which changing a current in one electric circuit switches a current on or off in another circuit. For the relay shown in Figure 9.1(a), when there is a current through the solenoid of the relay, a magnetic field is produced which attracts the iron armature, moves the push rod, and so closes the normally open (NO) switch contacts and opens the normally closed (NC) switch contacts.



Relays are often used in control systems. The output from a controller is a relatively small current and so it is often used in conjunction with a transistor to switch on the current through the relay solenoid and hence use the relay to switch on the much larger current needed to switch on or off a
final correction element such as an electric heater in a temperature control system or a motor. Figure 9.1(b) shows the type of circuit that might be used. Because relays are inductances, they can generate a back voltage when the energising current is switched off or when their input switches from a high to low signal. As a result, damage can occur in the connecting circuit. To
overcome this problem, a diode is connected across the relay. When the back e.m.f. occurs, the diode conducts and shorts it out. Such a diode is termed a free-wheeling or flyback diode.
solenoids consist of a coil of electrical wire with an armature which is attracted to the coil when a current passes through it and produces a magnetic field. The movement of the armature contracts a return spring which then allows the armature to return to its original position when the current ceases. The solenoids can be linear or rotary, on/off or variable positioning and operated by d.c. or a.c. Such an arrangement can be used to provide electrically operated actuators which are widely used for short stroke devices, typically up to 25 mm.

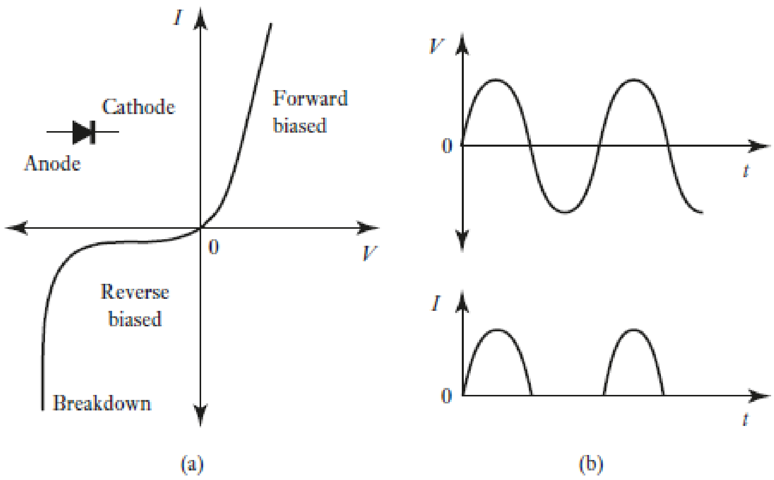
ii)Solenoid valves are another example of such devices, being used to control fluid flow in hydraulic or pneumatic systems (see Figure 7.9). When a current passes through a coil, a soft iron plunger form of armature is pulled into the coil and, in doing so, can open or close ports to allow the flow of a fluid. The force exerted by the solenoid on the armature is a function of the current in the coil and the length of the armature within the coil. With on/off valves, i.e. those used for directional control, the current in the coil is controlled to be either on or off and the core is consequently in one of two positions. With proportional control valves, the current in the coil is
controlled to give a plunger movement which is proportional to the size of the current.



i)Diodes. ii) MOSFET

The diode has the characteristic shown in Figure 9.3(a), only passing a current when forward biased, i.e. with the anode being positive with respect to the cathode. If the diode is sufficiently reverse biased, i.e. a very high voltage, it will break down. If an alternating voltage is applied across a diode, it can be regarded as only switching on when the direction of the voltage is such as to forward-bias it and being off in the reverse-biased direction. The result is that the current through the diode is half-rectified to become just the current due to the positive halves of the input voltage (Figure 9.3(b)), i.e. the circuit only 'switches on' for the positive half cycle.

Figure 9.3 (a) Diode characteristic, (b) half-wave rectification.



MOSFETs (metal-oxide field-effect transistors) come in two types, the n-channel and the p-channel. Figure 9.12(a) and (b) shows the symbols. The main difference between the use of a MOSFET for switching and a bipolar transistor is that no current flows into the gate to exercise the control. The gate voltage is the controlling signal. Thus drive circuitry can be simplified
in that there is no need to be concerned about the size of the current.

Figure 9.12 MOSFETs: (a) n-channel, (b) p-channel, (c) used to control a d.c. motor.

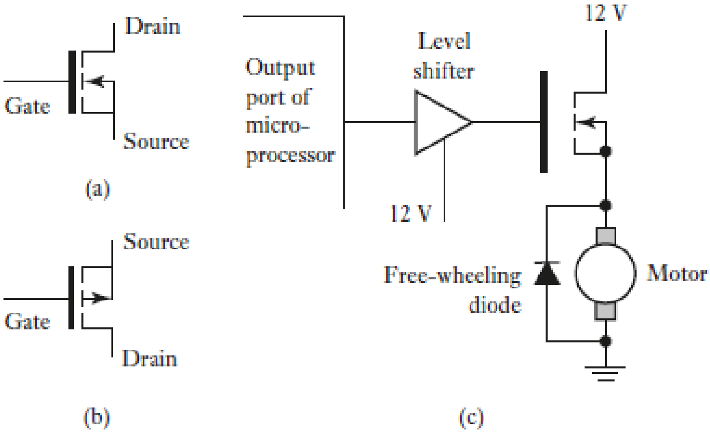


Figure 9.12(c) illustrates the use of a MOSFET as an on/off switch for a motor; compare the circuit with that in Figure 9.11 where bipolar transistors are used. A level shifter buffer is indicated, this being to raise the voltage level to that required for the MOSFET. With MOSFETs, very high-frequency switching is possible, up to 1 MHz, and interfacing with a microprocessor is simpler than with bipolar transistors.

Explain the method of transmitting the power between two shafts.

Gear trains are mechanisms which are very widely used to transfer and transform rotational motion. They are used when a change in speed or torque of a rotating device is needed. For example, the car gearbox enables the driver to match the speed and torque requirements of the terrain with the engine power available.

Gears can be used for the transmission of rotary motion between parallel shafts (Figure 8.15(a)) and for shafts which have axes inclined to one another (Figure 8.15(b)). The term bevel gears is used when the lines of the shafts intersect, as illustrated in Figure 8.15(b). When two gears are in mesh, the larger gear wheel is often called the spur or crown wheel and the smaller one the pinion. Gears for use with parallel shafts may have axial teeth with the teeth cut along axial lines parallel to the axis of the shaft (Figure 8.15(c)). Such gears are then termed spur gears. Alternatively they may have helical teeth with the teeth being cut on a helix (Figure 8.15(d)) and are then termed helical gears. Helical gears have the advantage that there is a gradual engagement of any individual tooth and consequently there is a smoother drive and generally prolonged life of the gears. However, the inclination of the teeth to the axis of the shaft results in an axial force component on the shaft bearing. This can be overcome by using double helical teeth (Figure 8.15(e)).

Figure 8.15 (a) Parallel gear axes, (b) axes inclined to one another, (c) axial teeth, (d) helical teeth, (e) double helical teeth.