higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T570(E)(A2)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

ENGINEERING SCIENCE N3

(15070413)

2 April 2014 (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, 1 information sheet and 1 formula sheet of 2 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ENGINEERING SCIENCE N3
TIME: 3 HOURS
MARKS: 100

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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. Answers must be rounded off to THREE decimal places.
5. All the calculations should consist of at least the following THREE steps:
   - The formula used or the manipulation thereof
   - Substitution of the given data in the formula
   - The answer with the correct SI unit
6. Drawing instruments must be used for all drawings/diagrams. All drawings/ diagrams must be fully labelled
7. One mark indicates one percentage point, that is 100 marks = 100%
8. The constant values, as they appear on the attached information sheet, must be used wherever possible.
9. Keep subsections of questions together.
10. Rule off on completion of each question.
11. Use $g = 9{,}8\ m/s^2$
12. Write neatly and legibly.

QUESTION 1: MOTION, POWER AND ENERGY

1.1 Complete the following definitions by filling in the missing words. Write only the word(s) next to the question number (1.1.1–1.1.4) in the ANSWER BOOK.

1.1.1 Speed is the ... covered by a moving body in ... ... (2)

1.1.2 Velocity is the ... of a moving body in relation to time. (1)

1.1.3 ... is the rate of change of velocity. (1)

1.1.4 The property that all objects have to resist movement from rest, and to resist a change to their motion in a straight line, is called ... (1)

1.2 A rope is used to hoist an object with a mass of 1,3 tons vertically through a distance of 100 m. The mass of the rope is 2 kg per metre.

Determine the following:

1.2.1 The total work done (3)

1.2.2 The average tension in the rope (2)

1.2.3 The power used if it takes 2 minutes to hoist the object (2)

1.3 A drilling machine has a V-belt, with a speed of 15 m/s. The driving pulley is driven at a speed of 8 r/s. The tension in the tight side is 3 250 N and the slack side is 1 400 N.

Determine the following:

1.3.1 The power transmitted (2)

1.3.2 The diameter of the driven pulley (2)
[16]

QUESTION 2: MOMENTS

2.1 Define the moments of a force. (2)

2.2 FIGURE 1 below shows a simply loaded beam ABCDE of a uniform cross section, loaded as shown.

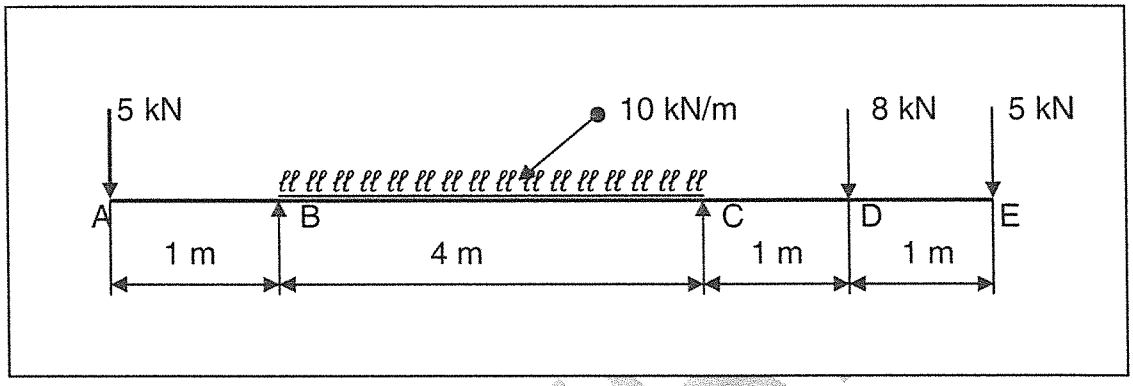

FIGURE 1

2.2.1 Calculate the reaction 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. (4)
[11]

QUESTION 3: FORCES

3.1 Name FIVE principles that will be applicable if more than three co-planar forces act on an object and the object remains in equilibrium. (5)

3.2 Determine the magnitude of force P and Q analytically if the system is in equilibrium as shown in FIGURE 2 below. (7)

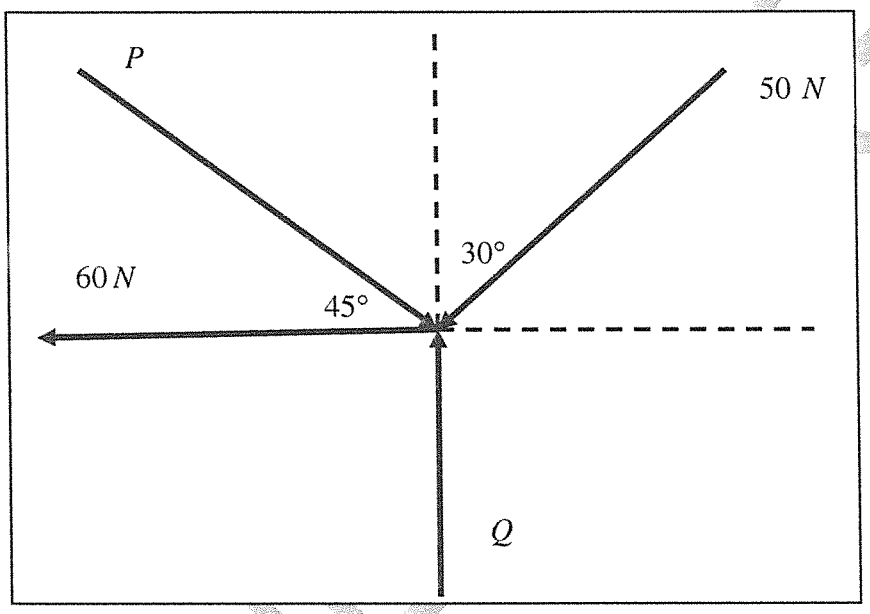

FIGURE 2

3.3 Calculate the magnitude of the unknown force shown in FIGURE 3 below.

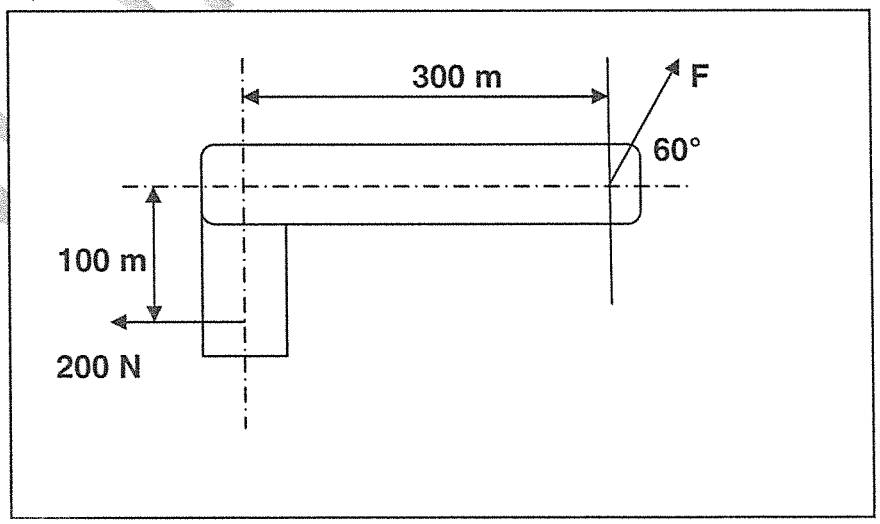

FIGURE 3

(4)
[16]

QUESTION 4: FRICTION

4.1 Explain the difference between static friction and kinetic friction. (4)

4.2 A mass with a weight of 600 N rests on a plane as shown in FIGURE 4 below.

Calculate the smallest force F needed to pull the mass up the incline of 15° if the coefficient of friction is 0,2.

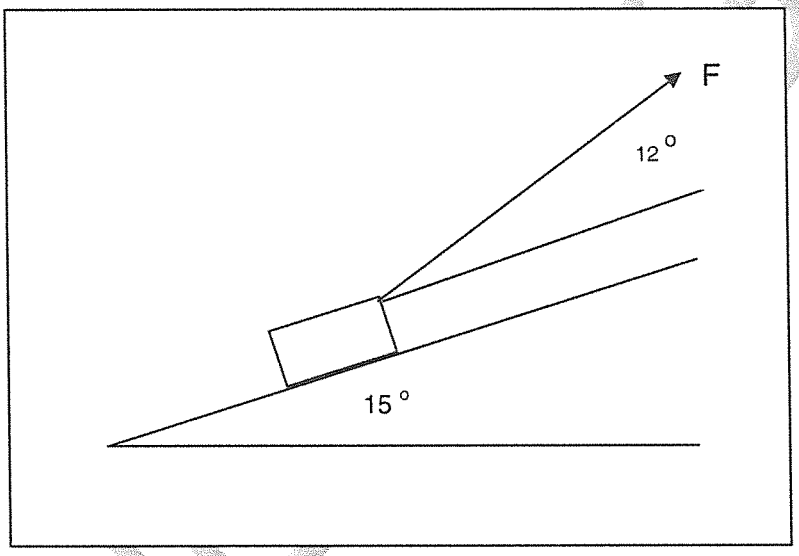

FIGURE 4

(6)
[10]

QUESTION 5: HEAT

5.1 Steel bars with a total mass of 3,5 kg are heated to 217 °C and immediately placed in 28 kg of water at 12 °C.

Determine the final temperature of the steel bars and the water. (4)

5.2 A rectangular brass sheet has a dimension of 450 mm x 350 mm at 10 °C. The coefficient of linear expansion is 20 x 10^{-6}/°C.

If the sheet temperature is raised to 100 °C, determine the following:

5.2.1 The area coefficient of expansion (1)

5.2.2 The increase in area at 100 °C in m^2 (3)

5.2.3 The dimensions at 100 °C (4)

5.3 The dryness fraction of 1 kg wet steam is 0,94. This steam is generated at a boiler pressure of 2,5 MPa.

Determine the following specific enthalpy (heat energy):

5.3.1 The liquid at saturated temperature (h_f or sensible heat) (1)

5.3.2 The dry steam (h_g or total heat for dry steam) (1)

5.3.3 To evaporate the liquid (h_{fg} or latent heat) (1)
[15]

QUESTION 6: HYDRAULICS

6.1 A variety of pumps are being used to pump hydraulic fluids through a system.

Name THREE of these pumps. (3)

6.2 The following information refers to a single-acting hydraulic press:

Diameter of ram	=	55 mm
Force applied to plunger	=	300 N
Diameter of the plunger	=	12 mm
Plunger stroke	=	200 mm

If the mechanical efficiency of the hydraulic system is 80% and that of the lever system is 85%, calculate the following:

6.2.1 The volume of the liquid displaced after 5 pumping strokes of the plunger

6.2.2 The distance in mm that the ram piston will move after 5 pumping strokes

6.2.3 The force exerted by the ram piston

6.2.4 The effort that must be applied to the lever in order to obtain a force of 300 N on the plunger if the mechanical advantage of the lever system is 10

6.2.5 The actual mechanical advantage of the system

(5 × 2) (10)
[13]

QUESTION 7: ELECTRICITY

7.1 The open circuit EMF of a certain cell was measured and found to be 1,48 V. When a 2 Ω resistor was connected across the terminals a current flow of 0,6 A was measured.

Calculate the following:

7.1.1 The internal resistance of the cell (2)

7.1.2 The terminal voltage with the 2 Ω resistor connected (2)

7.2 A 220 V electrical toaster is rated at 1,2 kW.

Calculate the following:

7.2.1 Its rated current (2)

7.2.2 The resistance of its heating element (2)

7.2.3 The current that it would draw if the supply falls to 200 V (2)

7.2.4 The cost to toast a slice of bread at 220 V if it takes the toaster 2 minutes to toast a slice of bread, and the cost of electricity is R1,64 per unit (3)

[13]

QUESTION 8: CHEMISTRY

8.1 Complete the following sentences by filling in the missing word(s) relating to well-known alloys. Write only the word(s) next to the question number (8.1.1–8.1.3) in the ANSWER BOOK.

... 8.1.1 ... is an alloy of steel, vanadium, nickel and molybdenum.

Tool steel is an alloy of ...8.1.2 ... with high proportions of chrome, molybdenum, vanadium and ... 8.1.3 ... (3)

8.2 Name THREE properties of brass. (3)

[6]

TOTAL: 100

INFORMATION SHEET

PHYSICAL CONSTANTS

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

FORMULA SHEET

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

$W = F.s$

$W = \rho.V$

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

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

$F = m.a$

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

$\mu = \tan\Phi$

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

$F_S = wsin\theta$

$F_C = wcos\theta$

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

$F_e = T_1 - T_2$

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

$P = F_e \ . \ v$

$v = \pi \ . \ d \ . \ n \ ... \ n = \frac{N}{60}$

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

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

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

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

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

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

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

$D_e = (D + t)$

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

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

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

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

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

$F_X = Fcos\theta$

$F_Y = Fsin\theta$

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

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

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

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

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

$m.ww = Q = m.hv$

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

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

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

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

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

$v = u + a.t$

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

$M = F \ . \perp s$

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

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

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

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

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

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

$$V = I \times R$$

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MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

ENGINEERING SCIENCE N3

2 APRIL 2014

This marking guideline consists of 11 pages.

QUESTION 1: MOTION, POWER AND ENERGY

1.1 1.1.1 (i) rate of distance ✓ (1)

(ii) relation to time ✓ (1)

1.1.2 (iii) rate of displacement ✓ (1)

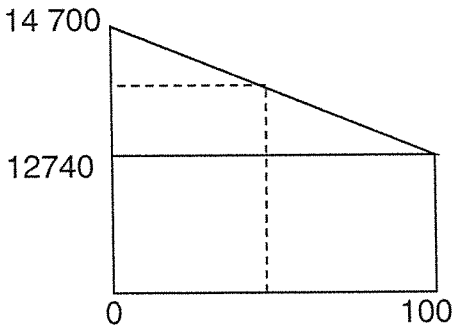
1.1.3 (iv) Acceleration ✓ (1)

1.1.4 (v) Inertia ✓ (1)

1.2 Mo = 1,3 tons = 1300 kg
S = 100 m
Force of object = 1300 x 9.8 = 12740 N

Mr = 2 kg/m = 2x100
= 200 kg

Force in rope = 200 x 9.8 = 1960 N



1.2.1 **WD =** 

= ℓ x b + ½b x h
= 12740 x 100 + ½ x 100 x 1960 ✓
= 1274000 + 98000 ✓
= 1372 000 J or 1372 kJ ✓ (3)

1.2.2 Average = $F_1 + F_2$ OR $\frac{14\,700 + 12\,740}{2}$ ✓
= 1300 x 9.8 + ½ (2x9.8x100) ✓ =13 720 N ✓
= 12 740 + 980 N
= 13 720 N ✓ (2)

1.2.3 Power = $\frac{Wd}{T}$

Power = $\frac{1372\,000}{2\,(60)}$ ✓

Power = 11433,333 W or 11,433 kW ✓ (2)

$P = F_{AV} \times v$

OR $= 13\,720 \times (\frac{100}{120})$ *where* $v = \frac{s}{t}$

= 11433.33 W or 11.433 kW

1.3.1 V = 15 m/s
Na = 8 r/s
T_1 = 3250N
T_2 = 1400 N

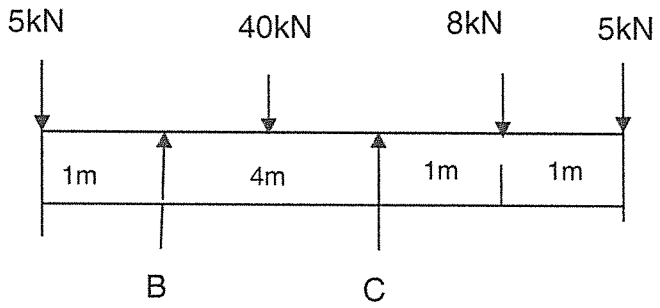
Po = $(T_1 - T_2)$ V
= (3250 – 1400) 15 ✓
= 27750 W 27,75 kW ✓ (2)

1.3.2 Y = π dn
D = Vx / N = 15 / πx8
= 0.597 m
Or 597,75 mm
Use 598 mm (2)
[16]

QUESTION 2: MOMENTS

2.1 The moment of a force is the force multiplied by the perpendicular distance from the fulcrum to the line of action of the force. (2)

2.2

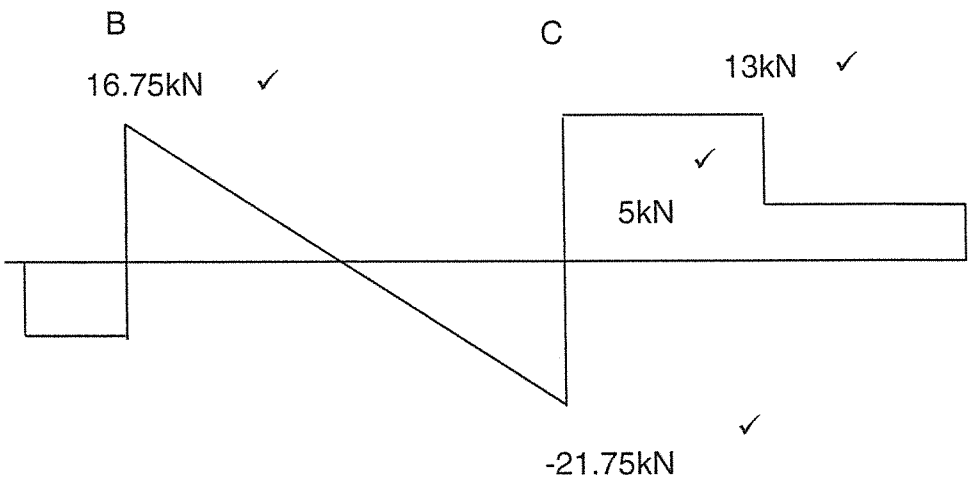


2.2.1 Taking moment about B
Sum of the anticlockwise moment = sum of the clock wise moment
Cx4 + 5x1 = 40x2 +8x5+5x6 ✓
Cx4+5=80+40+30
Cx4 = 150 -5
C=145/4
C= 36,250 kN ✓

Taking moments about C
Sum of the anticlock wise moments = sum of the clockwise moments.
B x 4 + 8 x 1+ 5 x 2 = 40 x 2 + 5 x 5 ✓
B x + 18 = 80 + 25
B = 21,75 kN ✓

Test
Upward force = Downward forces
B + C = S + 40+ 8 + 5
21,75 + 36,25 = 58 kN ✓
58 kN = 58 kN (5)

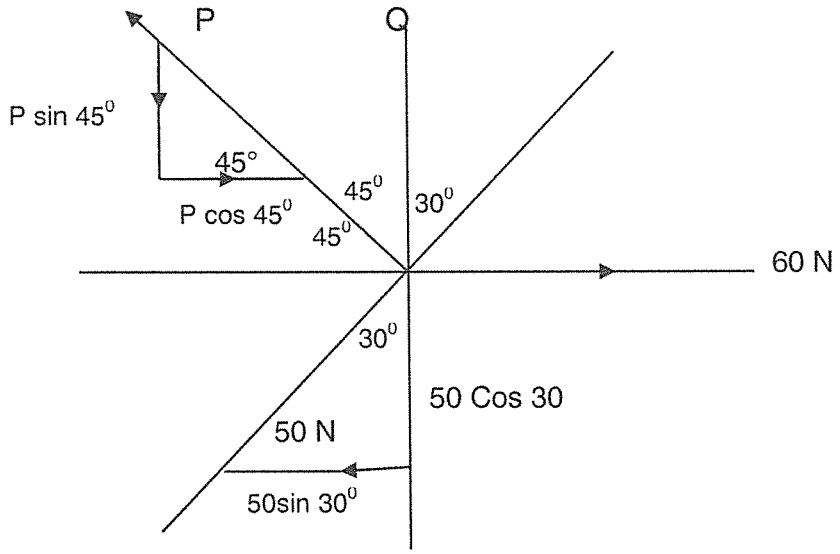
2.2.2



(4)
[11]

QUESTION 3: FORCES

3.1
- The vectors of the forces form a closed triangle.
- The algebraic sum of the components of the faces in any direction is equal to zero.
- The algebraic sum of the moments of the forces about any point is equal to zero.
- The lines of action of the forces meet a point.
- The forces or vector are co-planar. (5)



3.2

$$\Sigma F_L = \Sigma F_R$$

$50 \sin 30° + 60 = P \cos 45°$ ✓

$25 + 60 = P \cos 45$ ✓

$$p = \frac{85}{\cos 45}$$ ✓

$P = 120{,}209\ NE$ ✓

$\Sigma F_{up} = \Sigma F down$

$Q = P \sin 45 + 50 \cos 30$ ✓ ✓

$Q = 128{,}302\ N$ ✓

(7)

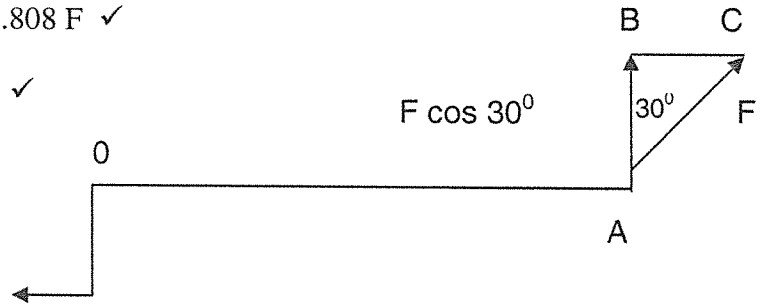
3.3

$\sum$ clockwise moments = $\sum$ anticlockwise moments

200 x 100 ✓ = 300 x F sin 60^0 ✓

20000 = 259.808 F ✓

F = 76.98 N ✓

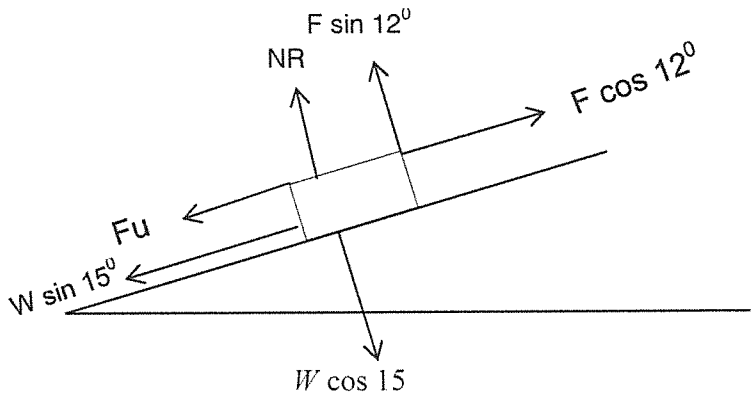


(4)
[16]

QUESTION 4: FRICTION

4.1 Static friction opposes the initial movement; ✓ the forces then required to just move the object is called static friction. ✓

Kinetic friction opposes the force causing the movement after the body is in motion. ✓The force then required to keep the object in motion is called kinetic friction. ✓ (4)



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

$NR + F\sin 12 = W\cos 15$

$NR + F\sin 12 = 600\cos 15$ ..... (1) ✓

$\Sigma F_L = \Sigma F_R$

$F_\mu + w\sin 15 = F\cos 12$

$0{,}2\ NR + 600\sin 15 = F\cos 12$ .....(2) ✓

In (1) $NR = 579{,}556 - F\sin 12$

sub in (2) $0{,}2(579{,}556 - F\sin 12) + 155{,}291 = F\cos 12$ ✓

$115{,}9112 - 0{,}2F\sin 12 + 155{,}291 = F\cos 12$

$271{,}2022 - 0{,}2F\sin 12 = F\cos 12$ ✓

$F(\cos 12 + 0{,}2\sin 12) = 271{,}2022$

$$F = \frac{271{,}2022}{\cos 12 + 0{,}2\sin 12}$$ ✓

$= 265{,}954\,N$ ✓ (6)

[10]

QUESTION 5: HEAT

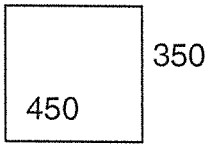
5.1

$M_5 = 3,5$ kg
$T_3 = 217$ °C
Mw = 28 kg

$Q_w = Q_5$
$MxCx\Delta t = MxCx\Delta t$
$28 \times 4187x (t_2-t_1) = 3,5x500x(t_3-t_2)$ ✓
$28x4187x(t_2-12) = 3,5 \times 500 \times (217 - t_2)$
$117236 (t_2-12) = 1750 (217 - t_2)$
$117236t_2 - 1406832 = 379750 - 1750t_2$ ✓
$117236t_2 + 1750t_2 = 379750 + 14606832$ ✓
$118986t_2 = 1786582$
$t_2 = \frac{1786582}{118986}$
$t_2 = 15$ °C ✓

(4)

5.2



$T_1 = 10$ °C
$\alpha = 20 \times 10^{-6}$
T2 – 100 °C

5.2.1 1 $\beta = 2 \times \alpha$
$= 2 \times 20 \times 10^{-6}$
$= 40 \times 10^{-6}$/°C ✓

(1)

5.2.2 The increase in area at 100° C in m^2
$\Delta A = A_0 \times \beta \times \Delta t$
$= (0,45 \times 0,35) \times 40 \times 16^{-6} \times (100 - 10)$ ✓
$= 0,1575 \times 40 \times 10^{-6} \times 90$
$= 5,67 \times 10^{-4}$ m^2 or 0,000567 m^2 ✓
$AF = A_0 + \Delta A = 0,1575 + 0,000567$ ✓
$= 0,158067$ m^2

(3)

5.2.3 The dimensions at 100 °C

$AL = \ell o \times a \times \Delta t$

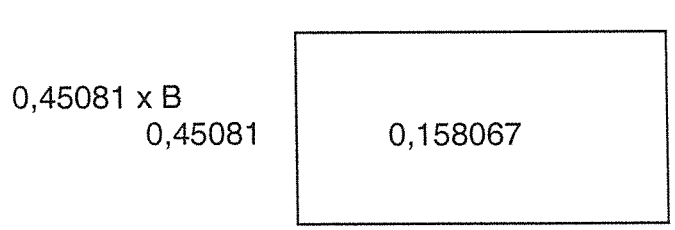
$= 0,45 \times 20\ 10^{-6} \times 90$ ✓

$= 0,00081$ m

$L_F = Lo + \Delta L$

$= 0,45 + 0,000811$

$= 0,45081$ m ✓



Area = L x B

0,1581 = ✓

$B = \frac{0,1581}{0,45081}$

B = 0,3507 m ✓

(4)

5.3 M = 1 kg

x = 0,94

Pr = $2,5 \times 10^6$ pa

5.3.1 The liquid at saturated (hf)

2500 kPa

Hf = 962 kJ/kg ✓ (1)

5.3.2 Dry steam

Hg = 2801 kJ/kg ✓ (1)

5.3.3 Evaporate the liquid (hfg)

Hfg = 1839 kJ/kg ✓ (1)

[15]

QUESTION 6: HYDRAULICS

6.1
- Centrifugal✓ (1)
- Rotary✓ (1)
- Reciprocating✓ (1)

6.2 6.2.1 The volume of the liquid displaced after 5 pumping strokes

Volume = Area x stroke length x no of strokes x efficiency

$= \frac{\pi(0.012)^2}{4} \times h \times 5$ ✓

$= \frac{\pi \times (0,012)^2}{4} \times 0,2 \times 5 \times 0,8$

$= 0,000\ 091\ m^3$ ✓ (2)

6.2.2 The distance in mm that the ram piston will move after 5 pumping strokes

D^2 x stroke length x no of strokes = D^2 x stroke length

$0,8x(0,012)^2 \times 0,2x5 = (0,055)^2 \times$ stroke length

$H = \frac{0,8x(0,012)^2 \times 0,2x5}{(0,055)^2}$ ✓

- ✓

$= 0,0380826$ m

$= 38.3$ mm

OR

$V_P = V_R$

$0,000\ 091 = \frac{\pi}{4}(0,055)^2 \times h$

$= 0,0383\ m$

$= 38,3\ mm$ (2)

6.2.3 $\frac{W}{D^2 \times (d)^2} = F$

$W = \frac{F \times D^2}{d^2}$

$= \frac{300x\ (0,055)^2}{(0,012)^2}$

$W = 6302,083$ N ✓

Force = W x $\frac{80}{100}$

$= 6302,0873° \times 0,8$ ✓

$= 5041,666$ ° N (2)

6.2.4 $MA = \frac{LOAD}{EFFORT}$

$E = \frac{L}{MA} = \frac{300}{10}$ ✓

$= 30\ N$

$EFFORT = \frac{30\ N}{0,85}$

$= 35,294\ N$ ✓ (2)

6.2.5 $MA = \frac{LOAD}{EFFORT}$ ✓

$= \frac{300}{35,294}$

$= 8,5$ ✓ (2)
[13]

QUESTION 7: ELECTRICITY

7.1 7.1.1 $r = \frac{E}{I} - R$ ✓

$= \frac{1,48}{0,6} - 2$

$= 2,467 - 2$ ✓

$= 0,467\ \Omega$ (2)

7.1.2 $V = E - IR$

$= 1,48 - 0,28$ ✓

$= 1,2\ V$ ✓ (2)

7.2 V = 220 V
P = 1,2 kW

7.2.1 Rated current (I):

$I = \frac{P}{V}$

$= \frac{1,2 \times 10^3}{220}$ ✓ ✓

$= 5,455\ A$ (2)

7.2.2 Resistance (R):

$R = \frac{V}{I}$

$= \frac{220}{5,455}$ ✓ ✓

$= 40,329\ \Omega$ (2)

7.2.3 $I = \frac{V}{R}$

$= \frac{200}{40,329}$ ✓ ✓

$= 4,959$ A (2)

7.2.4 1) T = 2 min ⟹ hours $\frac{2}{60}$

R 1,164 pk/Wh ⟹ $= 0,033$ h

P = 1,2 kW 1200 W ✓

Unit = kWh

$= \frac{1200 \times 0,033}{1000}$

$= 0,0396$ kWh ✓

Cost = unit x rate (cost)

$=0,0396 \times 164$ cents ✓

= R6,49 (3)

[13]

QUESTION 8: CHEMISTRY

8.1 8.1.1 Bright steel ✓

8.1.2 Steel ✓

8.1.3 Tungsten ✓ (3)

8.2 8.2.1 Corrosion resistant ✓

8.2.2 Easily machine-able ✓

8.2.3 Soft ✓ (3)

[6]

TOTAL: 100