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Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATION/ NATIONAL SENIOR CERTIFICATE EXAMINATION

MECHANICAL TECHNOLOGY: AUTOMOTIVE

2021

MARKS: 200

TIME: 3 hours

This question paper consists of 14 pages and a 2-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	10
5	Tools and Equipment	23	20
6	Engines	28	25
7	Forces	32	25
8	Maintenance	23	20
9	Systems and Control (Automatic Gearbox)	18	20
10	Systems and Control (Axles, Steering Geometry and Electronics)	32	30
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)

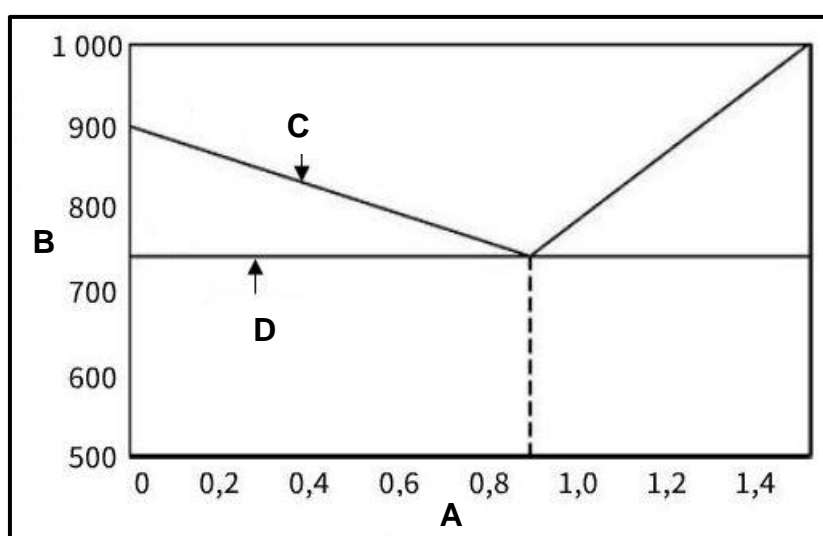
[6]

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. (4)

**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.

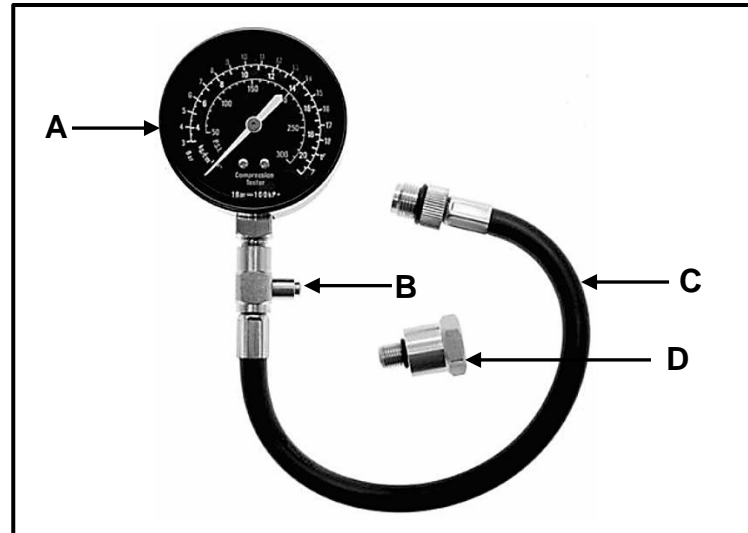
- 4.1 Which of the following procedures forms part of the cylinder leakage test?
- A Connecting a compression tester to a spark plug hole
 - B Cranking the engine
 - C Connecting compressed air to a cylinder leakage tester
 - D Cleaning around the cylinder leakage tester
- (1)
- 4.2 A compression test is performed when the engine is ...
- A at BDC.
 - B at TDC.
 - C turning.
 - D locked by the gearbox.
- (1)
- 4.3 What is the function of a supercharger? To effectively ...
- A heat the intake air
 - B cool the exhaust gas
 - C drive the blower
 - D fill the cylinder with air
- (1)
- 4.4 Which ONE of the following can determine wear on a crankshaft journal?
- A Check if the crankshaft is dynamically balanced.
 - B Measure the crankshaft journal for ovality.
 - C Measure the crankshaft stroke length.
 - D Check if the crankshaft is statically balanced.
- (1)
- 4.5 Which ONE of the following will raise the compression ratio of an engine?
- A Fit a thicker head gasket.
 - B Fit a piston with a lower crown.
 - C Increase the bore size of the cylinders.
 - D Fit a crankshaft with a shorter stroke.
- (1)
- 4.6 The total volume displaced by the piston when it moves from bottom dead centre to top dead centre is called the ...
- A compression volume.
 - B clearance volume.
 - C swept volume.
 - D piston volume.
- (1)
- 4.7 Brake power is defined as the ...
- A theoretical power generated by the engine.
 - B usable power measured at the flywheel.
 - C mechanical power transmitted by a rotating shaft.
 - D power that is calculated using the engine pressure.
- (1)

- 4.8 What is the cause of excessive oil pressure in the engine lubricating system?
A Viscosity of the oil is too high
B Worn oil pump
C Too little oil in the engine
D Too big crankshaft bearing clearances (1)
- 4.9 Which ONE of the following is an advantage of fitting an electric submerged fuel pump to a fuel system?
A High operating noise level
B A fuel return pipe is needed
C Prevents vapour lock
D Pump does not have to turn at high revolutions (1)
- 4.10 Reverse reduction is obtained with a single epicyclic gear system by using the following combination:
A The planet carrier is locked, the sun gear is the driving member and the annulus is the driven component.
B The annulus is locked with the sun gear and the planet carrier is the driven component.
C The planet carrier is locked and the sun gear is the driver.
D The annulus is locked and the sun gear is the driven component. (1)
- 4.11 The stator in the torque converter is responsible for the ...
A increase in torque.
B transfer of power.
C increase in power.
D vortex flow of the oil. (1)
- 4.12 Which ONE of the following statements best define *king pin inclination*?
A The distance between the front and rear wheels
B The angle formed between the perpendicular line and the centre line of the king pin as seen from the side
C The angle formed between the perpendicular line and the centre line of the wheel as seen from the front
D The angle formed between the perpendicular line and the centre line of the king pin as seen from the front (1)
- 4.13 Which component manages the operation of the injectors in electronic fuel injection systems?
A Fuel pump
B Engine sensors
C Electronic control unit
D Throttle valve (1)
- 4.14 Which ONE of the following methods can be used to increase the output frequency of the alternator?
A Decrease the rotational frequency at which the magnet rotates.
B Decrease the magnetic field.
C Increase the supply voltage to the rotor.
D Increase the number of coils of wire on the stator. (1)

[14]

QUESTION 5: TOOLS AND EQUIPMENT (SPECIFIC)

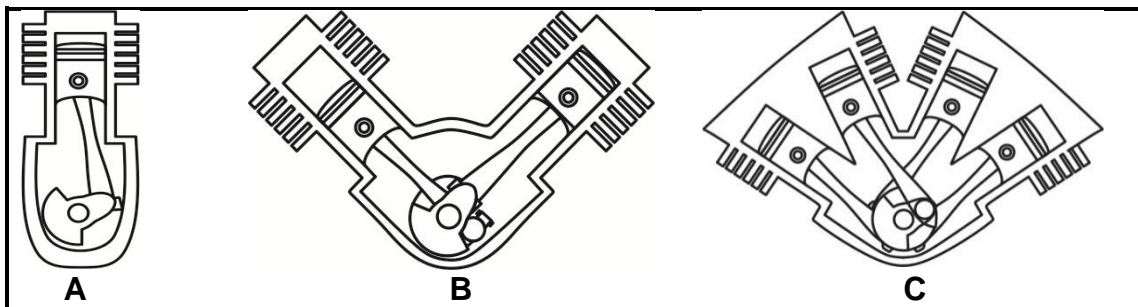
- 5.1 FIGURE 5.1 shows a compression tester. Label parts **A–D** as indicated in FIGURE 5.1.

**FIGURE 5.1**

- (4)
- 5.2 What is the function of the cylinder leakage tester? (2)
- 5.3 Briefly explain how to set up the cylinder leakage tester to check for leaks in the combustion chamber. (6)
- 5.4 Carbon monoxide (CO), nitrogen oxide (NO_x) and oxygen (O₂) are gases that are analysed when conducting an exhaust gas analysis. Name TWO other gases that can also be analysed by a exhaust gas analyser. (2)
- 5.5 State THREE precautions when performing an exhaust gas analysis test. (3)
- 5.6 Explain the function of the turn-tables when checking the wheel alignment angles. (2)
- 5.7 What is the optical alignment gauge used for? (1)
- 5.8 Describe THREE basic functions of the on-board diagnostic scanner. (3)
- [23]**

QUESTION 6: ENGINES (SPECIFIC)

- 6.1 State TWO methods to correct the static imbalance of a crankshaft. (2)
- 6.2 Define the following terms with regard to crankshaft balancing:
- 6.2.1 Dynamic balance (2)
- 6.2.2 Reciprocating mass (2)
- 6.3 Describe FOUR features that are built into an engine to improve engine balance. (4)
- 6.4 Name TWO types of vibration dampers. (2)
- 6.5 Identify the different types of cylinder arrangements, **A**, **B** and **C**, in FIGURE 6.5. (3)

**FIGURE 6.5**

- 6.6 Draw a neatly labelled sketch to illustrate the position of the crank pins in a three-cylinder in-line engine. (3)
- 6.7 Name THREE types of superchargers used on an internal combustion engine. (3)
- 6.8 State THREE advantages of using a turbocharger on an engine when compared to a normal induction engine. (3)

- 6.9 FIGURE 6.9 shows how a turbocharger is connected to an internal combustion engine. Label parts **A–D**, as indicated in FIGURE 6.9.

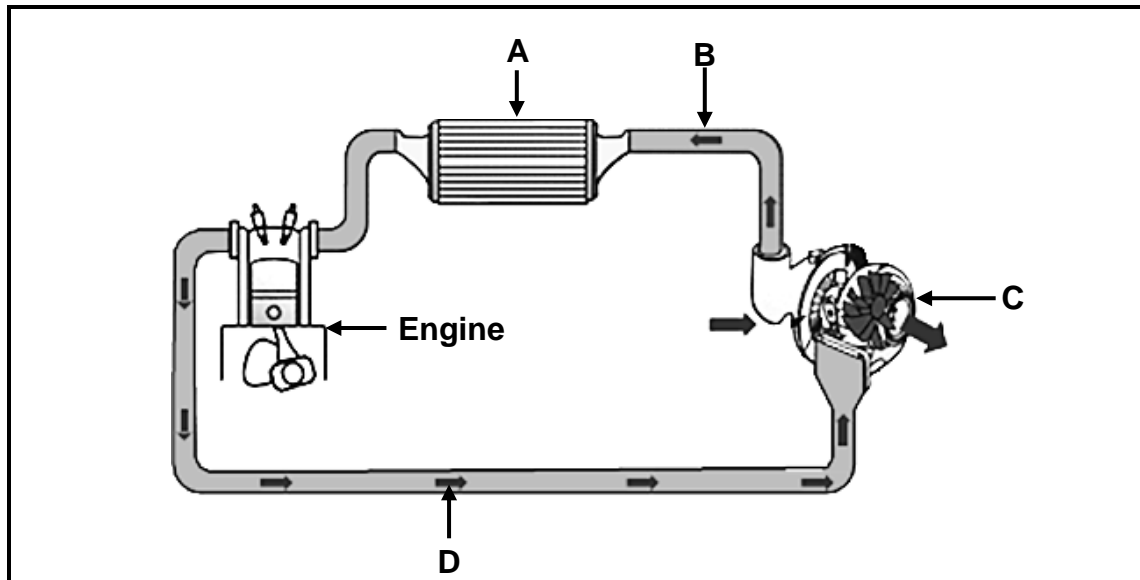


FIGURE 6.9

(4)
[28]

QUESTION 7: FORCES (SPECIFIC)

7.1 Define the following terms:

7.1.1 Power (2)

7.1.2 Compression ratio (2)

7.2 The bore of an engine is 70 mm and the stroke is 75 mm. The compression ratio is 9,5 : 1.

Determine the following by means of calculations:

7.2.1 The swept volume in cm^3 (3)

7.2.2 The original clearance volume in cm^3 (3)

7.2.3 The compression ratio of this engine was increased to 10 : 1 by boring the cylinder. The clearance volume and the stroke length remained unchanged.

What is the new diameter of the cylinder? Give the answer in mm. (6)

7.3 The following data was recorded during a test carried out on a four-cylinder four-stroke petrol engine.

Brake arm length:	420 mm
Spring balance reading:	25 kg
Crankshaft revolutions:	2 000 r/min
Mean effective pressure:	900 kPa
Cylinder bore:	84 mm
Stroke length:	86 mm

Determine the following by means of calculations:

7.3.1 Torque (3)

7.3.2 Indicated power in kW (8)

7.3.3 Brake power in kW (3)

7.3.4 Mechanical efficiency (2)

[32]

QUESTION 8: MAINTENANCE (SPECIFIC)

- 8.1 A pressure drop occurred during a cooling system pressure test. The table below shows possible causes and corrective measures. Complete the table below by writing only the question numbers (8.1.1 to 8.1.4) and the answer in the ANSWER BOOK.

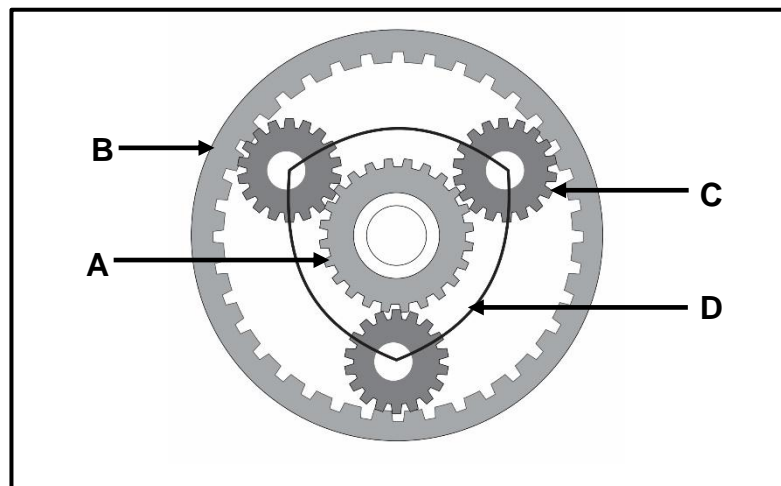
POSSIBLE CAUSES	CORRECTIVE MEASURES
Leaking water hose	8.1.1
8.1.2	Skim the cylinder head and replace the cylinder head gasket
Corroded welch plug or core plug	8.1.3
Pressure released at lower pressure than specified for the radiator cap	8.1.4

- 8.2 State TWO functions of the radiator cap. (2)
- 8.3 An exhaust gas analysis was conducted on a light delivery vehicle. State TWO possible causes for EACH of the following readings:
- 8.3.1 High carbon monoxide (CO) reading (2)
- 8.3.2 High nitrogen oxide (NO_x) reading (2)
- 8.3.3 High oxygen (O₂) reading (2)
- 8.4 State THREE safety requirements when setting up the oil pressure tester on a vehicle. (3)
- 8.5 State FOUR manufacturer's specifications that must be obtained before a fuel pressure test can be carried out. (4)
- 8.6 Explain why EACH of the following procedures need to be conducted when a compression test is done on a four-cylinder four-stroke engine:
- 8.6.1 Remove the high-tension leads (1)
- 8.6.2 Open the throttle fully (1)
- 8.6.3 Record the readings (1)
- 8.7 The result of a wet compression test indicates an increase in cylinder compression pressure. Which component in the engine is faulty? (1)

[23]

QUESTION 9: SYSTEMS AND CONTROL (AUTOMATIC GEARBOX) (SPECIFIC)

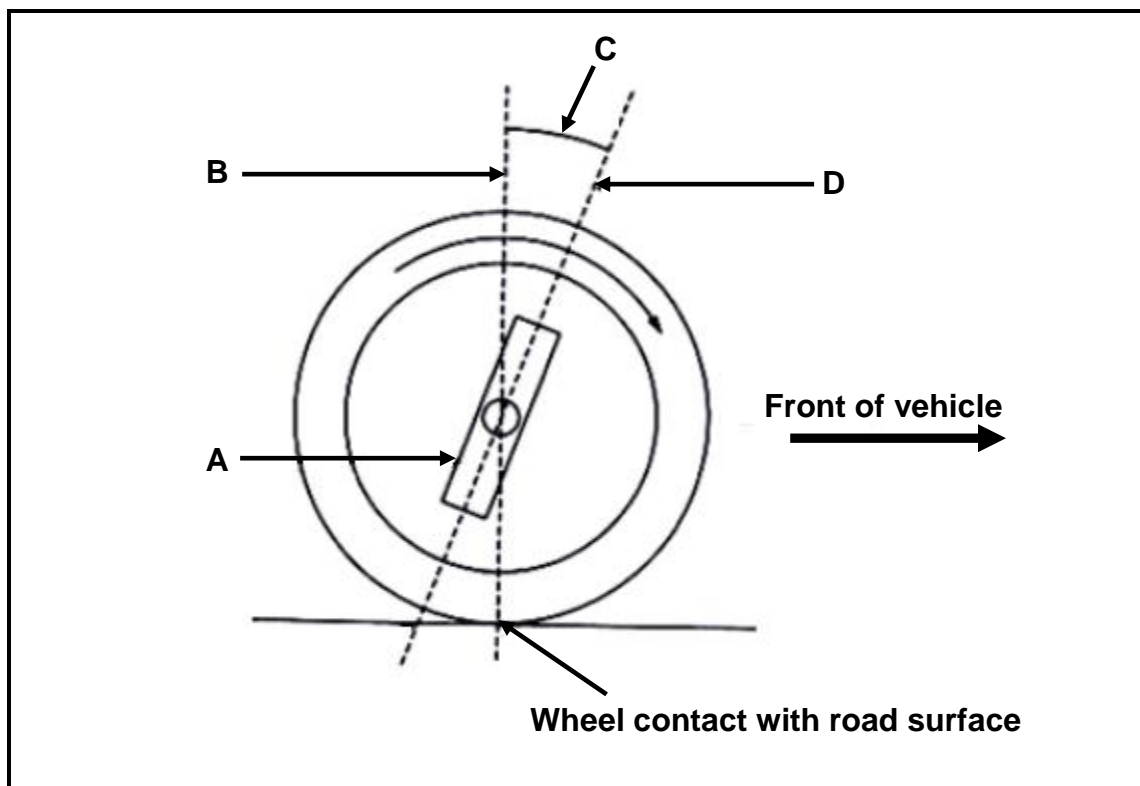
- 9.1 State ONE difference between driving a vehicle fitted with an automatic gearbox to driving a vehicle fitted with a manual gearbox. (2)
- 9.2 State TWO functions of the torque convertor in an automatic gearbox. (2)
- 9.3 Why is a lockup clutch used in torque converters? (2)
- 9.4 Describe the term *stall speed* in a torque converter. (2)
- 9.5 FIGURE 9.5 shows a single epicyclic gear system. Answer the questions that follow.

**FIGURE 9.5**

- 9.5.1 Label parts **A–D** in FIGURE 9.5. (4)
- 9.5.2 State TWO advantages of an epicyclic gear train. (2)
- 9.6 What is the function of the valve body in the automatic gearbox? (2)
- 9.7 Explain how the transmission oil is cooled in an automatic transmission vehicle. (2)
- [18]**

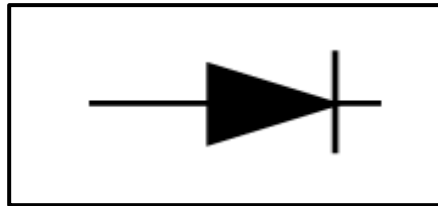
QUESTION 10: SYSTEMS AND CONTROL (AXLES, STEERING GEOMETRY AND ELECTRONICS) (SPECIFIC)

- 10.1 Describe THREE requirements of a well-planned steering mechanism. (3)
- 10.2 State ONE function of EACH of the following wheel alignment angles:
- 10.2.1 Positive camber (1)
- 10.2.2 Ackermann angle (1)
- 10.3 FIGURE 10.3 shows a wheel alignment angle. Answer the questions that follow.

**FIGURE 10.3**

- 10.3.1 Identify the wheel alignment angle indicated by **C** in FIGURE 10.3. (2)
- 10.3.2 Explain the purpose of wheel alignment angle **C**. (2)
- 10.3.3 Label **A**, **B** and **D**. (3)
- 10.4 Sensors and actuators are connected to the electronic control unit (ECU) in an engine management system. Answer the questions that follow.
- 10.4.1 Explain the basic function of a sensor. (2)
- 10.4.2 Explain the basic function of an actuator. (2)

- 10.5 State TWO requirements for a catalytic convertor to function effectively. (2)
- 10.6 Where is the lambda oxygen sensor fitted on an engine? (1)
- 10.7 State THREE benefits of an adaptive speed control system fitted to a vehicle for the driver. (3)
- 10.8 Study the symbol in FIGURE 10.8. Answer the questions that follow.

**FIGURE 10.8**

- 10.8.1 Identify the symbol in FIGURE 10.8. (1)
- 10.8.2 State the function of the component identified in QUESTION 10.8.1. (2)
- 10.9 State ONE function of the following components in the alternator:
- 10.9.1 Rectifier (1)
- 10.9.2 Stator (2)
- 10.9.3 Rotor (2)
- 10.10 State TWO functions of the check valve in the electric fuel pump. (2)
- [32]**

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY: AUTOMOTIVE

1. $F = m \times a$

Where:

 m = mass a = acceleration

2. $\text{Work done} = \text{Force} \times \text{Displacement}$ OR $W = F \times s$

3. $\text{Power} = \frac{\text{Force} \times \text{Displacement}}{\text{Time}}$ OR $P = \frac{F \times s}{t}$

4. $\text{Torque} = \text{Force} \times \text{Radius}$ OR $T = F \times r$

5. $IP = P \times L \times A \times N \times n$

Where:

 IP = Indicated power P = Mean effective pressure L = Stroke length A = Area of piston crown N = Number of power strokes per second n = Number of cylinders

6. $BP = 2 \pi N T$

Where:

 BP = Brake power N = Revolutions per second T = Torque

7. $\text{Brake power with Prony brake} = 2 \times \pi \times N \times F \times R$

Where:

 BP = Brake power N = Revolutions per second F = Force R = Brake arm length

$$8. \quad \text{Mechanical efficiency} = \frac{BP}{IP} \times 100\%$$

$$9. \quad \text{Compression ratio} = \frac{SV + CV}{CV}$$

Where:

SV = Swept volume

CV = Clearance volume

$$10. \quad SV = \frac{\pi D^2}{4} \times L$$

Where:

D = Bore diameter

L = Stroke length

$$11. \quad CV = \frac{SV}{CR-1}$$

$$12. \quad \text{Gear ratio} = \frac{\text{Product of teeth on driven gears}}{\text{Product of teeth on driver gears}}$$