



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

ENGINEERING SCIENCE N4

31 MARCH 2016

This marking guideline consists of 14 pages.

QUESTION 1

1.1 S (Horizontal) = 3 × S (vertical)

$$\frac{U^2 \sin 2\theta}{g} = \frac{3 U^2 \sin^2 \theta}{2g}$$

$$\frac{U^2 \sin 2\theta \times g}{g \times U^2} = \frac{3 U^2 \sin^2 \theta \times g}{g \times U^2} \quad \checkmark$$

$$\frac{3 \sin \theta \times \sin \theta \times 2}{2 \times \sin 2\theta \times 3} = \frac{\sin 2\theta \times 2}{\sin 2\theta \times 3} \quad \checkmark$$

But $\sin 2\theta = 2 \sin \theta \cos \theta$ (from compound angles)

$$\frac{\sin \theta \sin \theta}{2 \sin \theta \cos \theta} = \frac{2}{3} \quad \checkmark$$

$$\frac{\sin \theta}{\cos \theta} = \frac{2 \times 2}{3}$$

$$\tan \theta = \frac{4}{3} \quad \checkmark$$

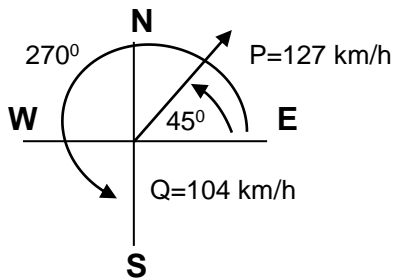
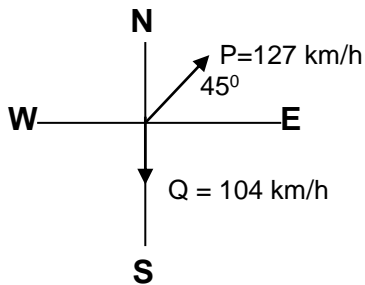
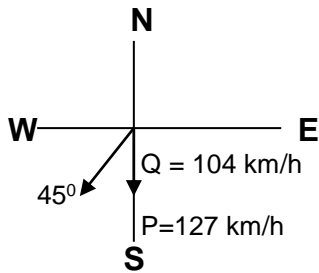
$$\theta = 53,13^\circ \quad \checkmark \quad (5)$$

OR

1.1	S (horizontal) = 270 Cos α(2)t	t(max. height): v = u + gt
	S (vertical) = 270sinαt + ½gt ²	0 = 270sinα – 9,8t
	S (horizontal) = 3 × S (vertical)	9,8t = 270sinα
	270 Cos α(2)t = 3(270 Sin αt + ½gt ²)	t = 27,55sinα
	270 Cosα(2) = 3(270sinα + ½gt)	
	540 Cos α = 810 Sin α – 14,7t	
	540 Cos α = 810 Sin α – 14,7(27,55 Sin α)	
	540 Cos α = 810 Sin α – 404,985 Sin α	
	540 Cos α = 405,015 Sin α	
	540/405,015 = Sin α/Cos α	
	540/405,015 = Tan α	
	α = 53,129°	

(5)

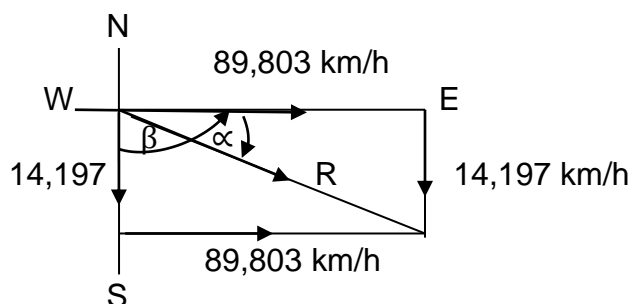
1.2 Given:
Stop relative velocity and change its direction



$$\begin{aligned} \text{The sum of the vertical} &= 127 \sin 45^\circ + 104 \sin 270^\circ \\ &= -14,147 \text{ km/h} \quad \checkmark \end{aligned}$$

$$\begin{aligned} \text{The sum of the horizontal} &= 127 \sin 45^\circ + 104 \sin 270^\circ \\ &= 89,803 \text{ km/h} \quad \checkmark \end{aligned}$$

$$\begin{aligned} \text{Resultant velocity} &= (-14,147^2 + 89,803^2)^{0,5} \\ &= 90,918 \text{ km/h} \quad \checkmark \end{aligned}$$



$$\theta = \tan^{-1} \frac{14,147}{89,803}$$

$$\theta = 8,984^\circ$$

✓

Relative velocity of Q to P = 90,918km/h E 8,984° S

or

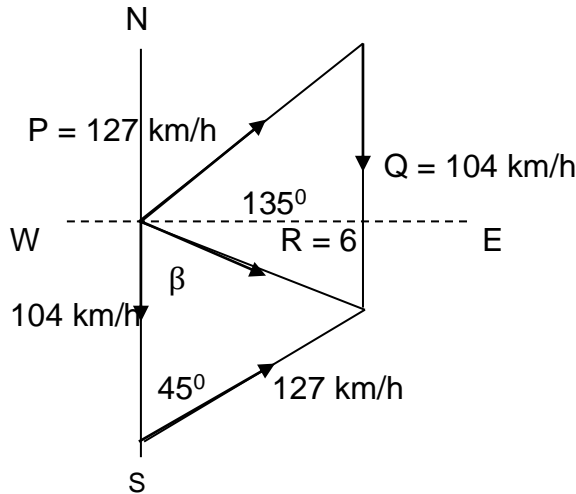
Relative velocity of Q to P = 90,918km/h S 81,016° E

✓

(5)

OR

1.2



$$R = b = (a^2 + c^2 - 2ac \cos B)^{0,5}$$

$$= (104^2 + 127^2 - 2 \times 104 \times 127 \cos 45^\circ)^{0,5}$$

$$= 90,918 \text{ km/h}$$

✓

✓

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$\frac{\sin \beta}{127} = \frac{\sin 45^\circ}{90,918}$$

$$\sin \beta = 0,988$$

$$B = \sin^{-1} 0,988$$

$$= 81,016^\circ$$

✓

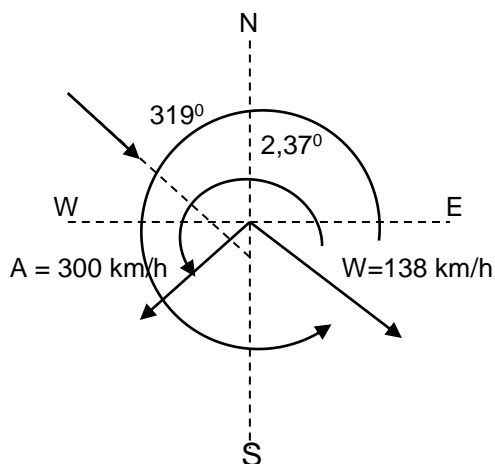
✓

Relative velocity of Q to P = 90,918 km/h S 81,016° E

✓

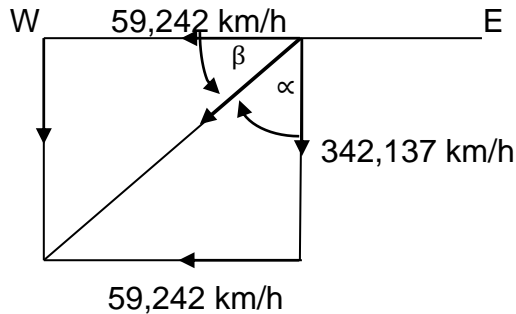
(5)

1.3



The sum of the vertical = $300 \sin 237^\circ + 138 \sin 319^\circ$
 $= -342,137 \text{ km/h}$ ✓

The sum of the horizontal = $300 \sin 237^\circ + 138 \sin 319^\circ$
 $= -59,242 \text{ km/h}$ ✓



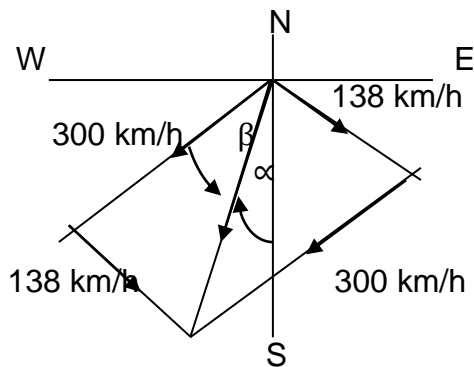
Resultant velocity = $(342,137^2 + 59,242^2)^{0,5}$
 $= 347,228 \text{ km/h}$ ✓

$\tan \beta = \frac{342,127}{59,242}$ ✓
 $B = 80,177^\circ$ ✓

Resultant velocity = $347,228 \text{ km/h W } 80,177^\circ \text{ S}$ ✓ (5)

OR

1.3



$R = b = (a^2 + c^2 - 2ac \cos B)^{0,5}$ ✓
 $= (138^2 + 300^2 - 2 \times 138 \times 300 \cos 98^\circ)^{0,5}$ ✓
 $= 347,228 \text{ km/h}$

$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$
 $\frac{\sin \beta}{138} = \frac{\sin 98}{347,22}$ ✓

$B = 23,204^\circ$ ✓

$\alpha = 33^\circ - 23,204^\circ$
 $= 9,8^\circ$

Resultant = $347,228 \text{ km/h S } 9,8^\circ \text{ W}$ ✓ (5)

[15]

QUESTION 2

2.1 $m = \text{mass} = 1\,000 \text{ kg}$
 $r = \text{radius} = 37 \text{ m}$
 $v = 120 \text{ km/h}$
 $v = \frac{120}{3,6}$
 $= 33,333 \text{ m/s}$

2.1.1 $\omega = \frac{v}{R}$ ✓
 $= \frac{33,333}{37}$ ✓
 $= 0,901 \text{ rad/s}$ ✓

(3)

2.1.2 $\theta = \frac{s}{R}$
 $= \frac{47}{37}$ ✓
 $= 1,27 \text{ radians}$ ✓

(2)

2.2 $T = \text{torque} = 750 \text{ Nm}$
 $P = \text{power} = 75 \text{ kW}$

$P = 2\pi NT \dots\dots\dots(N)$
 $N = \frac{P}{2\pi T}$ ✓
 $= \frac{75\,000}{2 \times \pi \times 750}$ ✓✓
 $= 15,916 \text{ rev/s}$ ✓

(4)

[9]**QUESTION 3**

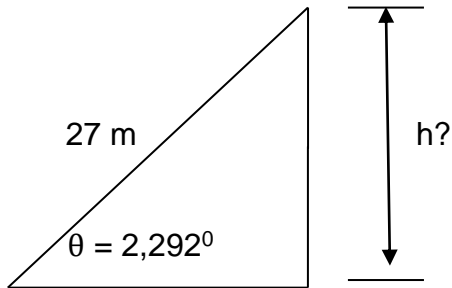
3.1 $U = \text{initial velocity} = 90 \text{ km/h}$
 $= 25 \text{ m/s}$

$V = \text{final velocity} = 0 \text{ m/s}$ ✓

$S = \text{distance moved} = 27 \text{ m}$ ✓

$\text{Slope} = \text{Sin}^{-1} (1/25) = 2,292^\circ$

$$\begin{aligned} \text{Kinetic energy horizontal} &= \frac{1}{2} mv^2 \\ &= \frac{1}{2} \times m \times 25^2 \\ &= 312,5 \text{ mass} \end{aligned}$$



$$\begin{aligned} h = \text{height} &= 27 \sin 2,292^\circ \\ &= 1,08 \text{ m} \end{aligned}$$

Total energy at the top = Potential energy

$$\begin{aligned} E = (\text{Potential}) &= mgh \\ &= m \times 9,8 \times 1,08 \quad \checkmark\checkmark \\ &= 10,584 \text{ mass} \end{aligned}$$

$$\begin{aligned} \text{Kinetic energy when descending} &= \frac{1}{2} mv^2 \\ &= 0,5 mv^2 \quad \checkmark \end{aligned}$$

The total energy absorbed by the brakes is always kept constant.

Kinetic energy horizontal = Potential energy at the top + Kinetic energy when descending

$$312,5 \text{ mass} = 10,582 \text{ mass} + 0,5 \text{ mass} \cdot v^2 \quad \checkmark$$

$$\frac{312,5 \text{ mass}}{\text{mass}} = \frac{10,582 \text{ mass}}{\text{mass}} + \frac{0,5 \text{ mass} \cdot v^2}{\text{mass}}$$

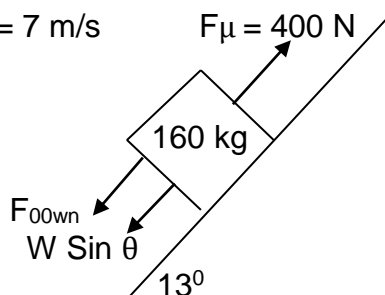
$$0,5 v^2 = 312,5 - 10,582$$

$$v^2 = \frac{312,5 - 10,582}{0,5}$$

$$v = 24,573 \text{ m/s} \quad \checkmark$$

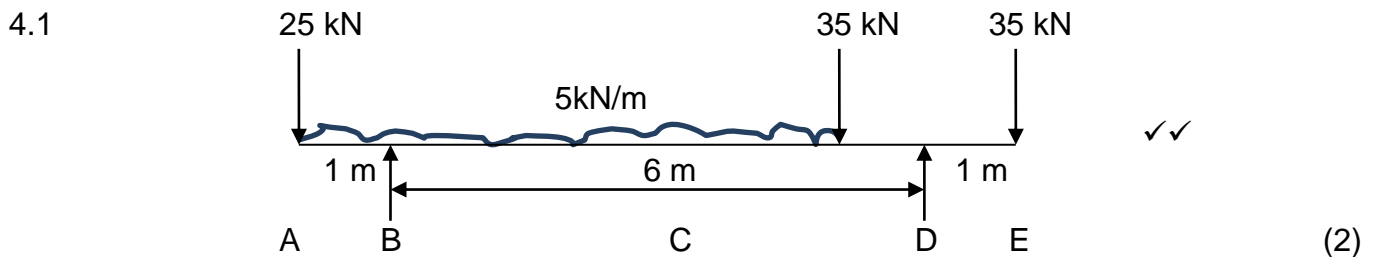
(7)

3.2 $V = 7 \text{ m/s}$



$$\begin{aligned}
 F \text{ (Total)} &= \text{Frictional force} - W \sin \theta \\
 &= 400 - 160 \times 9,8 \times \sin 13^\circ \quad \checkmark \\
 &= 47,277 \text{ N} \quad \checkmark
 \end{aligned}$$

$$\begin{aligned}
 P &= \text{Power} = \text{force total} \times \text{velocity} \quad \checkmark \\
 &= 47,277 \times 7 \quad \checkmark \\
 &= 330,939 \text{ W} \quad \checkmark
 \end{aligned}$$

(5)
[12]**QUESTION 4**

4.2 Moments about D

$$\begin{aligned}
 \text{Clockwise moments} &- \text{Anti-clockwise moments} \\
 (B \times 6) + (35 \times 1) &= (35 \times 1) + (25 \times 7) + (30 \times 4) \\
 B &= 49,167 \text{ kN} \quad \checkmark\checkmark
 \end{aligned}$$

$$\begin{aligned}
 2. \quad \text{The sum of forces facing up} &= \text{The sum of forces facing down} \\
 B + D &= 35 + 35 + 25 + 30 \quad \checkmark \\
 49,167 + D &= 125 \\
 D &= 75,833 \text{ kN} \quad (3)
 \end{aligned}$$

OR

2. Moments about B

$$\begin{aligned}
 \text{Anti-clockwise moments} &= \text{Clockwise moments} \\
 (D \times 6) + (25 \times 1) &= (30 \times 2) + (35 \times 5) + (35 \times 7) \quad \checkmark \\
 D &= 75,833 \text{ kN} \quad (3)
 \end{aligned}$$

4.3 1. Bending moment at B (from left hand side)

$$\begin{aligned}
 &= (-25 \times 1) + (-5 \times 1 \times 0,5) \\
 &= -27,5 \text{ kNm} \quad \checkmark
 \end{aligned}$$

OR

1. Bending moment at B (from right hand side)

$$\begin{aligned}
 &= (-5 \times 5 \times 2,5) + (-35 \times 5) + (75,833 \times 6) + (-35 \times 7) \\
 &= -27,5 \text{ kNm} \quad \checkmark
 \end{aligned}$$

2. Bending moment at C (from the left hand side)
 $= (-25 \times 6) + (49,167 \times 5) + (-5 \times 6 \times 3)$ ✓
 $= 5,835 \text{ kNm}$

OR

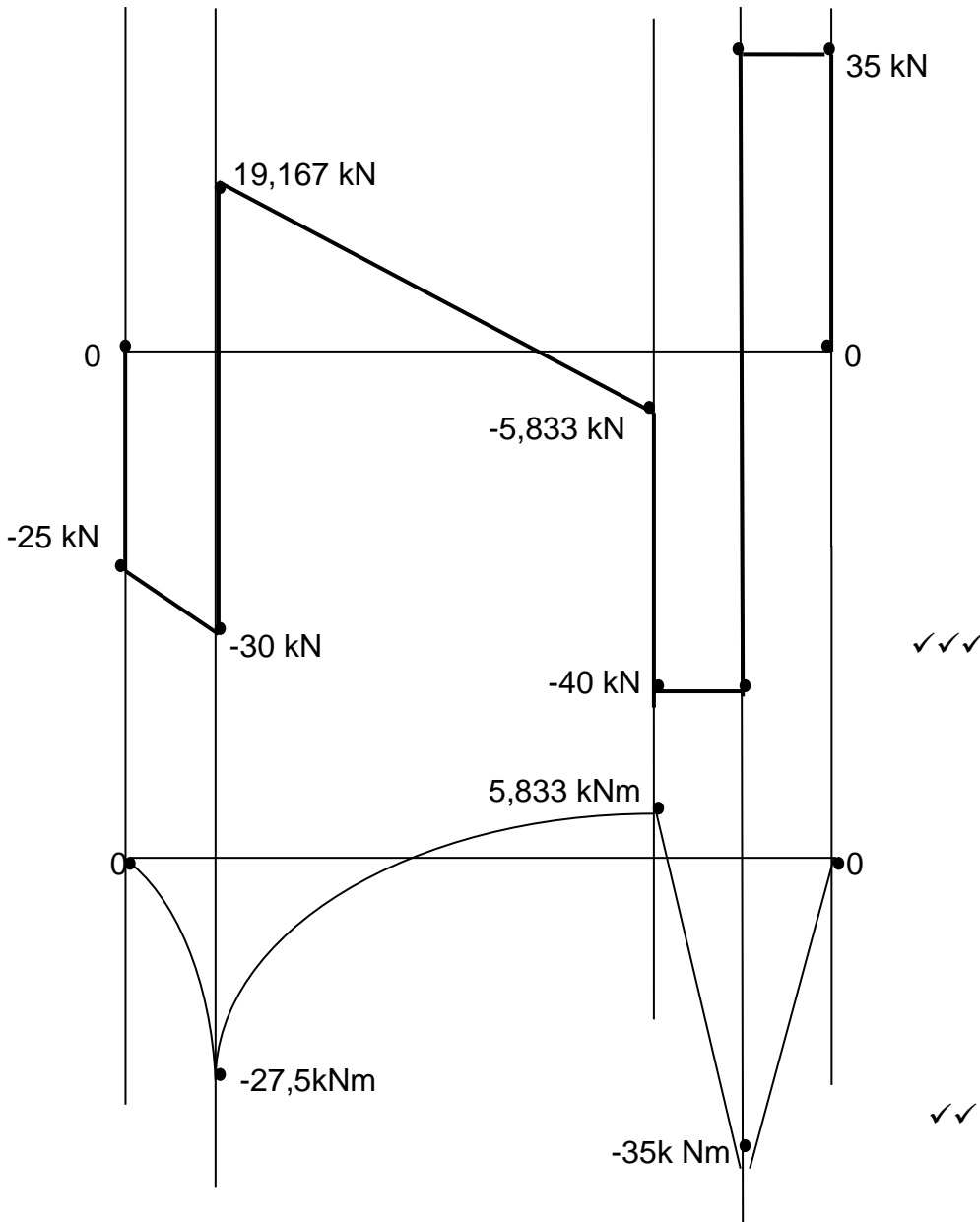
2. Bending moment at B (from the right hand side)
 $= (-35 \times 2) + (75,8335 \times 1)$ ✓
 $= 5, 833 \text{ kNm}$

3. Bending moment at D (from the left hand side)
 $= (-35 \times 1) + (-5 \times 6 \times 4) + (49,167 \times 6) + (-25 \times 7)$ ✓
 $= -35 \text{ kNm}$ (3)

OR

3. Bending moment at D (from right hand side)
 $= -35 \times 1$ ✓
 $= -35 \text{ kNm}$ (3)

4.4



(5)

4.5 Maximum bending moment = 35 kNm (sagging) ✓✓

or

Maximum bending moment = -35 kNm

Position = 1 m from the right-hand side or at point D

or

Position = 7 m from left hand-side or at point D

(2)
[15]

QUESTION 5

5.1 The function of a hydraulic accumulator is to accumulate hydraulic energy and to store hydraulic energy until it is needed. (2)

- 5.2
- Mass-loaded/weight-loaded accumulator
 - Spring-loaded accumulator
 - Air/gas type accumulator
- (Any 2 × ½) (1)

5.3
 $d = 12,5\% D$
 $= 0,125 D$
 $l = h = 100 \text{ mm} = 0,1\text{m}$
 $M.A. = 25$
 $\text{Slip} = 15\% = 0,15$
 $\text{Efficiency} = 85\% = 0,85$

5.3.1 $M = 6 \text{ tons} = 6\,000\text{kg}$ ✓

$$\frac{F}{d^2} = \frac{W}{D^2} \dots \dots \dots (F) \quad \checkmark$$

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

$$= \frac{6\,000 \times 9,8 \times 0,125D \times 0,125D}{D \times D} \quad \checkmark$$

$$= 918,75\text{N} \quad \checkmark \quad (2\frac{1}{2})$$

$$M.A. = \frac{F}{\text{Effort}} \dots \dots \dots (\text{effort}) \quad \checkmark$$

$$\text{Effort} = \frac{F}{M.A.}$$

$$= \frac{918,75}{25} \quad \checkmark$$

$$= 36,75\text{N} \quad \checkmark$$

$$85\% = 36,75 \quad \checkmark$$

$$100\% = X \quad \checkmark$$

$$X = \frac{100\% \times 36,75}{85\%} \quad \checkmark$$

$$= 43,235 \text{ N} \quad \checkmark \quad (3\frac{1}{2})$$

5.3.2 $n = \frac{\text{volume displaced by the ram}}{\text{volume displaced by plunger}}$

$$n = \frac{D^2 H}{d^2 h}$$

$$= \frac{D \times D \times 400}{0,125D \times 0,125D \times 100} \quad \checkmark \checkmark$$

$$= 256 \quad \checkmark \quad (3)$$

5.4 Force = F = 43 kN
Diameter = d = 22 cm = 220 mm = 0,22 m
Work done = W.D. = 15 kJ

5.4.1 W.D = F x s(s)

$$S = \frac{W.D.}{F}$$

$$= \frac{15\ 000}{43\ 000} \quad \checkmark$$

$$= 0,349m \quad \checkmark \quad (2)$$

5.4.2 Pressure = P = $\frac{FORCE}{AREA}$

$$= \frac{43\ 000 \times 4}{\pi \times 0,22 \times 0,22} \quad \checkmark$$

$$= 1\ 131,184\ kPa \quad \checkmark \quad (2)$$

5.4.3 W.D. = Pressure x Volume(Volume)
 Volume = V = $\frac{Work\ done}{Pressure}$

$$= \frac{15}{1\ 131,184} \quad \checkmark$$

$$= 0,0133m^3 \quad \checkmark$$

 Volume/second = volume x N/60

$$= 0,088403\ m^3/s \quad \checkmark$$

 But 1 000 litres of pure water = 1 m³
 Volume in l/s = 88,403 l/s $\checkmark \quad (4)$
[20]

QUESTION 6

6.1 $\beta : \gamma = 2 : 3$ or $1 : 1,5 \quad \checkmark\checkmark \quad (2)$

	Mercury	Flask/glass
Volume (original)	400 mm ³	400 mm ³
Temperature (original)	16 °C	16 °C
Temperature (final)	51 °C	51 °C
	$7 \times 10^{-5}/^{\circ}C$	$10 \times 10^{-6}/^{\circ}C$

6.2.1 Change in volume of mercury = V (original) x 3 α (t₂ – t₁)

$$= 400 \times 3 \times 7 \times 10^{-5} (51 - 16) \quad \checkmark$$

$$= 2,94\ mm^3 \quad \checkmark \quad (2)$$

6.2.2 Change in volume of flask = $400 \times 3 \times 10 \times 10^{-6}(51 - 16) \quad \checkmark$

$$= 0,42\ mm^3 \quad \checkmark$$

Overflow = Change in volume of mercury - Change in volume of flask

$$= 2,94 - 0,42 \quad \checkmark$$

$$= 2,52mm^3 \quad \checkmark \quad (4)$$

6.3 $T = 5\text{ }^{\circ}\text{C} = 5 + 273 = 278\text{ }^{\circ}\text{K}$ ✓
 $P_1 = P_2 = 185\text{ kPa}$
 $V_1\text{ (original)} = 0,26\text{m}^3$

6.3.1 $T_2 = -28 + 273 = 245\text{ }^{\circ}\text{K}$ ✓ (1)

OR

6.3.1 $T_2 = 250 - 273 = -23\text{ }^{\circ}\text{C}$ ✓ (1)

6.3.2 $\frac{V_2}{T_2} = \frac{V_1}{T_1} \dots\dots\dots(V_2)$
 $V_2 = \frac{T_1 \times V_1}{T_2}$
 $= \frac{278 \times 0,26}{245}$ ✓✓
 $= 0,294\text{ m}^3$ ✓ (3)

6.3.3 $P_1 V_1 = m RT_1 \dots\dots\dots(m)$
 $m = \frac{P_1 V_1}{RT_1}$
 $= \frac{185 \times 0,26}{0,288 \times 278}$ ✓✓
 $= 0,601\text{ kg}$ ✓ (3)

OR

6.3.3 $P_2 V_2 = m RT_2 \dots\dots\dots(m)$
 $m = \frac{P_2 V_2}{RT_2}$
 $= \frac{185 \times 0,234}{0,288 \times 250}$ ✓✓
 $= 0,601\text{kg}$ ✓ (3)

[15]

QUESTION 7

7.1 For an elastic object the strain is (directly) proportional to the stress producing it. ✓✓

OR

For an elastic object the extension is (directly) proportional to the load producing it. (2)

- 7.2 D = 3,2 d
L (original) = 720 mm = 0,72 m
F = 312 kN
X = 0,138 mm (0,138 x 10⁻³ m)
E = 200 GPa

$$E = \frac{F \times L}{A \times X} \dots \dots \dots (A)$$

$$A = \frac{F \times L}{E \times X}$$

$$= \frac{312\,000 \times 0,72}{200 \times 10^9 \times 0,138 \times 10^{-3}} \quad \checkmark \checkmark$$

$$= 8,138 \times 10^{-3} \text{ m}^2$$

Area of a pipe (A) = $\frac{\pi(D^2 - d^2)}{4}$

$$= \frac{\pi [(3,2d)^2 - (d^2)]}{4} \quad \checkmark$$

$$\frac{4(8,139 \times 10^{-3})}{\pi} = 9,24 d^2 \quad \checkmark$$

$$d^2 = 1,122 \times 10^{-3} \quad \checkmark$$

$$d = 0,033 \text{ m} \quad \checkmark$$

$$D = 3,2d$$

$$D = 0,106 \text{ m} \quad \checkmark$$

(7)

- 7.3 F = 10 kN
S = 194 mm (0,194 m)
L₁ (Original) = 5 m (5 000 mm)
X = 0,231 mm

7.3.1 Stress = force/area

$$= 10\,000 / 0,194 \times 0,194 \quad \checkmark$$

$$= 265,703 \text{ kPa} \quad \checkmark$$

(2)

7.3.2 Strain = x/l

$$= 0,231 / 5\,000 \quad \checkmark$$

$$= 4,62 \times 10^{-5} \quad \checkmark$$

(2)

7.3.3 E = 265 703 / 4,62 x 10⁻⁵

$$= 5,751 \text{ GPa} \quad \checkmark$$

(1)

[14]

TOTAL: 100