higher education
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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T590(E)(A8)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

ENGINEERING SCIENCE N3

(15070413)

8 April 2015 (Y-Paper)
13:00–16:00

REQUIREMENTS: Properties of water and steam (BOE 173)

Calculators may be used.

This question paper consists of 8 pages, a formula sheet of 2 pages and 1 information sheet.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ENGINEERING SCIENCE N3
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. ALL the calculations should consist of at least the THREE steps:

   4.1 The formula used or manipulation thereof
   4.2 Substitution of the given data in the formula
   4.3 The answer with the correct SI unit

5. Drawing instruments must be used for all drawings/diagrams. All drawings/-diagrams must be fully labelled.
6. The constant values, as they appear on the attached information sheet, must be used wherever possible.
7. Keep subsections of questions together.
8. Rule off on completion of each question.
9. Use $g = 9{,}8\ m/s^2$
10. Answers must be rounded off to THREE decimal places.
11. Write neatly and legibly.

QUESTION 1: MOTION, POWER AND ENERGY

1.1 Define the term *machine*. (2)

1.2 A ball with a mass of 2 kg rests on an incline with an angle of 10°. The ball is to be released to roll down the incline plane, neglecting all friction.

Determine the following:

1.2.1 The loss in potential energy after it has rolled 12 m (3)

1.2.2 The kinetic energy after it has rolled 12 m (1)

1.2.3 The velocity after it has rolled 12 m (2)

1.2.4 The original height that the ball has rolled from, in order to reach the bottom of the slope at 20 m/s (2)

1.3 A train with a mass of 120 Mg accelerates uniformly on a horisontal track. The resistance to movement is 5 N per kN of the mass of the train. The force in the draw-bar of the locomotive is 80 kN.

Calculate the following:

1.3.1 The force required for the constant speed (2)

1.3.2 The force that causes the acceleration (1)

1.3.3 The acceleration (2)

[15]

QUESTION 2: MOMENTS

2.1 Define *torque*. (2)

2.2 FIGURE 1 below shows a light horizontal beam **ABCDEF** of a uniform cross section, loaded as shown.

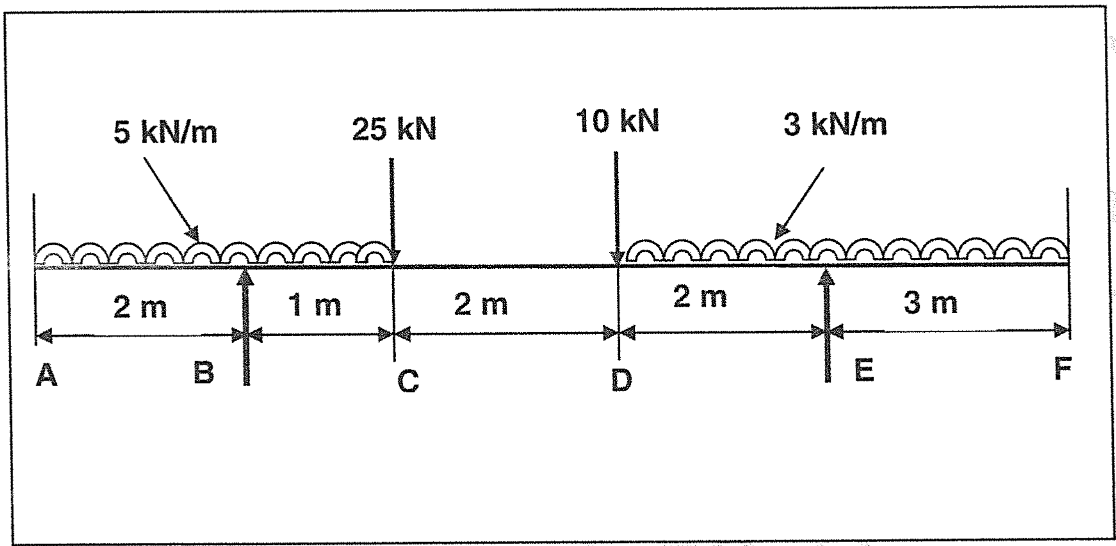

FIGURE 1

2.2.1 Calculate the reactions at the supports and test your answers. (5)

2.2.2 Draw a shear-force diagram, using a suitable scale. Show ALL the main values on the diagram. (3)

2.3 Explain TWO ways of solving problems with oblique forces. (2)
[12]

QUESTION 3: FORCES

3.1 Explain the term *scalar quantity*. (1)

3.2 Complete the following sentence by filling in the missing word(s). Write only the word(s) next to the question number (3.2.1–3.2.2) in the ANSWER BOOK.

A direct force is a force which acts (3.2.1 …) and (3.2.2 …) onto an object. (2)

3.3 Name TWO types of direct forces. (2)

3.4 Calculate the magnitude of the forces in the ropes **P** and **T** as shown in FIGURE 2 below if the system is in the state of equilibrium.

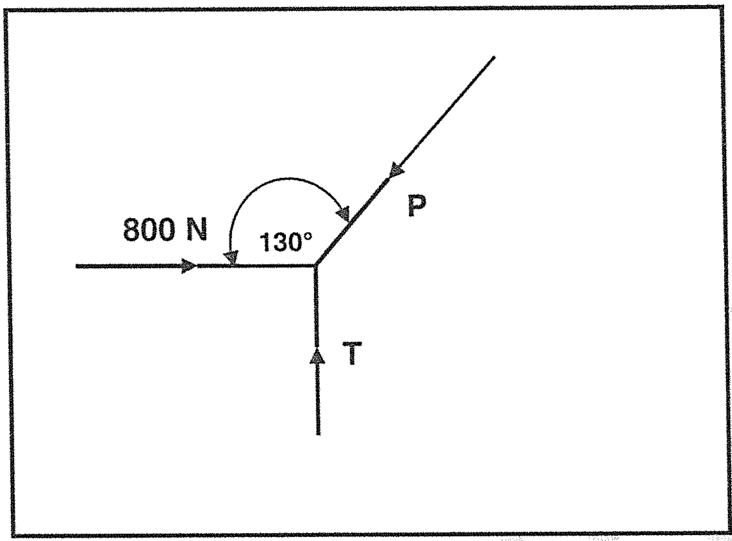

FIGURE 2 (4)

3.5 Determine the magnitude and nature of the forces in the members **AD** and **DC** of the roof truss in FIGURE 3 below.

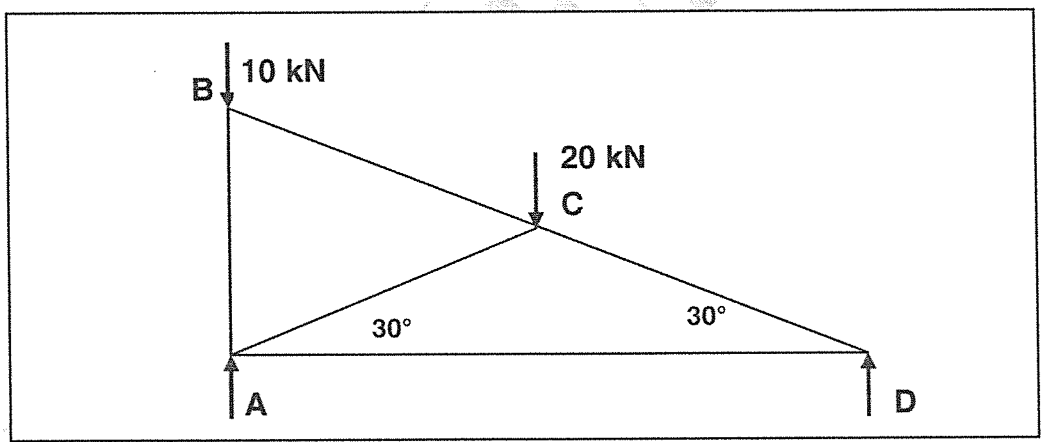

FIGURE 3 (6)

[15]

QUESTION 4: FRICTION

4.1 Name FOUR principles of kinetic friction. (4)

4.2 During an experiment on an adjustable incline plane, a block weighing 1,6 tons was placed on the plane. The incline is at an angle of 20° to the horisontal.

If the frictional force is 225 N, determine the following:

4.2.1 The weight component of the block parallel with the plane

4.2.2 The weight component of the block perpendicular to the plane

4.2.3 The smallest force required to pull the block upwards along the plane

4.2.4 The power if the block moves at a constant speed of 10 m/s

(4 × 2) (8)
[12]

QUESTION 5: HEAT

5.1 Explain the *law of conservation of energy.* (2)

5.2 Calculate the volume of water, in litres, required to cool 30 steel shafts. The initial temperature of the shafts are 800 °C and that of the water is 25 °C. The mass of each steel part is 200 g. The final temperature of the mixture is 80 °C. (6)

5.3 A 20 m aluminium bar is heated from 313 K to 453 K.

Determine the final length of the bar. (3)

5.4 In FIGURE 4 below a process of water to steam is shown.

Name the enthalpy symbols for QUESTIONS 5.4.1 to 5.4.4 as indicated in FIGURE 4 below. Write only the answers next to the question numbers (5.4.1–5.4.4)

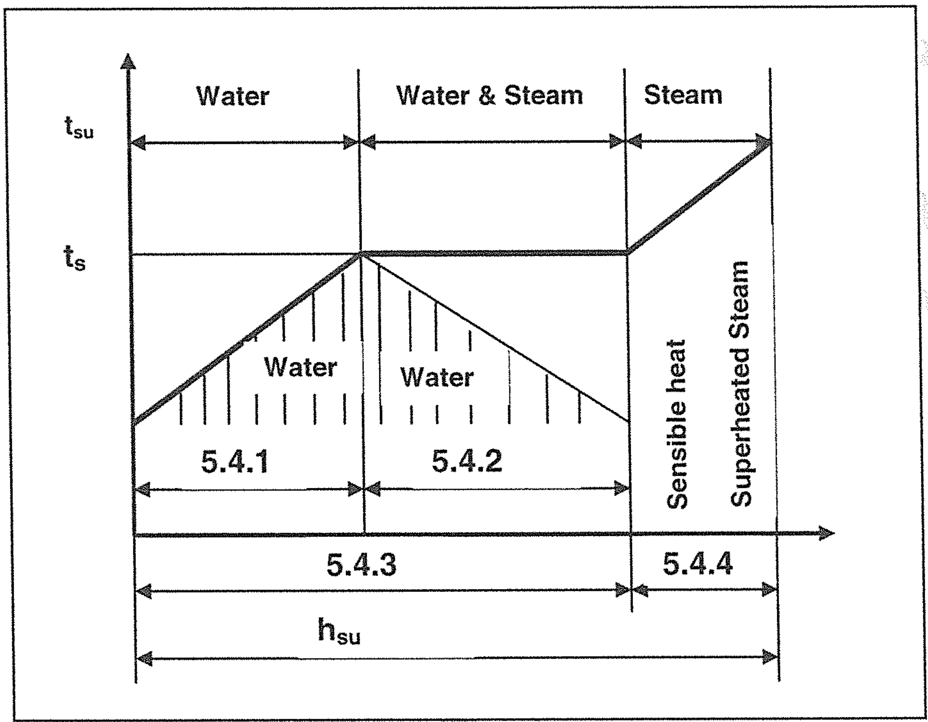

FIGURE 4

(4)
[15]

QUESTION 6: HYDRAULICS

6.1 Explain the following terms:

6.1.1 Pressure at a point

6.1.2 Total pressure

(2 × 1) (2)

6.2 The effective pressure in a single-acting piston pump installation is 550 kPa during a delivery stroke. The piston diameter of the pump is 150 mm and its stroke length is 250 mm.

Calculate the following:

6.2.1 The volume of water in m^3 displaced during the delivery stroke

6.2.2 The work done during the delivery stroke

(2 × 2) (4)

6.3 Illustrate by means of a sketch the following terms with reference to a centrifugal pump:

Suction head; static head; and delivery head (6)

[12]

QUESTION 7: ELECTRICITY

7.1 An electrical circuit consists of a battery with 2 cells, each with an EMF of 12 volts and an internal resistance of 0,4 ohms, connected in parallel. An ammeter with an internal resistance of 0.15 ohms is connected in series with resistor R_a = 2 ohms and resistor R_b = 4 ohms.

Calculate the following:

7.1.1 The total internal resistance of the battery

7.1.2 The ammeter reading

(2 × 2) (4)

7.2 Distinguish between *potential difference* and *electromotive force.* (2)

7.3 An electric bulb is marked 220 V – 60 W. An ammeter in the circuit shows that the bulb uses a current of 0,2727 A. The bulb burns for one hour.

Calculate the following:

7.3.1 The electrical energy consumption (2)

7.3.2 The cost for the bulb to burn for one hour if the cost of electricity is 17,45 cents per kW.h. (2)

7.4 Determine the power rating of a stove if it releases 200 kJ of heat energy in 4 minutes and 30 seconds. (3)

[13]

QUESTION 8: CHEMISTRY

Describe the following types of corrosion and give a practical example of each:

8.1 Pure chemical corrosion (3)

8.2 Pure electrochemical corrosion (3)

[6]

TOTAL: 100

ENGINEERING SCIENCE N3

FORMULA SHEET

All the formulae needed are not necessarily included.
Any applicable formula may also be used.

$W = F.s$

$W = \rho.V$

$P = \dfrac{W}{t}$

$\eta = \dfrac{Uitset/Output}{Inset/Input}\, 100\%$

$F = m.a$

$\mu = \dfrac{F_\mu}{N_R}$

$\mu = \tan\Phi$

$N_R = F_C \pm F_T sin\alpha \;...\; a = 0$

$F_S = wsin\theta$

$F_C = wcos\theta$

$F_T cos\alpha = F_\mu \pm F_S \;...\; a = 0$

$F_e = T_1 - T_2$

$\dfrac{T_1}{T_2} = tension\ ratio$

$P = F_e \,.\, v$

$v = \pi \,.\, d \,.\, n \;...\; n = \dfrac{N}{60}$

$W_\mu = F_\mu \,.\, s$

$\Delta E_p = m.g.\Delta h$

$\Delta E_K = \dfrac{1}{2}.m.\Delta v^2$

$Q = I^2 \,.\, R \,.\, t$

$m = I \,.\, z \,.\, t$

$\dfrac{V_P}{V_S} = \dfrac{N_P}{N_S} = \dfrac{I_S}{I_P}$

$m_1.u_1 \pm m_2.u_2 = m_1.v_1 \pm m_2.v_2$

$D_e = (D + t)$

$h_{nat/wet} = h_f + x.h_{fg}$

$P = 2.\pi.T.n \;...\; T = F.r$

$P = \dfrac{F_{RAM}}{A_{RAM}} = \dfrac{F_{PL}}{A_{PL}} \;...\; A = \dfrac{\pi D^2}{4}$

$V_{RAM} = V_{PL} \times n$

$A_{RAM} \,.\, H_{RAM} = A_{PL} \,.\, L_{PL}$

$F_X = Fcos\theta$

$F_Y = Fsin\theta$

$\Sigma F_X = F_1 cos\theta_1 + ... + F_n cos\theta_n$

$\Sigma F_y = F_1 sin\theta_1 + ... + F_n sin\theta_n$

$R = \sqrt{\Sigma F_X^2 + \Sigma F_Y^2}$

$tan\varphi = \dfrac{\Sigma F_Y}{\Sigma F_X}$

$Q = m \,.\, c \,.\, \Delta t \;...\; t_F = to \pm \Delta t$

$m.ww = Q = m.hv$

$P = \dfrac{Q}{t}$

$\Delta L = Lo \,.\, \alpha \,.\, \Delta t \;...\; L_f = Lo \pm \Delta L$

$\Delta A = A_0 \,.\, \beta \,.\, \Delta t \;...\; A_f = A_0 \pm \Delta A$

$2.a.s = v^2 - u^2$

$s = u.t + \dfrac{1}{2}.a.t^2$

$v = u + a.t$

$\Sigma \uparrow F = \Sigma \downarrow F$

$M = F \,.\, \perp s$

$$\Sigma\ CWM = \Sigma ACWM$$

$$P_{ABS} = P_{ATM} + P_{MET}$$

$$P = \delta \times g \times h$$

$$\frac{1}{R_{PAR}} = \frac{1}{R_1} + \ldots + \frac{1}{R_n}$$

$$R_{SER} = R_1 + \ldots R_n$$

$$V_1 - V_2 = -e(U_1 - U_2)$$

$$V = I \times R$$

INFORMATION SHEET

PHYSICAL CONSTANTS	VALUES	FISIESE KONSTANTE
Atmospheric pressure	101,3 kPa	Atmosferiese druk
Density of copper	8 900 kg/m^3	Digtheid van koper
Density of aluminium	2 770 kg/m^3	Digtheid van aluminium
Density of gold	19 000 kg/m^3	Digtheid van goud
Density of alcohol (ethyl)	790 kg/m^3	Digtheid van alcohol (etiel)
Density of mercury	13 600 kg/m^3	Digtheid van kwik
Density of platinum	21 500 kg/m^3	Digtheid van platina
Density of water	1 000 kg/m^3	Digtheid van water
Density of mineral oil	920 kg/m^3	Digtheid van minerale olie
Density of air	1,05 kg/m^3	Digtheid van lug
Electrochemical equivalent of silver	1,118 mg/C	Elektrochemiese ekwivalent van silwer
Electrochemical equivalent of copper	0,329 mg/C	Elektrochemiese ekwivalent van koper
Gravitational acceleration	9,8 m/s^2	Swaartekragversnelling
Heat value of coal	30 MJ/kg	Warmtewaarde van steenkool
Heat value of anthracite	35 MJ/kg	Warmtewaarde van antrasiet
Heat value of petrol	45 MJ/kg	Warmtewaarde van petrol
Heat value of hydrogen	140 MJ/kg	Warmtewaarde van waterstof
Linear coefficient of expansion of copper	17×10^{-6}/°C	Lineêre uitsettingskoëffisiënt van koper
Linear coefficient of expansion of aluminium	23×10^{-6}/°C	Lineêre uitsettingskoëffisiënt van aluminium
Linear coefficient of expansion of steel	12×10^{-6}/°C	Lineêre uitsettingskoëffisiënt van staal
Linear coefficient of expansion of lead	54×10^{-6}/°C	Lineêre uitsettingskoëffisiënt van lood
Specific heat capacity of steam	2 100 J/kg.°C	Spesifieke warmtekapasiteit van stoom
Specific heat capacity of water	4 187 J/kg.°C	Spesifieke warmtekapasiteit van water
Specific heat capacity of aluminium	900 J/kg.°C	Spesifieke warmtekapasiteit van aluminium
Specific heat capacity of oil	2 000 J/kg.°C	Spesifieke warmtekapasiteit van olie
Specific heat capacity of steel	500 J/kg.°C	Spesifieke warmtekapasiteit van staal
Specific heat capacity of copper	390 J/kg.°C	Spesifieke warmtekapasiteit van koper

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MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

ENGINEERING SCIENCE N3

8 APRIL 2015

This marking guideline consists of 11 pages.

QUESTION 1: MOTION, POWER AND ENERGY

1.1 A machine is a mechanical device which enables work to take place✓ more effectively or more easily. ✓ (2)

1.2 1.2.1

$$h = 12\sin 10°$$
$$= 2{,}084\,m \quad ✓$$

1 m value of h

$$E_P = mgh$$
$$= 2 \times 9{,}8 \times 2{,}084 \quad ✓$$
$$= 40{,}846\ J \quad ✓$$

1 m sub
1 m solution (3)

1.2.2

$$E_P = E_K$$
$$= 40{,}842\ J \quad ✓$$

1 m solution (1)

1.2.3

$$E_K = \frac{1}{2}mv^2$$
$$v = \sqrt{\frac{2 \times E_K}{m}}$$
$$= \sqrt{\frac{2 \times 40{,}842}{2}} \quad ✓ \quad ✓$$
$$= 6{,}387\ m/s$$

1 m sub

1 m solution (2)

1.2.4

$$E_K = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(2)(20)^2$$
$$= 400\ J \quad ✓$$

1 m EK

$$E_K = E_P = mgh$$
$$h = \frac{E_K}{mg}$$
$$= \frac{400}{2 \times 9{,}8}$$
$$= 20{,}408\ m \quad ✓$$

1 m solution (2)

1.3 1.3.1

$$F_L = F_a + F_{RT}$$
$$F_L = 0 + [5 \times \frac{120000 \times 9{,}8}{1000}] \quad ✓$$
$$= 5880\ N \quad ✓$$

1 m converting

1 m solution (2)

1.3.2 $F_L = F_a + F_{RT}$

$F_a = 80000 - 5880$

$= 74{,}12 \ kN$ ✓ 1 m solution (1)

1.3.3 $F_a = ma$

$a = \frac{F_a}{m}$

$= \frac{74{,}120 \times 1000}{120\ 000}$ ✓ 1 m sub

$= 0{,}618 \ m/s^2$ ✓ ✓ 1 m solution
-½ incorrect units (2)
[15]

QUESTION 2: MOMENTS

2.1 Turning moment (torque) is applied force in Newtons,✓multiplied by the distance from the axis or fulcrum.✓ (2)

2.2 2.2.1

(E x 5) + (15 x 0.5) = (25 x 1) + (10 x 3) + (15 x 5,5)

5E + 7.5 = 25 + 30 + 82.5 ✓

E = 26 kN ✓ 2 m for E (2)

$(25 \times 4) + (10 \times 2) + (15 \times 5{,}5) = (B \times 5) + (15 \times 0{,}5)$

$100 + 20 + 82{,}5 = 5B + 7{,}5$ ✓

$B = 39 \, kN$ ✓ 2 m for B (2)

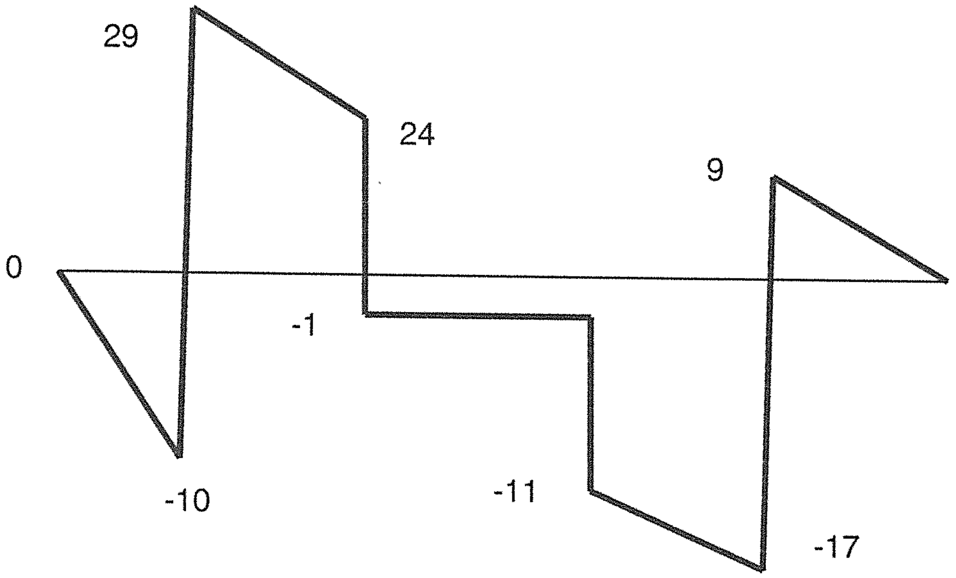
$F_{UP} = F_{DOWN}$

$26 + 39 = 15 + 25 + 10 + 15$

$65 \ kN = 65 kN$

1 m checking (1)

2.2.2



½ for 29

½ for -10

½ for 24

½ for -11

½ for -17

½ for 9 (3)

2.3 First, we must express the horizontal and vertical components in terms of the forces, F, and the given angle.✓
The second method is to resolve oblique force into components which can be used for calculating the moment of the force.✓ (2)

[12]

QUESTION 3: FORCES

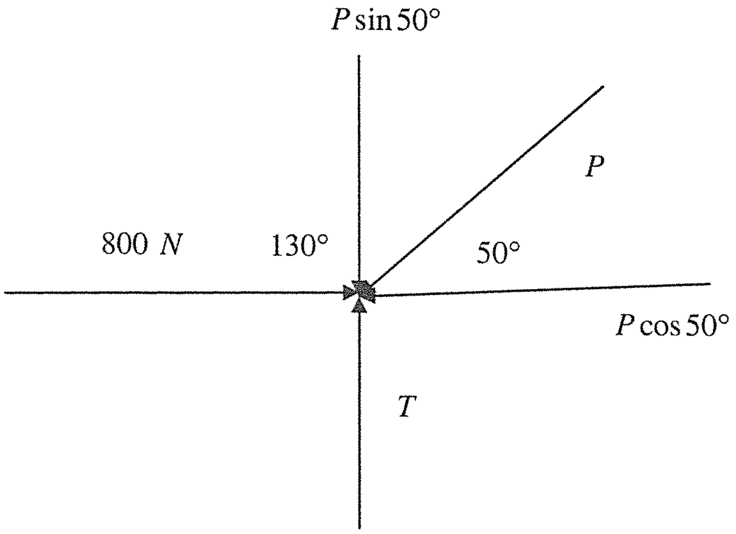
3.1 A scalar quantity is a quantity which possesses magnitude only. (1)

3.2 3.2.1 Directly (1)

3.2.2 Perpendicularly (1)

3.3 Tensile or pulling force✓
Compressive or pushing force✓ (2)

3.4



$F_L = F_R$

$P\cos 50 = 800$

$p = \frac{8}{\cos 50}$ ✓

$P = 1244,5$ ✓

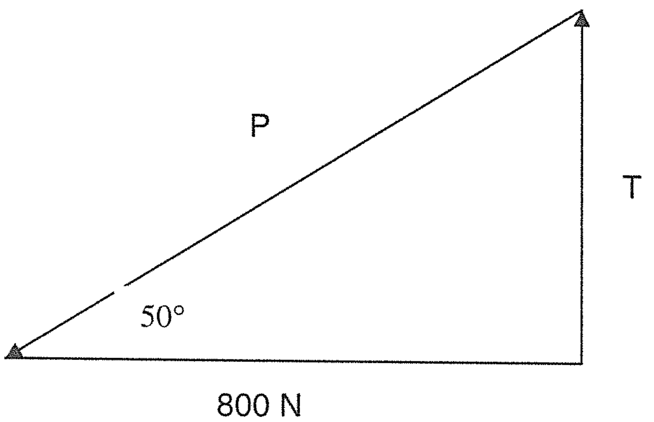
$F_{UP} = F_{DOWN}$

$T = P\sin 50$

$T = 1244,579\ \mathrm{si}$ ✓

$T = 953,40$ ✓

OR



$\tan\theta = \frac{T}{800}$

$T = 800\ \tan 50$

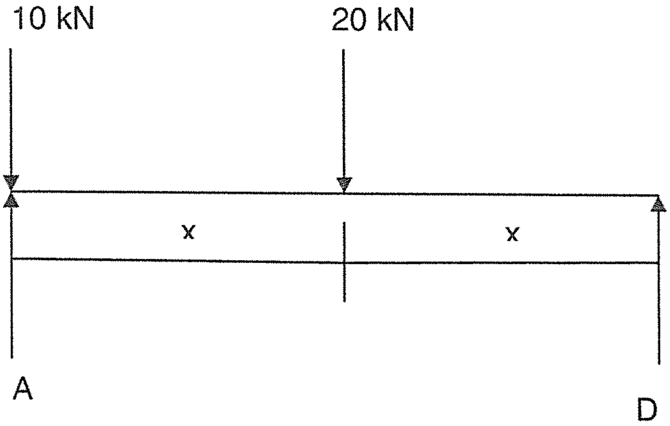
$T = 953,403\ N$

$\cos\ \theta = \frac{800}{\cos 50}$

$= 1244,579\ N$

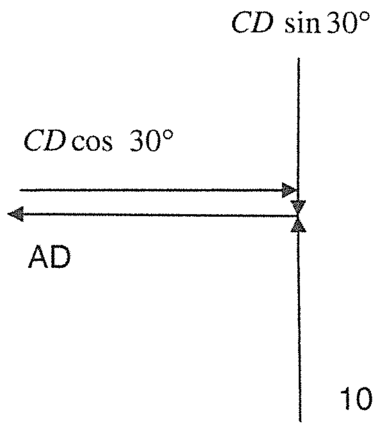
(4)

3.5



$20 \times x = D \times 2 \times x$ ✓

$D = 10\,kN$ ✓



$\sum F_{UP} = \sum F_{DOWN}$

$10 = CD \sin 30$ ✓

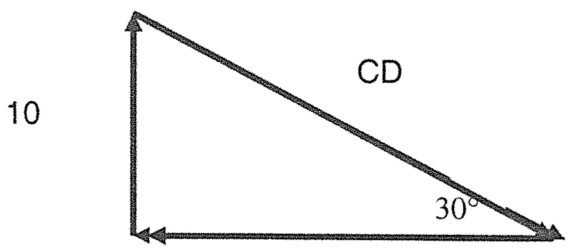
$CD = 20\,kN(strut\,/\,push)$ ✓

$\sum F_L = \sum F_R$

$AD = CD\ \cos 30$ ✓

$\quad = 17{,}32\ kN(pull\,/\,tie)$ ✓

OR



$$AD = \frac{10}{\tan 30}$$ AD

$$= 17{,}32\ kN\ (Pull/tie)\ ✓$$

$$CD = \frac{10}{\sin 30}$$

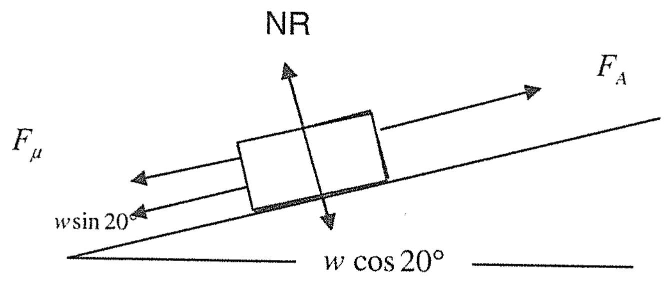
$$= 20\,kN\ (strut/push)$$

(6)
[15]

QUESTION 4: FRICTION

4.1
- Friction depends on the nature of the surfaces in contact.
- Friction is independent of the speed.
- Friction is independent of the size of the area in contact.
- Friction is proportional to the perpendicular force between the surfaces. (4)

4.2



4.2.1 The weight component parallel with the plane

= W Sin Θ

= 1 600 × 9,8 × Sin 20° ✓

= 5362,876 N ✓

4.2.2 The weight component perpendicular to the plane

= W Cos Θ

= 1 600 × 9,9 × cos 20✓

= 14 734,38 N✓

4.2.3 Force required to pull the block upward

Fup = Fμ = Fμ + Wsin Θ

= 75 + 5362,876

= 5587,876✓

= 55,87 kN✓

4.2.4 Power = $F \times V$

$= 5587{,}876 \times 10^3 \times 10$ ✓

$= 558787{,}6$ W ✓

$= 558{,}788$ kW

(4 × 2) (8)

[12]

QUESTION 5: HEAT

5.1 Energy can neither be created nor destroyed,✓ but only converted from one form to another. ✓ (2)

5.2 30 steel parts x 200 g = 6 kg

$M \times c \times \Delta t = m \times c \times \Delta t$

W S

$m \times 4187 \times (80 - 25) = 6 \times 500 \times (800 - 80)$

$m \times 4187 \times (80 - 25) = 232\ 5000$

$m = \dfrac{232\ 5000}{(4187 \times 55)}$

$M = 9{,}38$ kg

1 kg = 1 litre

$M = 9{,}38$ litres (6)

5.3 $\ell 0 = 20$ m

$t_1 = 313$ K

$t_2 = 453$ K

$\Delta l = l_0 \alpha \Delta t$

$= 20 \times 23 \times 10^{-6} \times (453 - 313)$ ✓

$= 0{,}0644$ m ✓

$L_f = Lo + \Delta \ell$

$= 20 + 0,\ 0644$

$= 20{,}0644$ m ✓ (3)

5.4 5.4.1 h_f

5.4.2 h_{fg}

5.4.3 h_g

5.4.4 h_{ss}

(4 × 1) (4)
[15]

QUESTION 6: HYDRAULICS

6.1 6.1.1 Pressure at a point in a liquid is the force exerted by the liquid due to its weight per unit area, acting downwards.✓

6.1.2 Total pressure on an area means the force or weight acting over the whole area.✓

(2 × 1) (2)

6.2 6.2.1

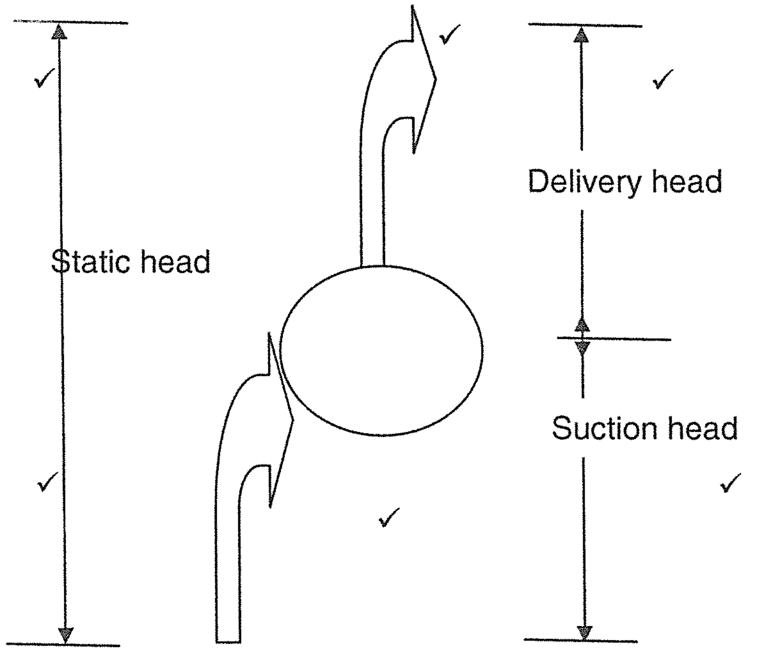
$$P = 550 \quad 000$$
$$d = 150 \ mm = 0{,}15 \ m$$
$$L_s = 250 \ mm = 0{,}25 \ m$$
$$V = A \times L_s$$
$$= \frac{\pi (0{,}15)^2}{4} \times 0{,}25 \ \checkmark \checkmark$$
$$= 4{,}418 \times 10 \ \ldots$$
$$OR \ 0{,}004418 \ m^3$$

6.2.2

$$W = PV$$
$$= 550 \times 10^3 \times 4{,}418 \times 10^{-3} \ \checkmark$$
$$= 2429{,}826 \ J \ \checkmark$$
$$= 2{,}429 \ kJ$$

(2 × 2) (4)

6.3



(6)
[12]

QUESTION 7: ELECTRICITY

7.1 7.1.1

$$r_T = \frac{0,4}{2} \checkmark$$
$$= 0,2\ \Omega \checkmark$$

7.1.2

$$I = \frac{E}{R+r}$$
$$= \frac{12}{6,15+0,2} \checkmark$$
$$= 1,89\ A \checkmark$$

(2 × 2) (4)

7.2 The potential difference (PD) of a cell is the voltage measured at the poles of a cell when current flows through it.✓

The electromotive force (emf) of a cell is the voltage measured at the poles of a cell when no current flows through it.✓ (2)

7.3 7.3.1

$V = 220\ V$

$P = 60\ W$

$I = 0{,}2727\ A$

$t = 1\ hour$

$Q = IVt$

$= 0{,}2727 \times 220 \times 3600$ ✓

$= 215\ 978{,}4\ J$ ✓

$OR\ 215{,}98\ kJ$

7.3.2 Time = 1 hour

$unit = kWh$

$= \dfrac{60 \times 1\ h}{1000}$

$= 0{,}06\ kWh \times 17{,}45$ ✓

$= 1{,}05$ ✓

(2 × 2) (4)

7.4

$Q = 200000\ J$

$t = 4\,\text{min}\,30\,\text{sec} = 4 \times 60 + 30 = 270\ \text{sec}$

$P = \dfrac{Q}{t}$

$= \dfrac{200\ 000}{270}$ ✓

$= 740{,}741\ W$ ✓

(3)
[13]

QUESTION 8: CHEMISTRY

8.1 Pure corrosion takes place when a bare surface✓comes into contact with an acidic on caustic liquid of gas.✓ A typical example is when battery acid gets onto bare metal parts in the engine compartment.✓ (3)

8.2 A typical example is an ordinary dry battery cell, of the kind used in torches and radios.✓ When current flows through the cell, the zinc oxidises and flows as zinc ions in solution through the electrolyte to combine with the manganese dioxide.✓ The zinc container becomes thinner and thinner as the metal decays from oxidation until it may open up in places and let some electrolyte leak out.✓ (3)
[6]

TOTAL: 100