



# higher education & training

Department:  
Higher Education and Training  
**REPUBLIC OF SOUTH AFRICA**

**NATIONAL CERTIFICATE**  
**ENGINEERING SCIENCE N4**

(15070434)

**20 November 2020 (X-paper)**  
**09:00–12:00**

**This question paper consists of 6 pages, 1 formula sheet and 1 information sheet.**

183Q1E2020

**DEPARTMENT OF HIGHER EDUCATION AND TRAINING**  
**REPUBLIC OF SOUTH AFRICA**  
NATIONAL CERTIFICATE  
ENGINEERING SCIENCE N4  
TIME: 3 HOURS  
MARKS: 100

---

**INSTRUCTIONS AND INFORMATION**

1. Answer all the questions.
  2. Read all the questions carefully.
  3. Number the answers according to the numbering system used in this question paper.
  4. Subsections of questions should be kept together.
  5. Rule off across the page on completion of each question.
  6. All formulas should be shown in the answer. Show all the steps in your answers.
  7. All sketches and diagrams must be done in pencil.
  8. Take  $g = 9,8 \text{ m/s}^2$ .
  9. Write neatly and legibly.
-

**QUESTION 1**

- 1.1 Two cars leave a fork in a road simultaneously. Car X travels at 60 km/h to the west and car Y travels at 100 km/h in a direction N 45° E.



Calculate the relative velocity of car Y with respect to car X in magnitude and direction.

(5)

- 1.2 A boy throws a cricket ball at an angle of 15° to the horizontal with an initial velocity of 50 m/s. The path of the ball is that of a projectile.

Calculate the following:

1.2.1 The time to reach the maximum height

1.2.2 The maximum height reached by the ball

1.2.3 The horizontal displacement of the ball



(3 × 2)

(6)

- 1.3 A canoeist is rowing on the Vaal Dam at a velocity of 4 m/s in a northerly direction. A wind of 3 m/s suddenly starts blowing in a south-easterly direction.

Calculate the resultant velocity of the canoe in magnitude and direction.

(5)  
[16]**QUESTION 2**

- 2.1 Define *angular velocity*. (1)

- 2.2 The wheel of a motorbike has a diameter of 50 cm and accelerates from 4 rad/s to 10 rad/s in 10 seconds.

Calculate the following:

2.2.1 The angular acceleration of the wheel



2.2.2 The angular displacement of the wheel in radians

2.2.3 The number of revolutions completed by the wheel during this time

(3 × 2)

(6)

- 2.3 A force of 600 N is applied to the end of a spanner. The perpendicular distance between the nut and the working line of the force is 30 cm.

Calculate the following:

2.3.1 The torque on the spanner



2.3.2 The work done when the nut is turned through an angle of 60°

(2 × 2)

(4)

[11]

**QUESTION 3**

- 3.1 A bus is travelling on a horizontal road at a velocity of 126 km/h when the bus driver notices an object in the road. The brakes are applied and the bus is brought to rest over a distance of 150 metres. The frictional resistance is 2 500 N and the bus has a mass of 6 000 kilogram.

Calculate the following:

3.1.1 The retardation of the bus (3)

3.1.2 The time taken to come to a complete standstill (2)

3.1.3 The braking force of the brakes  (2)

- 3.2 A locomotive is pulling a train with a mass of 150 tons up a hill with an incline of  $10^\circ$  at a constant velocity of 72 km/h. The train experiences a frictional force of 8 000 N.

Calculate the power required by the locomotive engine to pull the train. (4)  
[11]

**QUESTION 4**

A light, horizontal beam, ABCDE, with A on the left-hand side is 13 metres long. It is supported at two points, A and D. At B, 6 metres from A, there is a point load of 10 kN. At C, 3 metres from B, there is a point load of 15 kN. There is a uniformly distributed load of 4 kN/m between A and B. D is 2 metres from C.

4.1 Make a neat, labelled diagram of the beam described above. (1)

4.2 Calculate the reactions of the supports at points A and D and test your answers. (5)

4.3 Draw a shear force diagram and show all the main values on the diagram. (4)

4.4 Calculate the bending moments at B and C.  (2)

4.5 Draw a neat bending moment diagram and show all the main values on the diagram. (3)  
[15]

**QUESTION 5**

- 5.1 A three-cylinder, single-acting pump has a plunger diameter of 200 mm and a stroke length of 300 mm and is working at a speed of 230 r/min. There is a slip of 15%.



Calculate the volume of water delivered in litres/minute:  
(1 000 liter = 1 000 kg = 1 m<sup>3</sup>)

(4)

- 5.2 A farmer uses a water pump to pump water out of a dam. The diameter of the plunger is 150 mm and a force of 12 kN is applied to the plunger of the pump. The work done during each delivery stroke is 4 kJ.

Calculate the following:

5.2.1 The stroke length of the plunger (2)

5.2.2 The pressure in the water during ONE delivery stroke (3)

5.2.3 The volume of water delivered during ONE pumping stroke (3)

- 5.3 The plungers of a three-cylinder, single-acting pump have diameters of 5 cm each and stroke lengths of 15 cm each. The pressure during the delivery stroke is 2 MPa.



Calculate the power required to drive the pump at 150 r/min if the efficiency of the motor is only 80%.

(5)

- 5.4 Define the unit *Pascal*

(1)

**[18]****QUESTION 6**

- 6.1 Explain the difference between *tensile stress* and *compressive stress*. (2)

- 6.2 A bar with a square profile of 30 mm x 30 mm is subjected to a tensile test. A load of 100 kN causes an extension of 0,5 mm. The initial length of the bar was 330 mm.

Calculate the following:

6.2.1 The stress in the bar



6.2.2 The strain of the bar

6.2.3 Young's modulus of elasticity of the material

(3 × 2)

(6)

- 6.3 The steel spoke of a bicycle wheel has a cross-sectional area of  $2,5 \text{ mm}^2$  and a length of 400 mm. The nut of the spoke is fastened until the spoke stretches by 0,25 mm.

Calculate the tensile force on the spoke. E for the steel is 300 GPa.

(3)

- 6.4 A tensile test is done on a metal specimen and the following readings are obtained during the test:



Original length = 80 mm

Original diameter = 20 mm

|                  |   |        |        |        |        |        |
|------------------|---|--------|--------|--------|--------|--------|
| Load in kN       | 0 | 10     | 20     | 30     | 40     | 50     |
| Elongation in mm | 0 | 0,0121 | 0,0243 | 0,0361 | 0,0485 | 0,0618 |

- 6.4.1 Draw the stress-strain graph for these values.

(3)

- 6.4.2 Determine Young's modulus of elasticity for the specimen with the aid of a graph.

(2)

**[16]**

## QUESTION 7

- 7.1 What is the difference between the *Kelvin scale* and the *Celsius scale*?

(2)

- 7.2 The surface of the ocean at a certain point has a temperature of  $27^\circ\text{C}$  at a pressure of 1 atmosphere (101,325 kPa). The temperature at the bottom is  $10^\circ\text{C}$ . An air bubble with a diameter of 16 mm is let loose.



Calculate the difference in pressure at the surface and at the bottom of the ocean if the air bubble has a diameter of 42 mm when it reaches the surface of the ocean. (Volume of a sphere =  $\frac{4}{3}\pi r^3$  and density of water =  $1\,000 \text{ kg/m}^3$ .)

(4)

- 7.3 A given mass of chlorine has a volume of  $40 \text{ cm}^3$  at  $20^\circ\text{C}$ .

Calculate its volume at  $50^\circ\text{C}$  if the pressure remains constant.

(2)

- 7.4 A patient is supplied with oxygen contained in an oxygen cylinder with a capacity of 40 litres. The cylinder was filled with oxygen at a temperature of  $50^\circ\text{C}$  at a pressure of 380 kPa. Later it is found that the pressure has dropped to 280 kPa and the temperature has decreased to  $25^\circ\text{C}$  as a result of the supply to the patient. The gas constant is  $R = 265 \text{ J/kg.K}$ .

Calculate the following:

- 7.4.1 The mass of oxygen in the container initially

(2)

- 7.4.2 The mass of oxygen used by the patient



(3)

**[13]**

**TOTAL: 100**

**ENGINEERING SCIENCE N4****FORMULA SHEET**

Any applicable formula may also be used.

$$S = \frac{u + v}{2} \times t$$

$$a = \alpha R$$

$$H.V. = \frac{F_p}{F_h} = M.A.$$

$$\bar{V} = \frac{s}{t}$$

$$v = \pi DN$$

$$AV = mgh = WD$$

$$v = u + at$$

$$T = FR$$

$$Q = mc\Delta t$$

$$s = ut + \frac{1}{2}at^2$$

$$AV = T\theta = WD$$

$$\Delta l = l_o \alpha \Delta t$$

$$v^2 = u^2 + 2as$$

$$P = 2\pi NT$$

$$\beta = 2\alpha$$

$$v_g = \frac{u + v}{2}$$

$$P = Fv$$

$$\gamma = 3\alpha$$

$$\omega = 2\pi N$$

$$P = T\omega$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\omega = \frac{\theta}{t}$$

$$F_a = ma$$

$$PV = mRT$$

$$\theta = \frac{\omega_2 + \omega_1}{2} \times t$$

$$E_p = mgh$$

$$\epsilon = \frac{x}{l}$$

$$\omega_2 = \omega_1 + \alpha t$$

$$E_k = \frac{1}{2}mv^2$$

$$E = \frac{\sigma}{\epsilon}$$

$$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$$

$$P = \frac{F}{A}$$

$$\sigma = \frac{F}{A}$$

$$v = \omega R$$

$$m = \rho \times vol$$

$$E = \frac{Fl}{Ax}$$

$$\theta = 2\pi n$$

$$P = \rho gh$$

$$\bar{y} = \frac{A_1 y_1 \pm A_2 y_2 \dots}{A_1 \pm A_2 \dots}$$

$$S = R\theta$$

$$\frac{W_r}{F_p} = \frac{D^2}{d^2}$$

$$\bar{y} = \frac{v_1 y_1 \pm v_2 y_2 \dots}{v_1 \pm v_2 \dots}$$

$$\alpha = \frac{\omega_2^2 - \omega_1^2}{2\theta}$$

$$W.D. = P \times V = A.V.$$

**INFORMATION SHEET****PHYSICAL CONSTANTS**

| QUANTITY                                     | CONSTANTS                            |
|----------------------------------------------|--------------------------------------|
| Atmospheric pressure                         | 101,3 kPa                            |
| Density of copper                            | 8 900 kg/m <sup>3</sup>              |
| Density of aluminium                         | 2 770 kg/m <sup>3</sup>              |
| Density of gold                              | 19 000 kg/m <sup>3</sup>             |
| Density of alcohol (ethyl)                   | 790 kg/m <sup>3</sup>                |
| Density of mercury                           | 13 600 kg/m <sup>3</sup>             |
| Density of platinum                          | 21 500 kg/m <sup>3</sup>             |
| Density of water                             | 1 000 kg/m <sup>3</sup>              |
| Density of mineral oil                       | 920 kg/m <sup>3</sup>                |
| Density of air                               | 1,05 kg/m <sup>3</sup>               |
| Electrochemical equivalent of silver         | 1,118 mg/C                           |
| Electrochemical equivalent of copper         | 0,329 mg/C                           |
| Gravitational acceleration                   | 9,8 m/s <sup>2</sup>                 |
| Heat value of coal                           | 30 MJ/kg                             |
| Heat value of anthracite                     | 35 MJ/kg                             |
| Heat value of petrol                         | 45 MJ/kg                             |
| Heat value of hydrogen                       | 140 MJ/kg                            |
| Linear coefficient of expansion of copper    | $17 \times 10^{-6}/^{\circ}\text{C}$ |
| Linear coefficient of expansion of aluminium | $23 \times 10^{-6}/^{\circ}\text{C}$ |
| Linear coefficient of expansion of steel     | $12 \times 10^{-6}/^{\circ}\text{C}$ |
| Linear coefficient of expansion of lead      | $54 \times 10^{-6}/^{\circ}\text{C}$ |
| Specific heat capacity of steam              | 2 100 J/kg.°C                        |
| Specific heat capacity of water              | 4 187 J/kg.°C                        |
| Specific heat capacity of aluminium          | 900 J/kg.°C                          |
| Specific heat capacity of oil                | 2 000 J/kg.°C                        |
| Specific heat capacity of steel              | 500 J/kg.°C                          |
| Specific heat capacity of copper             | 390 J/kg.°C                          |