The starting system consists of the battery, cables, starter motor, flywheel ring-gear, and the ignition switch.

During starting two actions occur. The pinion of the starter motor engages with the flywheel ring gear, and the starter motor then operates to turn over, or ‘crank’, the engine.

The starter motor is an electric motor mounted on the engine block, and operated from the battery. It is designed to have high turning effort at low speeds.

The starter cables are the thickest on the vehicle, as a high current must be delivered to the starter motor, to turn the crankshaft from rest, and keep it turning until the engine fires, and runs on its own.

1. The starter cables are the ……………………… on the vehicle, as a high current must be delivered to the starter motor, to turn the crankshaft from rest.

2. The starting system consists of the battery, cables, starter motor, flywheel ring-gear, and the ……………………… switch.

3. The pinion of the starter motor engages with the ……………………… ring gear, and the starter motor then operates to turn over, or ‘crank’, the engine.
Starter motor principles

Summary
The starter motor converts electrical energy to mechanical energy and is mounted on the cylinder block in a position to engage a ring gear on the engine flywheel.

The starter motor converts electrical energy to mechanical energy and is mounted on the cylinder block in a position to engage a ring gear on the engine flywheel.

Starting is usually accomplished by the operator activating a starter switch as part of ignition key operation. This allows a relatively small current to flow to a starter solenoid relay and operate a plunger attached to a drive pinion engagement lever.

The plunger movement engages the drive pinion with the ring gear and closes a set of heavy duty contacts, allowing a large current to flow from the battery to the starter motor, rotating the armature and drive pinion, and causing the crankshaft to spin.

When the engine starts and is able to run on its own, the operator usually releases the key and this withdraws the pinion from the ring gear and brings the armature to a halt.

1. The plunger movement engages the drive pinion with the __________ gear and closes a set of heavy duty contacts, allowing a large current to flow from the battery to the starter motor, rotating the armature and drive pinion, and causing the crankshaft to spin.

2. Activating a starter switch allows a relatively small current to flow to a starter solenoid __________ and operate a plunger attached to a drive pinion engagement lever.

3. The starter motor converts electrical energy to mechanical energy and is mounted on the cylinder __________ in a position to engage a ring gear on the engine flywheel.

Score .......... / 3

Supervisor/Instructor information:

Name .................................................. Signature .................................................. Date ..................................
A basic starter motor consists of:

- field coils
- armature
- commutator
- brushes
- a drive pinion with an over-running clutch
- and a drive pinion engagement solenoid and shift fork.

The armature is the revolving component of the direct current motor. The armature shaft is supported at each end by bushes pressed into end frames which locate the armature centrally in the outer casing or yoke of the motor.

The commutator end frame carries the copper-impregnated carbon brushes which conduct current through the armature when it is being rotated in operation. The brushes are mounted in brush holders and are kept in contact with the commutator by tensioned spiral springs.

Half of the brushes are connected directly to the end-frame and via the ground return of the vehicle frame to the battery negative terminal. The other half are insulated from the end-frame and connected to the positive battery terminal via the main starter solenoid input terminal.

This can be a direct connection in the case of a permanent magnet type starter or indirectly via the electro-magnetic field poles of a series wound motor.
1. The end frame carries the copper-impregnated carbon brushes which conduct current through the armature when it is being rotated in operation.

2. The armature shaft is supported at each end by pressed into end frames which locate the armature centrally in the outer casing or yoke of the motor.

3. The commutator serves as a sliding electrical connection between the motor windings and the brushes and is mounted on one end of the shaft.
Starter magnet types

Summary
Normally four stationary field poles are mounted in the outer casing or yoke and these can be electro-magnets or permanent magnets.

The electro-magnets are formed by current flow through heavy strip copper windings, wound around iron pole shoes which are fastened to the yoke. Permanent magnets are located similarly, but occupy less space. The yoke is made of iron and serves to concentrate the magnetic field produced by the field magnets.

Starter motors with electro-magnetic field windings for light vehicle applications are series wound motors. Because the resistance of the field and armature windings is low, the current flow is high when the motor starts under load and this generates a strong magnetic field that will produce a high turning effort at low speeds. This high initial torque drops sharply as motor speed increases due to the back EMF induced in the armature windings which opposes current flow and reduces torque output.

Some series wound motors have the field windings in parallel with each other but then in series with the armature. These are referred to as a series-parallel field, series motor. By connecting the field windings in this way, more current can flow in the circuit and an overall increase in torque is obtained.

1. The yoke is made of iron and serves to concentrate the magnetic field produced by the field ............................................

2. Because the resistance of the field and armature windings is low, the current flow is high when the motor starts under load and this generates a strong magnetic field that will produce a high turning effort at ............................... speeds.

3. Some series wound motors have the field windings in ............................ with each other but then in series with the armature.

Score .......... / 3

Supervisor/Instructor information:
Name ........................................................ Signature ......................................................... Date ........................................

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Starter motor engagement

Engagement is provided by operation of the ignition switch in the start position which activates a starter mounted solenoid whose plunger is engaged with the hooked end of a pinion shift lever and operating fork.

Solenoid operation moves the operating fork causing the pinion to engage with the ring gear and also causes the plunger contacts to bridge the main starter terminals.

The fork locates in a guide ring on a pinion driver which is coupled to the pinion via a roller type over-running clutch designed to transmit drive in one direction only.

The pinion driver is mounted on a helix, machined on the armature shaft to form a very coarse thread. This allows the pinion driver to rotate slightly when it is moved towards the ring gear and this feature together with a chamfer on the leading edge of the ring gear and pinion teeth, is designed to assist meshing and easy engagement. However, if the pinion teeth butt against the ring gear teeth and engagement is prevented, the guide ring continues its axial movement by sliding over the sleeve of the driver and compressing a meshing spring until the plunger contacts bridge the main terminals and the armature begins to turn.

Slight armature rotation and the force from the meshing spring allows the pinion teeth to drop into mesh with the ring gear assisted by the screw action of the helix. The helix forces the pinion further into the ring gear until the pinion contacts a stop ring on the armature shaft. This prevents further axial movement and the driver and pinion now lock to the shaft via the helix and over-running clutch and transfer the armature rotation to the flywheel.

The pinion has only a small number of teeth compared to the ring gear and this means the armature will rotate several times for each revolution of the flywheel. The gear reduction also multiplies the torque from the starter motor.

As soon as the engine starts, its rotational speed will eventually exceed the speed of the armature. At this instant the over-running clutch breaks the connection between the pinion and the armature shaft and prevents over-speeding and damage of the armature.

The pinion remains meshed as long as the engaging lever is held in the engaged position. Releasing the starter switch allows the solenoid plunger return spring, to return the engaging lever, driver and pinion to their original position.
1. Slight armature rotation and the force from the meshing spring allows the pinion to drop into mesh with the ring gear assisted by the screw action of the helix.

2. The pinion has only a small number of teeth compared to the and this means the armature will rotate several times for each revolution of the flywheel.

3. The fork locates in a guide ring on a pinion driver which is coupled to the pinion via a roller type over-running designed to transmit drive in one direction only.
Commutation

When current flows in a conductor, an electromagnetic field is generated around it. If the conductor is placed so that it cuts across a stationary magnetic field, the conductor will be forced out of the stationary field. This happens because the lines of force of the stationary field are distorted by the electromagnetic field around the conductor and try to return to a straight line condition.

Reversing the direction of current flow in the conductor will cause the conductor to move in the opposite direction. This is known as the motor effect and is greatest when the current carrying conductor and the stationary magnetic field are at right angles to each other.

A conductor loop which can freely rotate within the magnetic field is the most efficient design. In this position, when current flows through the loop the stationary magnetic field is distorted and the lines of force try to straighten. This forces one side of the loop up and the other side of the loop down.

The motor effect causes the loop to rotate until it is at ninety degrees to the magnetic field. To continue rotation, the direction of current flow in the conductor must be reversed at this static neutral point.

A commutator is used for this purpose.

An example commutator consists of two semi-circular segments which are connected to the two ends of the loop and are insulated from each other. Carbon impregnated brushes provide a sliding connection to the commutator to complete the circuit and allow current to flow through the loop.

Rotation commences with both sides of the conductor loop cutting the stationary field. When the loop passes the point where the field is no longer being cut, the momentum of rotation carries the loop and the commutator segments over so that the brushes maintain current flow in the same direction in each side of the loop relative to the stationary field.

This process will maintain a consistent direction of rotation of the loop. In order to achieve a uniform motion and torque output, the number of loops must be increased. The additional loops smooth out the rotational forces. A starter motor armature has a large number of conductor loops and so has many segments on the commutator.
1. Carbon impregnated brushes provide a sliding connection to the \ldots to complete the circuit and allow current to flow through the loop.

2. If the \ldots is placed so that it cuts across a stationary magnetic field, the conductor will be forced out of the stationary field.

3. Reversing the direction of current flow in the conductor will cause the conductor to move in the \ldots direction.
Switching

**Summary**
The starter motor is brought into operation by a starter switch incorporated as a part of the ignition key. It operates a solenoid which has two functions. To engage the drive pinion with the engine flywheel and connect the battery directly to the starter motor.

The starter motor is usually brought into operation by activating a starter switch as part of ignition key operation.

This remote control operates a starter mounted solenoid which has two functions:

- It acts as a solenoid to engage the pinion with the flywheel ring gear,
- and it acts as a relay to bridge the main starting terminals.

In the control circuit, the ignition lock start switch has a positive connection from the battery and a connection to two windings in the starter solenoid. One of these is a “pull-in” winding which has a low resistance value and the other is a “hold-in” winding which has a high resistance.

The pull-in winding is connected to the main starter terminal leading to the field and armature windings and its circuit will be completed through the armature to ground on the starter casing and by frame return to the negative battery terminal.

The hold-in winding is connected to ground on the starter casing.

With the ignition key in the START position, current passes from the positive battery terminal through the start switch and through both windings. The high current flow through the low resistance pull-in winding creates a strong magnetic field which attracts the solenoid plunger towards the main terminals. Plunger movement also operates the shift fork lever engaging the pinion with the ring gear.

The plunger contacts a switching pin which transfers the motion through a contact spring to a moving contact which then bridges the main terminals. This allows a large current to flow from the battery through the starter motor windings causing armature and pinion rotation and rotation of the engine crankshaft. Bridging the contacts also shortcircuits the pull-in winding and the plunger is held in position by the action of the hold-in winding only. The pull-in winding is short-circuited because battery voltage is now being applied to both sides of the winding and this stops current flow through it.

During engine cranking, the action of the helix on the rotating armature shaft causes the pinion to be forced as deeply as possible into the flywheel ring gear and this holds the pinion in mesh. The hold-in winding is only used to ensure that the moving contact continues to bridge the main starter terminals.

When the engine initially fires, the ring gear tries to drive the pinion and the force acting through the helix is relieved. When the starter switch is released, this opens the circuit between the battery and the hold-in winding and current flow through the winding ceases. The return springs in the solenoid return the plunger, the moving contact and the pinion to the rest position.
1. The pull-in winding is connected to the main starter terminal leading to the field and armature windings and its circuit will be completed through the armature to ground on the starter casing and by frame return to the ………………………… battery terminal.

2. One of these is a “pull-in” winding which has a low resistance value and the other is a “hold-in” winding which has a …………………………… resistance.

3. This remote control operates a starter mounted ………………………… which has two functions:

4. When the engine initially fires, the ring gear tries to drive the pinion and the force acting through the ………………………… is relieved.

5. Plunger movement also operates the shift fork lever engaging the pinion with the ………………………… gear.

Score ………... / 5

Supervisor/Instructor information:

Name …………………………………………….. Signature …………………………………………….. Date …………………………………

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