basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATION/ NATIONAL SENIOR CERTIFICATE EXAMINATION

MECHANICAL TECHNOLOGY: AUTOMOTIVE

2021

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 20 pages.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS (GENERIC)

1.1 B ✓ (1)

1.2 A ✓ (1)

1.3 C ✓ (1)

1.4 C ✓ (1)

1.5 D ✓ (1)

1.6 A ✓ (1)
[6]

QUESTION 2: SAFETY (GENERIC)

2.1 **First aid basic treatment:**

- Examination ✓
- Diagnosis ✓
- Treatment ✓ (3)

2.2 **Drill press (Already been switched on):**

- Never leave the drill unattended while in motion. ✓
- Switch off the drill when leaving. ✓
- Use a brush or wooden rod to remove chips. ✓
- When reaching around a revolving drill, be careful that your clothes do not get caught in the drill or drill chuck. ✓
- Don't stop a revolving chuck with your hand. ✓
- Don't adjust the drill while working. ✓
- Don't open any guard while in motion. ✓
- Keep hands away from action points. ✓
- Do not force the drill bit into the material. ✓
- Apply cutting fluid if required. ✓

(Any 2 x 1) (2)

2.3 **Isolation of electrode holder:**

To prevent electric shock. ✓ (1)

2.4 **Disadvantages of the process layout:**

- Production is not always continuous. ✓
- Transportation costs between process departments may be high. ✓
- Additional time is spent in testing and sorting as the product moves to the different departments. ✓
- Damage to fragile goods may result from extra handling. ✓

(Any 2 x 1) (2)

2.5 **Advantages of the product layout:**

- Handling of material is limited to a minimum. ✓
- Time period of manufacturing cycle is less. ✓
- Production control is almost automatic. ✓
- Control over operations is easier. ✓
- Greater use of unskilled labour is possible. ✓
- Less total inspection is required. ✓
- Less total floor space is needed per unit of production. ✓

(Any 2 x 1) (2)
[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 **Heat-treatment:**

- Heat the metal slowly to a certain temperature. ✓
- Soak the metal for a certain period to ensure a uniform temperature. ✓
- Cool the metal at a certain rate to room temperature. ✓

(3)

3.2 **Quenching mediums:**

- Water ✓
- Brine ✓
- Liquid salts ✓
- Oil ✓
- Soluble oil and water ✓
- Sand ✓
- Molten lead ✓
- Air ✓
- Lime ✓

(Any 3 x 1) (3)

3.3 **Annealing:**

- To relieve internal stresses of the steel ✓
- Soften steel to make machining possible ✓
- Make steel ductile ✓
- Refine grain structure ✓
- Reduce brittleness ✓

(Any 1 x 1) (1)

3.4 **Carbon steels:**

- Low carbon steel ✓
- Medium carbon steel ✓
- High carbon steel ✓

(3)

3.5 **Iron-carbon equilibrium diagram:**

A Percentage carbon / carbon content ✓
B Temperature in °C ✓
C AC3 line / Higher critical temperature ✓
D AC1 line / Lower critical temperature ✓

(4)
[14]

QUESTION 4: MULTIPLE-CHOICE QUESTIONS (SPECIFIC)

4.1	C ✓	(1)
4.2	C ✓	(1)
4.3	D ✓	(1)
4.4	B ✓	(1)
4.5	C ✓	(1)
4.6	C ✓	(1)
4.7	B ✓	(1)
4.8	A ✓	(1)
4.9	C ✓	(1)
4.10	A ✓	(1)
4.11	A ✓	(1)
4.12	D ✓	(1)
4.13	C ✓	(1)
4.14	D ✓	(1)

[14]

QUESTION 5: TOOLS AND EQUIPMENT (SPECIFIC)

5.1 **Compression tester labels:**
A – Pressure gauge/Pressure meter ✓
B – Pressure release valve ✓
C – Air hose/Pipe/Flexible pipe ✓
D – Spark plug connector/Adapter ✓ (4)

5.2 **Function of Cylinder Leakage Tester:**
- To check where the combustion chamber/cylinder leaks gases ✓ during compression stroke/power stroke. ✓
- To determine the percentage ✓ pressure loss ✓ from the combustion chamber.

(Any 1 x 2) (2)

5.3 **Cylinder leakage test procedure:**
- Turn the crank shaft until both valves, on the cylinder to be tested, are closed. ✓
- Remove the HT leads / spark plugs ✓
- Connect the spark plug adaptor (tester) to the spark plug hole. ✓
- Lock the crankshaft pulley so that it cannot turn. ✓
- Couple the compressed air pipe to the tester and calibrate the tester. ✓
- Couple the spark plug adapter hose to the cylinder leakage tester. ✓
- Note the results and location of gas leakage occurring in the combustion chamber. ✓

(Any 6 x 1) (6)

5.4 **Exhaust gas analyser:**
- Hydrocarbon (fuel and oil vapour) / HC ✓
- Carbon dioxide / CO_2 ✓
- Sulphur dioxide / SO_2 ✓

(Any 2 x 1) (2)

5.5 **Exhaust gas analysis test precautions:**
- Always calibrate the exhaust gas analyser with the pick-up hose removed. ✓
- The pick-up hose must not be stepped on or restricted in any way. ✓
- The pick-up hose connections must be airtight. ✓
- The vehicle being tested should have no leaks in the exhaust, manifolds or vacuum systems. ✓
- Must be conducted in a well-ventilated area. ✓
- Take good care when handling the equipment. ✓

(Any 3 x 1) (3)

5.6 **Function of Turn-tables:**
To make it possible ✓ to turn the front wheels in and out / side to side ✓ when checking the wheel alignment angles. (2)

5.7 **Use of optical alignment gauge:**
To measure / check the toe-in and toe-out of the vehicle. ✓ (1)

5.8 **Functions of OBD scanner:**

- Scan for faults (diagnostics). ✓
- Programme the ECU. ✓
- Reset fault codes. ✓
- Programme the keys to vehicle's ignition system. ✓

(Any 3 x 1) (3)
[23]

QUESTION 6: ENGINES (SPECIFIC)

6.1 **Correcting static imbalance:**

- By fitting balance mass pieces to the crank webs. ✓
- By removing metal from the crank webs. ✓
- By arranging the crank pins of the crankshaft. ✓

(Any 2 x 1) (2)

6.2 **Crankshaft balancing:**

6.2.1 **Dynamic balancing:**
Balancing in all directions ✓ while crankshaft is rotating. ✓ (2)

6.2.2 **Reciprocating mass:**
The mass of the pistons, gudgeon pins ✓ and the upper third of the connecting rod. ✓ (2)

6.3 **Features to improve engine balance:**

- Connecting rods and pistons are kept as light as possible / static balanced. ✓
- Flywheel is carefully balanced. ✓
- Counterweights on the crankshaft. ✓
- The firing order is reconfigured. ✓ (4)

6.4 **Types of vibration dampers:**

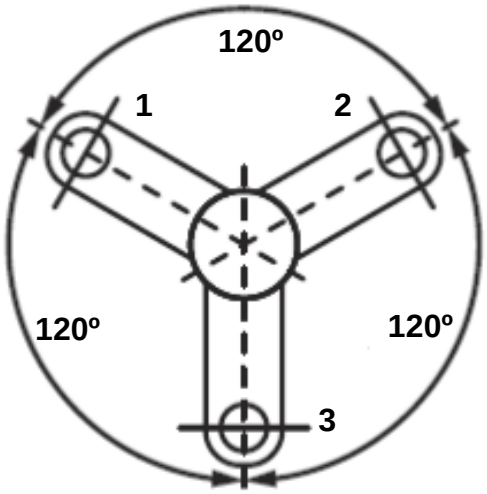
- Friction face-type ✓
- Combined rubber and friction disc ✓
- Rubber type ✓
- Inertia ring type ✓

(Any 2 x 1) (2)

6.5 **Different types of cylinder arrangements:**

A Inline type / Straight arrangement ✓
B V-type ✓
C W-type / double-V type ✓ (3)

6.6 **Three-cylinder inline engine:**



Marking:
Labelling power impulse angle 120°. ✓
Drawing position of crankpins. ✓
Numbering of crankpins. ✓ (3)

6.7 **Types of superchargers:**

- Roots ✓
- Twin-screw ✓
- Centrifugal and ✓
- Vane ✓

(Any 3 x 1) (3)

6.8 **Advantages of using a turbocharger:**

- More power is obtained from an engine with the same engine capacity. ✓
- A turbocharger is driven by the exhaust gases of the engine and therefore there is no power loss. ✓
- It gives improved fuel consumption in proportion to engine capacity. ✓
- The effect of height above sea level on power is eliminated. ✓
- Improve volumetric efficiency. ✓

(Any 3 x 1) (3)

6.9 **Turbocharger:**

A Intercooler/air cooler ✓
B Compressed air flow ✓
C Turbine/Turbine housing/Turbocharger ✓
D Exhaust gas flow/exhaust system/exhaust manifold ✓ (4)
[28]

QUESTION 7: FORCES (SPECIFIC)

7.1 **Terms:**

7.1.1 **Power:**
Power is the rate ✓ at which work is done. ✓ (2)

7.1.2 **Compression Ratio:**
It is the ratio between the total volume of a cylinder when the piston is at bottom dead centre (BDC) ✓ to the volume in a cylinder when the piston is at top dead centre (TDC). ✓ (2)

7.2 **Calculation of compression ratio:**

7.2.1 **Swept volume:**

$$\text{Swept Volume} = \frac{\pi D^2}{4} \times L$$

$$= \frac{\pi \times 7^2}{4} \times 7{,}5 \quad \checkmark \checkmark$$

$$SV = 288{,}63 \text{ cm}^3 \checkmark$$

(3)

7.2.2 **Original clearance volume:**

$$CV = \frac{SV}{CR - 1}$$

$$= \frac{288{,}63}{9{,}5 - 1} \quad \checkmark \checkmark$$

$$= \frac{288{,}63}{8{,}5}$$

$$CV = 33{,}96 \text{ cm}^3 \quad \checkmark$$

(3)

7.2.3 **New bore diameter:**

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

$$= \frac{SV}{CV} + 1$$

$$SV = CV(CR - 1) \quad \checkmark$$

$$= 33,96(10 - 1) \quad \checkmark$$

$$SV = 305,64 \text{ cm}^3 \quad \checkmark$$

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

$$\text{Diameter} = \sqrt{\frac{SV \times 4}{\pi \times L}} \quad \checkmark$$

$$D = \sqrt{\frac{305,64 \times 4}{\pi \times 7,5}} \quad \checkmark$$

$$D = 7,203 \text{ cm}$$

$$D = 72,03 \text{ mm} \quad \checkmark$$

(6)

7.3 **Power calculations:**

7.3.1 **Torque:**

$$\text{Torque} = \text{Force} \times \text{Radius}$$

$$= (25 \times 10) \times \frac{420}{1000} \quad \checkmark \quad \checkmark$$

$$= 250 \times 0,42$$

$$= 105 \text{ N.m} \quad \checkmark$$

(3)

7.3.2 **Indicated power:**

$P = 900kPa = 900 \times 10^3\,Pa$

$L = 86mm = \frac{86}{1000} = 0,086m$ ✓

$D = 84mm$

$= \frac{84}{1000} = 0,084m$ ✓

$A = \frac{\pi \times D^2}{4}$

$= \frac{\pi \times 0,084^2}{4}$ ✓

$= 5,54 \times 10^{-3}\,m^2$ ✓

OR

$A = \frac{\pi \times D^2}{4}$

$= \frac{\pi \times 84^2}{4}$ ✓

$= 5541,77mm^2$ ✓

$= 5541,77 \times 10^{-6}\,m^2$ ✓

$N = 2000r/min = \frac{2000}{60 \times 2}$ ✓ $= 16,667$ power stroke/sec ✓

$n = 4$ cylinders

$IP = PLANn$

$= (900 \times 10^3) \times 0,086 \times 5541,77 \times 10^{-6} \times 16,667 \times 4$ ✓

$= 28596\,W$

$= 28,60\,kW$ ✓

OR

$N = 2000\,r/min = \frac{2000}{60} = 33,333\,r/sec$ ✓

$n = \frac{4}{2} = 2$ power strokes ✓

$IP = PLANn$

$= (900 \times 10^3) \times 0,086 \times 5541,77 \times 10^{-6} \times 33,333 \times 2$ ✓

$= 28600\,W$

$= 28,60\,kW$ ✓

(8)

7.3.3 **Brake power:**

$$\text{Brake Power} = 2\pi NT$$
$$= 2 \times \pi \times \frac{2000}{60} \times 105 \quad ✓$$
$$= 21\,991{,}149 \text{ W} \quad ✓$$
$$= 21{,}99 \text{ kW} \quad ✓$$

(3)

7.3.4 **Mechanical efficiency:**

$$\text{Mechanical efficiency} = \frac{BP}{IP} \times 100$$
$$= \frac{21{,}99}{28{,}60} \times 100 \quad ✓$$
$$= 76{,}89\ \% \quad ✓$$

(NO UNIT, NO MARK FOR FINAL ANSWER)

(2)
[32]

QUESTION 8: MAINTENANCE (SPECIFIC)

8.1 **Cooling system pressure test:**

8.1.1 Repair or replace water hose or clamp. ✓ (1)

8.1.2 Cylinder head gasket blown. / Cylinder head warped. ✓ (1)

8.1.3 Replace Welch or core plug. ✓ (1)

8.1.4 Replace radiator cap with suitable replacement. ✓ (1)

8.2 **Function of the radiator cap:**

- Regulates the pressure in the cooling system. ✓
- Allows coolant to return to the radiator from the expansion tank. ✓
- The radiator cap seals / close the cooling system. ✓

(Any 2 x 1) (2)

8.3 **Exhaust gas readings causes:**

8.3.1 **Possible causes of high carbon monoxide (CO) reading:**

- Too rich mixture ✓
- Ignition misfire ✓
- Dirty or restricted air filter ✓
- Improper operation of the fuel delivery system. ✓
- Faulty thermostat / stuck in open position or coolant sensor ✓
- Non-functioning PCV valve system ✓
- Catalytic converter not working ✓

(Any 2 x 1) (2)

8.3.2 **Possible causes high nitrogen oxide (NO_x) reading:**

- Lean fuel mixture ✓
- Improper spark advance ✓
- Malfunctioning EGR valve ✓
- Malfunctioning catalytic converter ✓

(Any 2 x 1) (2)

8.3.3 **Possible causes high oxygen (O_2) reading:**

- Too lean air-fuel ratio ✓
- Ignition problems ✓
- Vacuum leaks ✓
- Malfunctioning catalytic converter ✓

(Any 2 x 1) (2)

8.4 **Safety requirements when setting up the oil tester:**

- Ensure the tester can read the expected pressures of the engine. ✓
- Clean the sender unit area before fitting the tester. ✓
- Ensure that the rubber hoses of the tester are not perished. ✓
- Keep the tester away from moving engine parts when conducting the test.✓

(Any 3 x 1) (3)

8.5 **Fuel-pressure test/manufacturers' specifications:**

- Fuel pressure (suction) before the fuel pump. ✓
- Fuel pump delivery pressure (after the fuel pump). ✓
- Fuel-line pressure at idle speed. ✓
- Fuel-line pressure at high revolutions. ✓
- Fuel pressure in the common rail (at injectors). ✓

(Any 4 x 1) (4)

8.6 **Compression test:**

8.6.1 **High tension leads:**

- The ignition system will be disabled. ✓
- Prevent electrical shock. ✓
- To have access to the spark plugs in order to remove them. ✓

(Any 1 x 1) (1)

8.6.2 **Throttle valve fully open:**

- To ensure maximum amount of air enters the cylinder. ✓
- To obtain a correct reading. ✓

(Any 1 x 1) (1)

8.6.3 **Recording the readings:**

- Compared to the specifications reading. ✓
- To note the differences in readings between the cylinders. ✓

(Any 1 x 1) (1)

8.7 **Increase in compression after wet test:**

- Piston ring / Compression ring ✓
- Cylinder (sleeve / walls) ✓

(Any 1 x 1) (1)
[23]

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

9.1 **Differences between an automatic gearbox and a manual gearbox:**

- Manual – clutch pedal operated. ✓
  Automatic – no clutch pedal operated. ✓
- Manual – Gears selected manually with gear lever. ✓
  Automatic – Gears selected automatically by the gearbox. ✓

(Any 1 x 2) (2)

9.2 **Function of torque converter:**

- Multiplies engine torque automatically according to road and engine speeds. ✓
- Transfers drive from the engine to the transmission. ✓
- Acts as a Flywheel to keep the engine turning during the idle strokes. ✓
- Slips during initial acceleration and while stopping to prevent stalling. ✓
- Dampens torsional vibrations of the engine. ✓
- Drives the Transmission oil pump. ✓

(Any 2 x 1) (2)

9.3 **Lockup clutch:**

To overcome slip ✓ that occurs inside the torque converter. ✓ (2)

9.4 **Stall speed:**

- The condition when the impeller of a torque converter rotates at maximum speed ✓ and the turbine is almost stationary. ✓
- When the pump has reached the highest velocity ✓ and the turbine is at stall (standing still). ✓
- When the vehicle is stationary ✓ just before it starts moving / while the engine is idling. ✓

(Any 1 x 2) (2)

9.5 **Single epicyclic gear system:**

9.5.1 **Epicyclic gear train:**

A Sun gear ✓
B Annulus / Ring gear ✓
C Planet gear ✓
D Planet carrier ✓ (4)

9.5.2 **Advantages of an epicyclic gear train:**

- The input shaft and output shaft have the same axis of rotation. ✓
- Load is distributed to several planetary gears. ✓
- Many transmission-ratio options from ONE or a combination of several gear trains. ✓
- Longer service life compared to traditional gearboxes for similar load. ✓
- Epicyclic gearbox has the ability to transmit higher torque. ✓
- It has less inertia. ✓
- Used to obtain higher gear ratios. ✓
- Compact in size.
- All the gears are constantly in mesh. ✓

(Any 2 x 1) (2)

9.6 **Function of the valve body:**

- It detects the load ✓ and adjust the gear ratio according to the torque requirements. ✓
- It directs the oil pressure ✓ to the correct hydraulic actuator. ✓

(Any 1 x 2) (2)

9.7 **Methods of cooling the automatic transmission oil:**

- By using a special oil cooler alongside the engine cooling radiator ✓ and circulating transmission fluid through it. ✓
- Circulating transmission fluid ✓ through a radiator. ✓
- The transmission oil sump ✓ is designed with fins to assist with cooling. ✓

(Any 1 x 2) (2)
[18]

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

10.1 **Requirements of a well-planned steering mechanism:**
It must be …
- light and easy to control. ✓
- free from vibration and road shocks. ✓
- as direct as possible without needing too much driver attention or effort.✓
- self-centring. ✓
- able to operate without being unduly affected by the action of the suspension or braking systems. ✓

(Any 3 x 1) (3)

10.2 **Wheel alignment angles:**

10.2.1 **Function of Positive camber:**
- Less steering effort ✓
- The vehicle mass being carried by the larger inner front wheel bearing. ✓

(Any 1 x 1) (1)

10.2.2 **Function of Ackermann's angle:**
It allows for variable toe-out to the front wheels on turns. ✓ (1)

10.3 **Caster:**

10.3.1 **Wheel alignment angle:**

C Negative ✓ caster ✓ angle (2)

10.3.2 **Negative caster angle purpose:**
Negative caster ensures easier turning ✓ and provides better cornering to the vehicle. ✓ (2)

10.3.3 **Caster angle labels:**

A. King pin / Steering axis ✓
B. Perpendicular line ✓
D. Centre line of kingpin / Steering axis ✓ (3)

10.4 **Engine management system:**

10.4.1 **Function of sensor:**
- It detects the engine operating conditions. ✓✓
- It gives the input information to the ECU. ✓✓

(Any 1 x 2) (2)

10.4.2 **Function of actuators:**
- It gets the output information / signal from the ECU. ✓✓
- It makes the necessary adjustments. ✓✓

(Any 1 x 2) (2)

10.5 **Requirements to make the catalytic convertor function effectively:**

- The convertor working temperature must not exceed 600 °C. ✓
- Unleaded petrol must be used. ✓
- Prevent persistent misfire. ✓
- Prevent burnt engine oil from melting the ceramic monolith. ✓
- The lambda sensor must function properly. ✓

(Any 2 x 1) (2)

10.6 **Lambda sensor:**

The lambda sensor is fitted on the exhaust system. ✓ (1)

10.7 **Adaptive speed control:**

- Maintain a speed as set by the driver. ✓
- Adapt the speed to maintain a safe distance from the vehicle in front. ✓
- Provide a warning if there is a risk of a collision. ✓
- Prevent driver fatigue. ✓
- Improve fuel economy. ✓
- A constant controlled speed setting prevents speeding fines. ✓

(Any 3 x 1) (3)

10.8 **Diode:**

10.8.1 Diode ✓ (1)

10.8.2 **Function of the diode:**

- The function of the diode is used to change alternating current ✓ into direct current. ✓
- It allows the current flow in the circuit in one direction only ✓ and blocks it from flowing in the opposite direction. ✓

(Any 1 x 2) (2)

10.9 **Function of components in the alternator:**

10.9.1 **Rectifier:**
Converts alternating current (AC) to direct current (DC). ✓ (1)

10.9.2 **Stator:**
- To provide a core ✓ that concentrates the magnetic lines of force onto the stator windings. ✓
- To provide a coil ✓ into which a voltage is induced which is used to charge the battery. ✓
- Converts the rotating magnetic field ✓ to electric current to charge the battery. ✓

(Any 1 x 2) (2)

10.9.3 **Rotor:**
- Provides a rotating ✓ electro-magnet. ✓
- Induces an electric voltage ✓ into the stator windings. ✓
- Fitted with slip rings ✓ to allow for a moving electrical connection. ✓

(Any 1 x 2) (2)

10.10 **Functions of the check valve in the electric fuel pump:**
- It ensures the pressure in the fuel line is maintained. ✓
- It allows the fuel to flow in one direction only from the fuel tank. ✓ (2)

[32]

TOTAL: 200