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GRADE 12

MECHANICAL TECHNOLOGY: AUTOMOTIVE

NOVEMBER 2023

MARKS: 200

TIME: 3 hours

This question paper consists of 19 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 $9,81 \text{ m/s}^2$ or 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 Electronic)	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 E.

- 1.1 Who is responsible for safe working conditions in the workplace?
- A Workers' union
 - B Employer
 - C Employee
 - D Department of Labour
- (1)
- 1.2 Identify the Act that seeks to protect the worker from physical injuries in the workplace:
- A Occupational Health and Safety Act (OHSA), 1993 (Act 85 of 1993)
 - B Labour Relations Act (LRA), 1995 (Act 66 of 1995)
 - C Employment Equity Act (EEA), 1998 (Act 55 of 1998)
 - D Basic Conditions of Employment Act (BCEA), 1997 (Act 75 of 1997)
- (1)
- 1.3 Which safety precaution must be applied when arc welding?
- A Wet the work piece before welding to prevent overheating.
 - B Do not let oil and grease come into contact with the oxygen fittings.
 - C Use completely insulated electrode holders.
 - D Ensure that you always open the acetylene valve slowly.
- (1)
- 1.4 Identify the test shown in FIGURE 1.4 below.

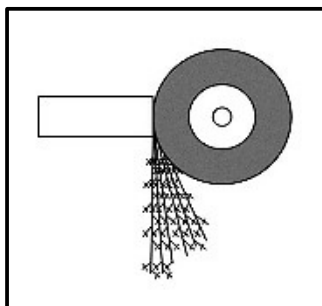


FIGURE 1.4

- A Sound test
 - B Ultrasonic test
 - C Spark test
 - D Cutting test
- (1)

1.5 Which heat-treatment process relieves the internal stresses produced by machining, forging and welding?

- A Normalising
- B Case hardening
- C Tempering
- D Hardening

(1)

1.6 FIGURE 1.6 below shows the changes in metal structures during the annealing process. What change is indicated at Y?

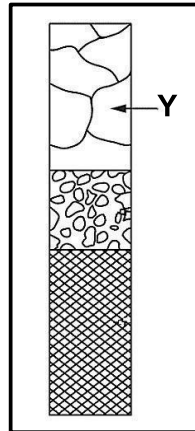


FIGURE 1.6

- A Recovery
- B Grain growth
- C Recrystallisation
- D Grain crystallisation

(1)

[6]

QUESTION 2: SAFETY (GENERIC)

2.1 State TWO checks that must be done on injured persons before removing them from a danger zone.

(2)

2.2 Name TWO safety devices fitted to power guillotines.

(2)

2.3 State TWO safety precautions that must be conducted on a grinding wheel before it is fitted to a bench grinder.

(2)

2.4 Name TWO safety devices fitted to gas-welding equipment.

(2)

2.5 State TWO advantages of a workshop with a process layout.

(2)

[10]

QUESTION 3: MATERIALS (GENERIC)

- 3.1 Give ONE reason why the lengths of metals are normally marked or colour-coded at the ends. (1)
- 3.2 State ONE property of metals that can be determined by EACH of the following tests:
- 3.2.1 Sound test (1)
- 3.2.2 Bending test (1)
- 3.2.3 Machining test (1)
- 3.3 Why is metal soaked in heat when performing heat-treatment processes? (2)
- 3.4 State TWO methods of conducting case hardening. (2)
- 3.5 Explain how steel is annealed during heat-treatment processes. (3)
- 3.6 Name TWO quenching mediums that rapidly cool metal after heat-treatment processes. (2)
- 3.7 Which heat-treatment process follows the hardening process of a metal? (1)
- [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 Identify the equipment shown in FIGURE 4.1 below.



FIGURE 4.1

- A Cylinder leakage tester
- B Compression tester
- C Fuel pressure tester
- D Exhaust gas analyser (1)

4.2 When performing the cylinder leakage test, the piston should be at the top dead centre at the end of the ...

- A intake stroke.
- B compression stroke.
- C power stroke.
- D exhaust stroke. (1)

4.3 To ensure equal firing periods, the power impulses in an eight-cylinder engine should occur every ...

- A 30°.
- B 60°.
- C 90°.
- D 120°. (1)

- 4.4 When balancing the reciprocating mass of an engine, ...
- A the mass of both the crank pin and the big end of the connecting rod are taken into consideration.
 - B the mass of the upper third of the connecting rod is taken into consideration.
 - C the mass of the lower third of the connecting rod is taken into consideration.
 - D the mass of the connecting rod is not taken into consideration. (1)
- 4.5 Engine capacity is the measurement of an engine's ...
- A torque.
 - B power.
 - C volume.
 - D mean effective pressure. (1)
- 4.6 Work is defined as ...
- A the rotational frequency of a shaft.
 - B a force causing linear movement.
 - C the rate at which power is generated.
 - D the twisting force applied to a rotating shaft. (1)
- 4.7 What is measured by the dynamometer on an engine?
- A Indicated power
 - B Brake power
 - C Mean effective pressure
 - D Torque developed (1)
- 4.8 What will the cause be of a worn oil pump?
- A The pump will work slower.
 - B It will have no effect on the oil pressure.
 - C The oil will become thicker.
 - D The oil pressure will be lower. (1)
- 4.9 Why should you be careful when removing a radiator cap when the engine is hot?
- A The cylinder head gasket may blow.
 - B The engine will overheat.
 - C You may burn yourself.
 - D The tester will not have an accurate reading. (1)

4.10 Stall speed in a torque converter occurs ...

- A when the engine stalls.
- B when a vehicle drives at the lowest speed before stalling.
- C just before a vehicle starts moving.
- D when the turbine and pump rotate at the highest speed and at the same speed. (1)

4.11 The device that controls the functioning of the electronic automatic transmission is the ...

- A power management system.
- B transmission control unit.
- C body control unit.
- D throttle positioning sensor. (1)

4.12 What is the cause of the tyre wear pattern shown in FIGURE 4.12 below?



FIGURE 4.12

- A Excessive camber
- B Excessive toe-in angles
- C Imbalanced wheel
- D Over-inflated wheel (1)

4.13 Which CORRECT combination of components form part of the distributorless ignition system (DIS)?

- A Electronic control unit, crankshaft position sensor and ignition coil
- B Electronic control unit, crankshaft position sensor and distributor
- C Electronic control unit, ignition coil and distributor
- D Electronic control unit, camshaft position sensor and distributor (1)

4.14 Why are the calibration values of the diesel injector loaded into the ECM?

- A To reduce engine vibrations
 - B To increase fuel usage
 - C To reduce engine speed
 - D To increase the injection duration (1)
- [14]**

QUESTION 5: TOOLS AND EQUIPMENT (SPECIFIC)

5.1 Answer the following questions on a compression tester:

- 5.1.1 Explain the function of the compression tester. (2)
- 5.1.2 Give ONE reason for low compression in a cylinder. (1)
- 5.1.3 Explain the reason why a card-type compression tester would be preferred when performing a compression test. (2)

5.2 FIGURE 5.2 below shows a cylinder leakage tester. Answer the questions that follow.

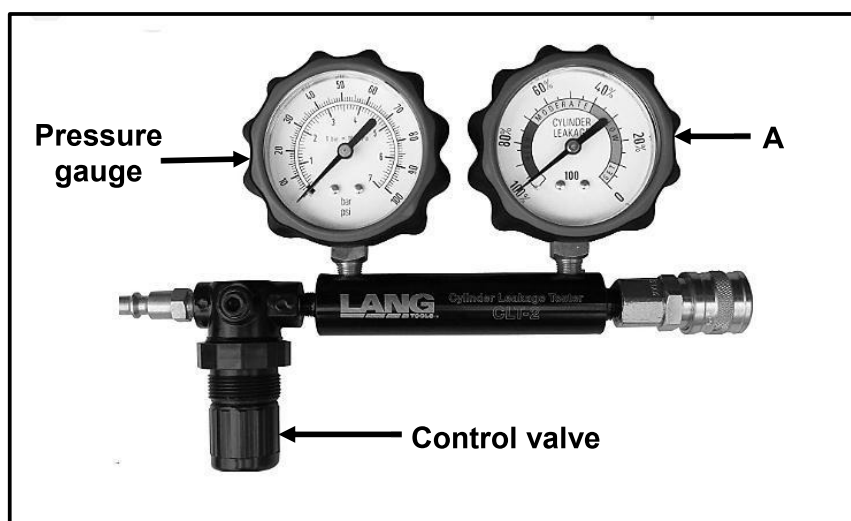


FIGURE 5.2

- 5.2.1 Explain the function of the cylinder leakage tester. (2)
- 5.2.2 Identify gauge **A**. (1)
- 5.2.3 State the use of the control valve. (1)
- 5.3 When performing the exhaust gas analysis, what unit is used to measure EACH of the following gases?
- 5.3.1 Carbon dioxide (CO₂) (1)
- 5.3.2 Hydrocarbon (HC) (1)

- 5.4 Give TWO reasons why the pick-up/inlet hose must be removed from the exhaust before calibrating an exhaust gas analyser. (2)
- 5.5 Name TWO places inside a car cabin where an OBD-II plug is usually located. (2)
- 5.6 State THREE manufacturer's specifications that must be entered into an OBD-II scanner before a diagnostic test can be conducted. (3)
- 5.7 What type of wheel balance procedure is described when the wheel stops with the heavy spot at the bottom during wheel balancing? (1)
- 5.8 FIGURE 5.8 below shows a bubble gauge. What is measured by gauges 1 to 4? (4)

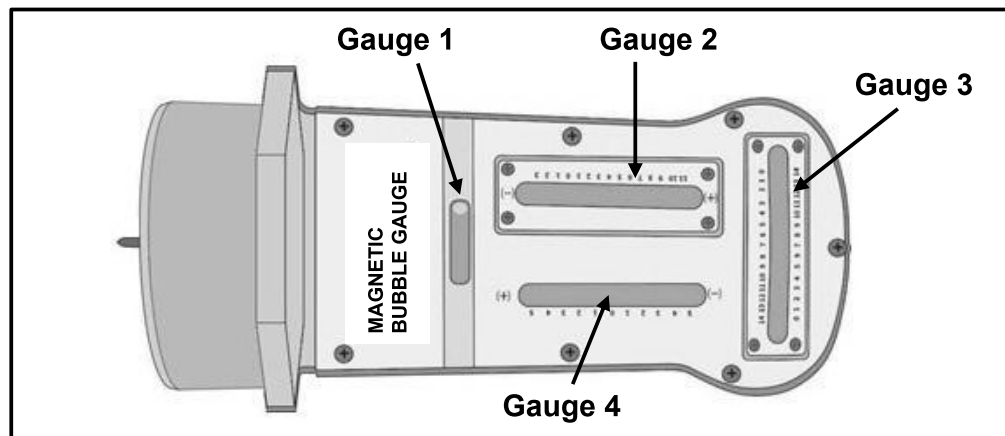
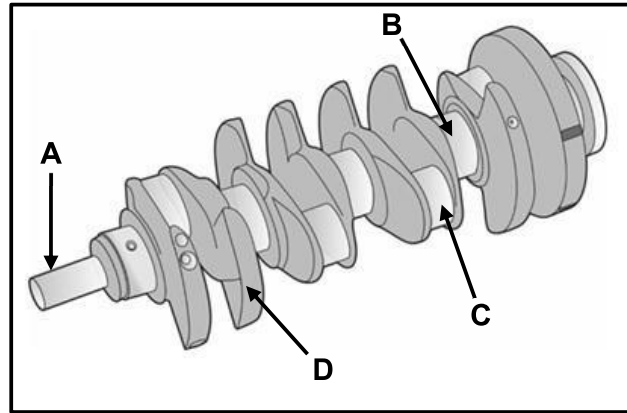


FIGURE 5.8

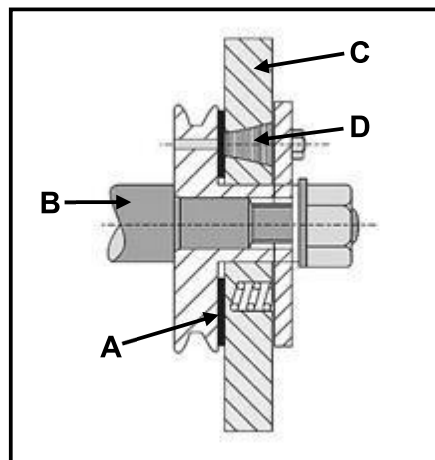
(4)
[23]

QUESTION 6: ENGINES (SPECIFIC)

- 6.1 FIGURE 6.1 below shows the crankshaft of a four-cylinder engine. Answer the questions that follow.

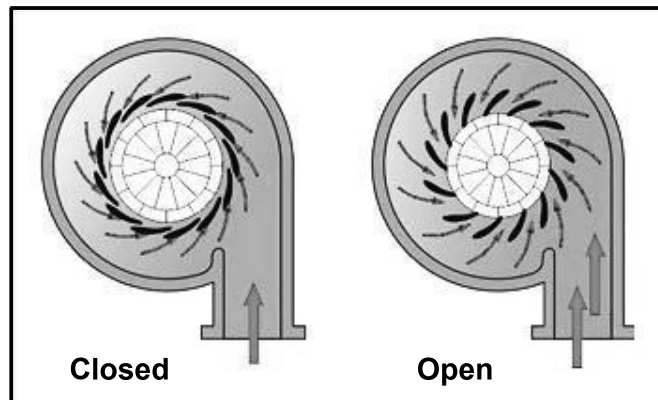
**FIGURE 6.1**

- 6.1.1 Label parts **A–D**. (4)
- 6.1.2 Explain TWO ways of correcting the imbalance of a crankshaft when performing dynamic balancing. (2)
- 6.2 FIGURE 6.2 below shows a combined rubber and friction disc vibration damper used on an internal combustion engine. Answer the questions that follow.

**FIGURE 6.2**

- 6.2.1 Label parts **A–D**. (4)
- 6.2.2 Where in the engine is the vibration damper fitted? (1)
- 6.2.3 What is the function of the vibration damper? (1)

- 6.3 Name TWO engine cylinder configurations. (2)
- 6.4 How many power strokes per revolution are there for EACH of the following four-stroke engines?
- 6.4.1 Four-stroke four-cylinder engine (1)
- 6.4.2 Four-stroke six-cylinder engine (1)
- 6.5 FIGURE 6.5 below shows views of the turbine of a turbocharger with the vanes closed and open. Answer the questions that follow.

**FIGURE 6.5**

- 6.5.1 Identify the type of turbocharger. (1)
- 6.5.2 Why is a turbocharger able to achieve a boost in engine power? (2)
- 6.5.3 State TWO factors that influence the lifespan and reliability of a turbocharger. (2)
- 6.6 State THREE disadvantages of a turbocharger compared to a supercharger. (3)
- 6.7 State ONE disadvantage of EACH of the following superchargers:
- 6.7.1 Roots supercharger (1)
- 6.7.2 Twin-screw supercharger (1)
- 6.8 Give TWO reasons why a vehicle is fitted with both a supercharger and a turbocharger on its engine. (2)

[28]

QUESTION 7: FORCES (SPECIFIC)

7.1 Explain ONE difference between the *indicated power* and the *brake power* of an engine. (2)

7.2 The bore of a cylinder is 75 mm and the stroke length of the piston is 80 mm. The compression ratio is 10 : 1.

Calculate the following:

7.2.1 The swept volume (3)

7.2.2 The clearance volume (3)

7.2.3 The new stroke length if the compression ratio is increased to 11 : 1. The clearance volume and bore remain unchanged. The answer must be in mm. (6)

7.3 Describe TWO methods to lower the compression ratio of an engine. (2)

7.4 The following data was recorded during a Pröny brake test on a four-stroke four-cylinder engine:

Mean effective pressure: 950 kPa
 Bore diameter: 90 mm
 Stroke length: 85 mm
 Brake arm length: 400 mm
 Scale reading: 30 kg
 Engine speed during test: 2 000 r/min

Calculate the following:

7.4.1 The torque developed (4)

7.4.2 Brake power in kW (3)

7.4.3 Indicated power in kW (7)

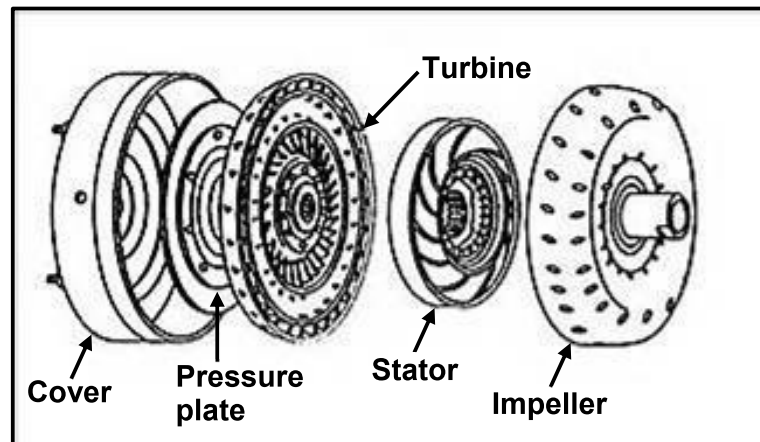
7.4.4 Mechanical efficiency (2)
[32]

QUESTION 8: MAINTENANCE (SPECIFIC)

- 8.1 Answer the following questions on the exhaust gas analysis:
- 8.1.1 How will a leak on the exhaust system, inlet manifold or vacuum system affect the readings? (2)
- 8.1.2 State TWO ideal exhaust gas readings. (2)
- 8.2 State TWO pre-checks that must be done on a compression tester before conducting a compression test on an internal combustion engine. (2)
- 8.3 Tabulate THREE faults and their possible causes when a leak is detected during a cylinder leakage test. (6)
- 8.4 State THREE manufacturer's specifications required when conducting an oil-pressure test on an internal combustion engine. (3)
- 8.5 State FOUR possible causes of a low fuel pressure reading. (4)
- 8.6 Explain step by step how to conduct a pressure test on a radiator cap. (4)
- [23]**

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

- 9.1 Explain FOUR reasons why a vehicle fitted with an automatic gearbox would be preferred over a vehicle fitted with a manual gearbox. (4)
- 9.2 Describe how a vehicle fitted with an automatic gearbox should be towed over a long distance. (2)
- 9.3 FIGURE 9.3 below shows an exploded view of a torque converter. Answer the questions that follow.

**FIGURE 9.3**

- 9.3.1 Describe THREE functions of a torque converter. (3)
- 9.3.2 Which component prevents slip in a torque converter? (1)

- 9.4 FIGURE 9.4 below shows an exploded view of a brake band in an automatic gearbox. Answer the questions that follow.

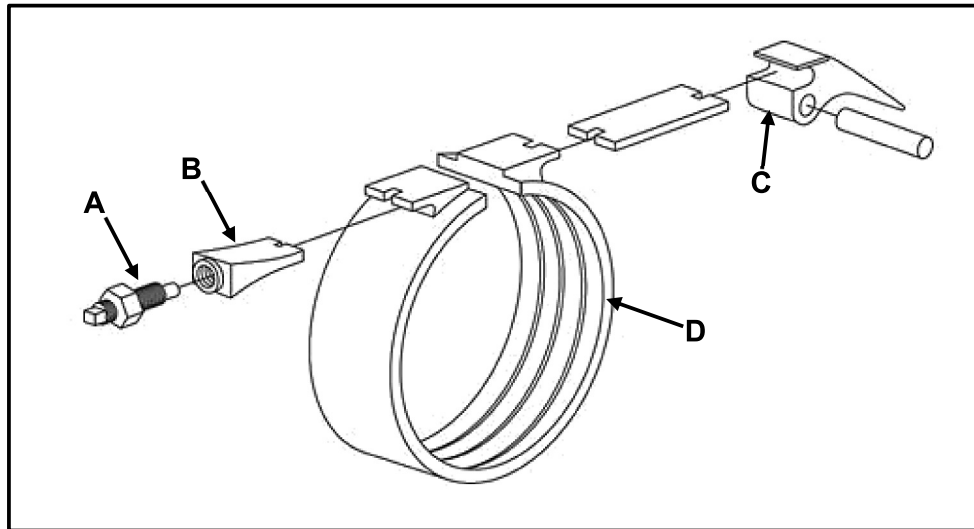


FIGURE 9.4

- 9.4.1 Label parts **A–D**. (4)
- 9.4.2 What is the function of part **D**? (1)
- 9.4.3 Which component of the automatic gearbox controls the brake band? (1)

- 9.5 FIGURE 9.5 below shows a double epicyclic gear train/system. Answer the questions that follow.

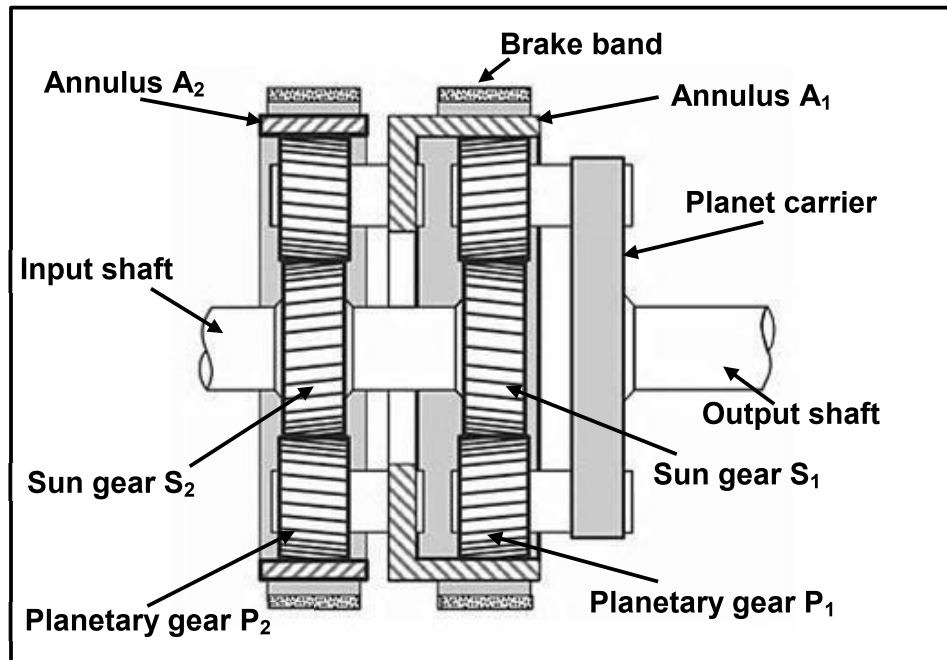


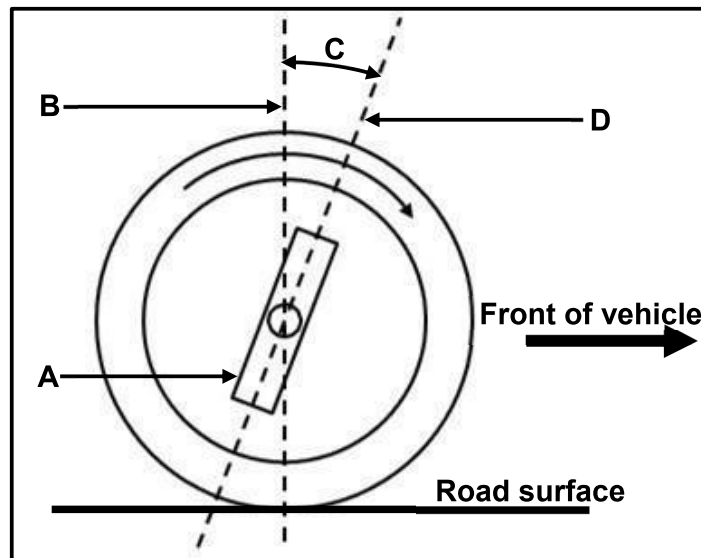
FIGURE 9.5

- 9.5.1 Which gear is selected when sun gears S_1 and S_2 are driven by the engine while annulus A_1 is held stationary? (1)
- 9.5.2 Which gear is selected when sun gears S_1 and S_2 are driven by the engine while annulus A_2 is held stationary? (1)

[18]

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

- 10.1 Explain the function of a steering mechanism. (2)
- 10.2 State TWO signs of an unbalanced wheel on a vehicle. (2)
- 10.3 Describe how static wheel balance is done and how an imbalanced wheel can be corrected. (4)
- 10.4 FIGURE 10.4 below shows a sketch of a wheel alignment angle. Label **A–D**.

**FIGURE 10.4**

- (4)
- 10.5 Explain TWO advantages of an electric fuel pump fitted on a vehicle. (2)
- 10.6 State the purpose of EACH of the following components fitted to the fuel delivery system:
- 10.6.1 Pressure regulator (1)
- 10.6.2 Fuel filter (1)

- 10.7 FIGURE 10.7 below shows an air-induction system. Answer the questions that follow.

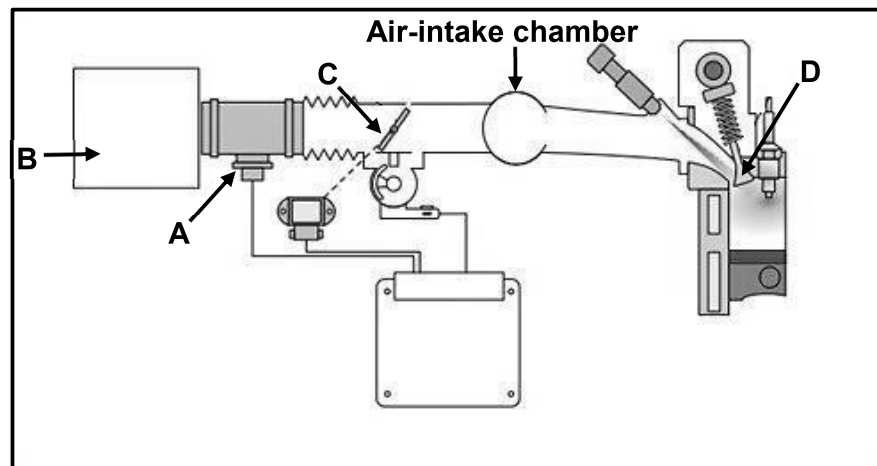


FIGURE 10.7

- 10.7.1 Label **A–D**. (4)
- 10.7.2 What is the purpose of the air-induction system fitted on an internal combustion engine? (2)
- 10.8 What is the purpose of the lambda sensor in an exhaust system? (2)
- 10.9 Draw TWO neat labelled sketches to show the two different stator winding connections in an alternator. (4)
- 10.10 State TWO methods to increase the output of an alternator. (2)
- 10.11 Explain TWO main aims of an adaptive speed control fitted to a vehicle. (2)
- [32]**

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY: AUTOMOTIVE

1. $F = m \times a$

Where:

$m = \text{Mass}$

$a = \text{Acceleration}$

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:

$IP = \text{Indicated power}$

$P = \text{Mean effective pressure}$

$L = \text{Stroke length}$

$A = \text{Area of piston crown}$

$N = \text{Number of power strokes per second}$

$n = \text{Number of cylinders}$

6. $BP = 2 \pi N T$

Where:

$BP = \text{Brake power}$

$N = \text{Revolutions per second}$

$T = \text{Torque}$

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

Where:

$BP = \text{Brake power}$

$N = \text{Revolutions per second}$

$F = \text{Force}$

$R = \text{Brake arm length}$

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

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

Where:

SV = Swept volume

CV = Clearance volume

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

Where:

D = Bore diameter

L = Stroke length

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

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