



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

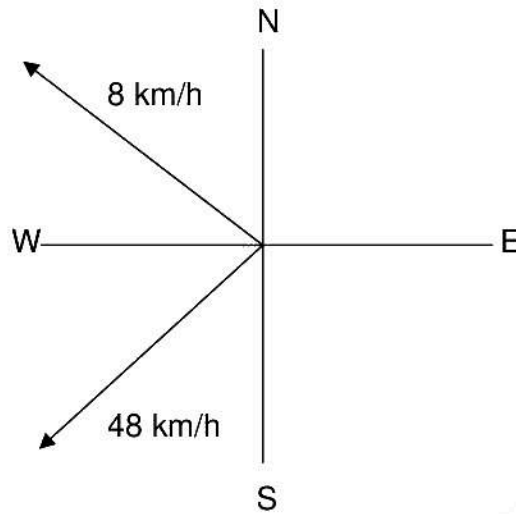
ENGINEERING SCIENCE N4

25 November 2024

This marking guideline consists of 13 pages.

QUESTION 1: KINEMATICS

1.1



$$\begin{aligned} 1.1.1 \quad \sum VC &= 8 \sin 154^\circ + 48 \sin 225^\circ \\ &= -30,434 \text{ km/h} \\ &= 30,434 \text{ km/h South} \checkmark \end{aligned}$$

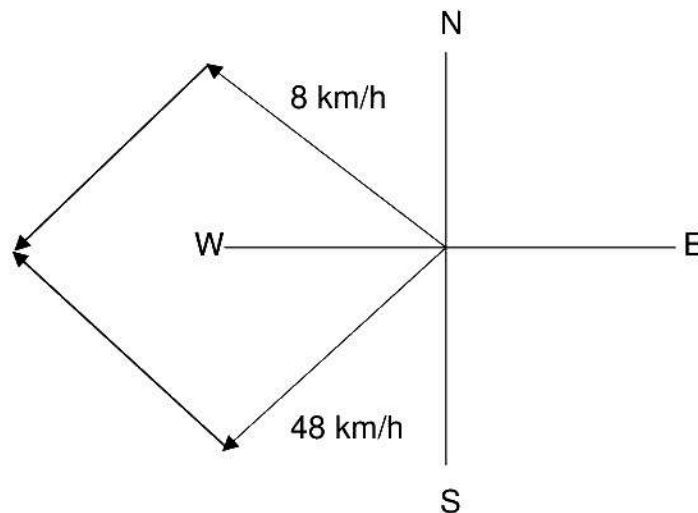
$$\begin{aligned} \sum HC &= 8 \cos 154^\circ + 48 \cos 225^\circ \\ &= -41,132 \text{ km/h} \\ &= 41,132 \text{ km/h West} \checkmark \end{aligned}$$

$$\begin{aligned} R &= \sqrt{30,434^2 + 41,132^2} \\ &= 51,167 \text{ km/h} \checkmark \end{aligned}$$

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{30,434}{41,132}\right) \\ &= 36,498^\circ \checkmark \end{aligned}$$

$$\begin{aligned} \therefore R &= 51,167 \text{ km/h, W } 36,498^\circ \text{ S} \\ \text{OR} \\ R &= 51,167 \text{ km/h, S } 53,501^\circ \text{ W} \checkmark \end{aligned}$$

ALTERNATIVE



$$\begin{aligned}
 R &= b = \sqrt{a^2 + c^2 - 2ac \cos B} \\
 &= \sqrt{48^2 + 8^2 - 2(8)(48) \cos(109)} \\
 &= 51,167 \text{ km/h} \checkmark
 \end{aligned}$$

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

$$\begin{aligned}
 \sin A &= \frac{a \sin B}{b} \\
 \sin A &= \frac{8 \sin 109}{51,167} \\
 &= 0,148 \checkmark
 \end{aligned}$$

$$A = 8,501^\circ \checkmark$$

$$\theta = \text{actual angle} = 45^\circ + 8,501^\circ = 53,501^\circ \checkmark$$

$$\therefore R = 51,167 \text{ km/h, W } 36,498^\circ \text{ S}$$

OR

$$R = 51,167 \text{ km/h, S } 53,501^\circ \text{ W} \checkmark$$

(5)

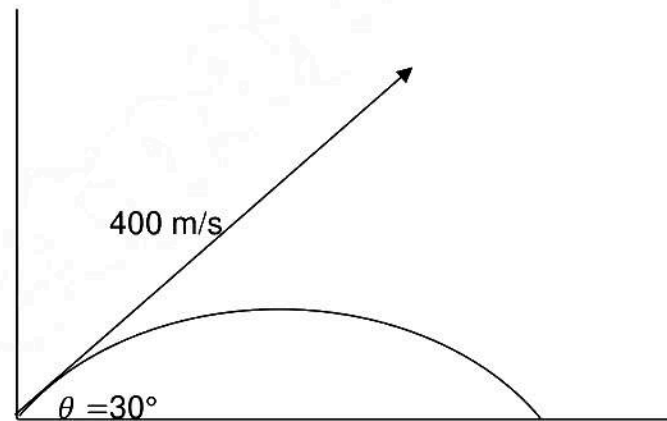
1.1.2

$$\begin{aligned}
 S &= Vt \\
 &= 51,167 \times 5 \\
 &= 255,835 \text{ km} \checkmark
 \end{aligned}$$

(1)

1.2

$$\begin{aligned}
 \theta &= 30^\circ \\
 V &= 400 \text{ m/s}
 \end{aligned}$$



1.2.1

$$\begin{aligned}
 S_{\text{vertical}} &= \frac{u^2 \sin^2 \theta}{2g} \\
 &= \frac{(400 \sin 30^\circ)^2}{2 \times 9,8} \checkmark \\
 &= 2040,816 \text{ m} \\
 &= 2,041 \text{ km} \checkmark
 \end{aligned}$$

ALTERNATIVE

$$\begin{aligned}
 S &= \frac{v^2 - u^2}{2g} \\
 &= \frac{0^2 - (400 \sin 30^\circ)^2}{2 \times 9,8} \checkmark \\
 &= 2040,816 \text{ m} \\
 &= 2,041 \text{ km} \checkmark
 \end{aligned}$$

1.2.2

$$\begin{aligned}
 S_{vertical} &= \frac{u^2 \sin 2\theta}{g} \\
 &= \frac{400^2 \sin(2 \times 30^\circ)}{9,8} \checkmark \\
 &= 14139,190 \text{ m} \\
 &= 14,139 \text{ km} \checkmark
 \end{aligned}$$

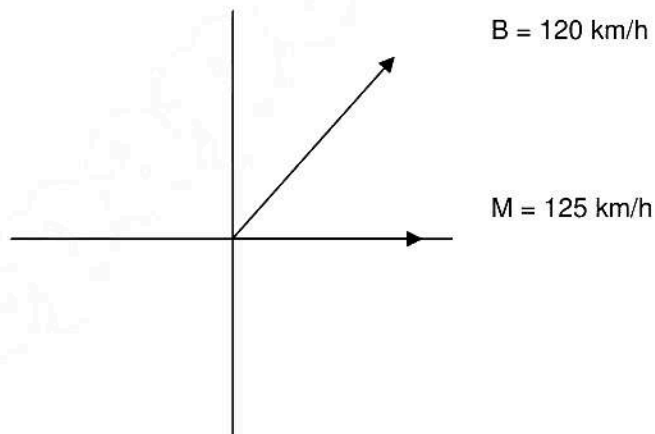
ALTERNATIVE

$$\begin{aligned}
 S_{horizontal} &= V_{horizontal} \times t, \quad \text{but } t = 2 \times t_{\max h} \\
 t_{\max h} &= \frac{u \sin \theta}{g} \\
 &= \frac{400 \sin 30^\circ}{9,8} \\
 &= 20,408 \text{ sec} \checkmark \\
 S_{horizontal} &= 400 \cos 30^\circ \times 2 \times (20,408) \\
 &= 14139,077 \text{ m} \\
 &= 14,139 \text{ km} \checkmark
 \end{aligned}$$

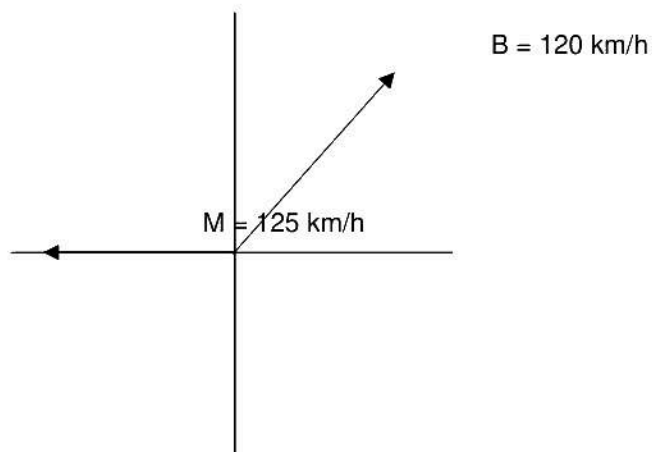
(2 × 2) (4)

1.3

$$\begin{aligned}
 V_B &= 120 \text{ km/h} \\
 V_M &= 125 \text{ km/h}
 \end{aligned}$$



Stop M and change its direction



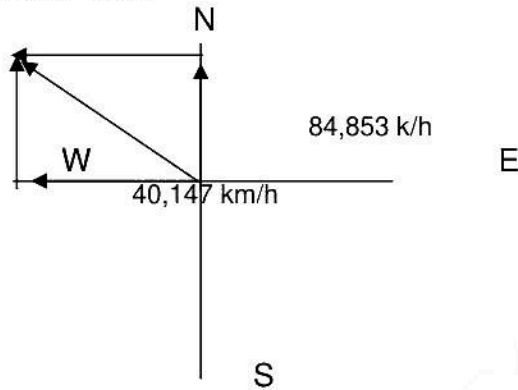
$$\sum VC = 120 \sin 45^\circ + 125 \sin 180^\circ$$

$$= 84,853 \text{ km/h, north} \checkmark$$

$$\sum HC = 120 \cos 45^\circ + 125 \cos 180^\circ$$

$$= -40,147 \text{ km/h}$$

$$= 40,147 \text{ km/h, West} \checkmark$$



$$R = \sqrt{84,853^2 + 40,147^2}$$

$$= 93,871 \text{ km/h} \checkmark$$

$$\theta = \tan^{-1}\left(\frac{84,871}{40,147}\right)$$

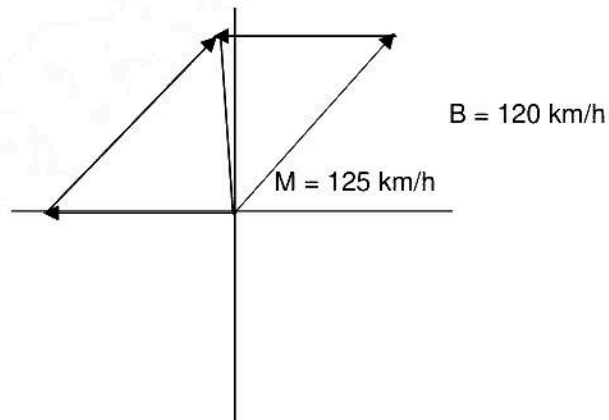
$$= 64,68^\circ \checkmark$$

$\therefore$ Velocity of M relative the velocity of B = 90,871 km/h, E64,68°S

OR

90,871 km/h, S 25,32° E ✓

ALTERNATIVE



$$R = \sqrt{120^2 + 125^2 - 2(120)(125) \cos(45^\circ)} \checkmark$$

$$= 93,871 \text{ km/h} \checkmark$$

$$\frac{\sin \theta}{120} = \frac{\sin 45^\circ}{93,871}$$

$$\theta = \sin^{-1}(0,904) \checkmark$$

$$= 64,68^\circ \checkmark$$

$\therefore$ Velocity of M relative the velocity of B = 90,871 km/h, E64,68°S

OR

90,871 km/h, S 25,32° E ✓

(5)

QUESTION 2: ANGULAR MOTION

- 2.1 D
2.2 B
2.3 A
2.4 C

(4 × 2) [8]

QUESTION 3: DYNAMICS

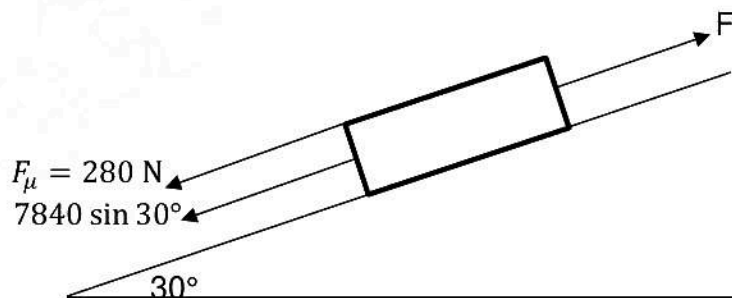
- 3.1 $u = 30 \text{ km/h} = 22,222 \text{ m/s}$
 $V = 0 \text{ m/s}$
 $S = 40 \text{ m}$
 $m = 1000 \text{ kg}$

$$\begin{aligned} 3.1.1 \quad v^2 &= u^2 + 2aS \\ a &= \frac{v^2 - u^2}{2S} \checkmark \\ &= \frac{0^2 - 22,222^2}{2 \times 40} \\ &= -6,173 \text{ m/s}^2 \checkmark \end{aligned}$$

$$\begin{aligned} 3.1.2 \quad F &= ma \\ &= 1000 \times 6,173 \checkmark \\ &= -6173 \text{ N} \\ &= 6,173 \text{ kN} \checkmark (\text{Opposite direction}) \end{aligned}$$

(2 × 2) (4)

- 3.2 $V = 100 \text{ km/h} = 27,778 \text{ m/s}$
 $U = 0 \text{ m/s}$
 $M = 800 \text{ kg}$
 $t = 8 \text{ s}$



$$\begin{aligned} 3.2.1 \quad V &= u + at \\ 27,778 &= 0 + a(8) \\ a &= \frac{27,778}{8} \\ &= 3,472 \text{ m/s}^2 \checkmark \end{aligned}$$

$$\begin{aligned} S &= ut + \frac{1}{2}at^2 \\ &= 0(8) + 0,5(3,472)(8)^2 \\ &= 111,104 \text{ m} \checkmark \end{aligned}$$

$$\begin{aligned} W &= F \times s \\ &= 280 \times 111,104 \\ &= 31,109,120 \text{ J} \checkmark \end{aligned}$$

$$\begin{aligned} 3.2.2 \quad W &= (mg \sin \theta) \times s \\ &= [800 \times 9,8 \sin(30^\circ)] \times 111,104 \checkmark \\ &= 435527,68 \text{ J} \checkmark \\ &= 435,528 \text{ kJ} \end{aligned} \quad (2)$$

$$\begin{aligned} 3.2.3 \quad F_a &= ma \\ &= 800 \times 3,472 \\ &= 2777,6 \text{ N} \checkmark \\ &= 2,778 \text{ kN} \\ \\ W &= F \times s \\ &= 2777,6 \times 111,104 \checkmark \\ &= 308602,4704 \text{ J} \\ &= 308,603 \text{ kJ} \checkmark \end{aligned} \quad (3)$$

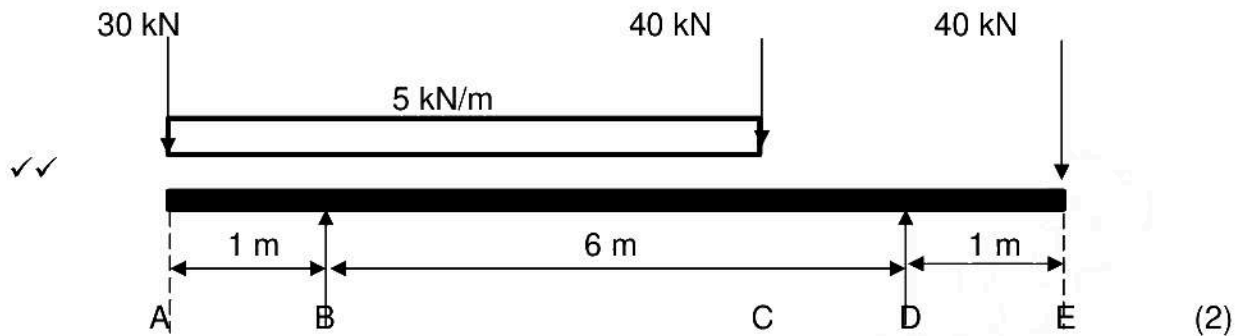
$$\begin{aligned} 3.2.4 \quad F_{\text{up}} - F_{\text{down}} &= ma \\ F - 280 - 800 \times 9,8 \times \sin(30^\circ) &= 800 \times 3,472 \checkmark \\ F &= 2777,6 + 3920 + 280 \checkmark \\ &= 6977,6 \text{ N} \\ &= 6,977 \text{ kN} \checkmark \end{aligned} \quad (3)$$

$$\begin{aligned} 3.2.5 \quad P &= \frac{W}{t} \\ &= \frac{6977,6 \times 3,472}{8} \checkmark \\ &= 96904,9088 \text{ W} \checkmark \\ &= 96,905 \text{ kW} \end{aligned} \quad (2)$$

[17]

QUESTION 4: STATICS

4.1 4.1.1



4.1.2

Taking moments about D

$$\begin{aligned} \sum \text{clockwise moments} &= \sum \text{anticlockwise moments} \\ (40 \times 1) + (B \times 6) &= (40 \times 1) + (30 \times 7) + (30 \times 4) \checkmark \\ B &= 55 \text{ kN} \checkmark \end{aligned}$$

Taking moments about B

$$\begin{aligned} \sum \text{clockwise moments} &= \sum \text{anticlockwise moments} \\ (40 \times 7) + (40 \times 5) + (30 \times 2) &= (30 \times 1) + (D \times 6) \checkmark \\ D &= 85 \text{ kN} \checkmark \end{aligned}$$

OR

$$\begin{aligned} \sum \text{Upward Forces} &= \sum \text{Downward Forces} \\ B + D &= 40 + 40 + 30 + 30 \checkmark \\ 55 + D &= 125 \\ D &= 85 \text{ kN} \checkmark \end{aligned}$$

(4)

4.1.3

BM at A (from the left)

$$\begin{aligned} &= (-30 \times 1) + (-5 \times 1 \times 0,5) \\ &= -32,5 \text{ kNm} \checkmark \end{aligned}$$

OR

BM at B (from the right)

$$\begin{aligned} &= (-5 \times 5 \times 2,5) + (-40 \times 5) + (85 \times 6) + (-40 \times 7) \\ &= -32,5 \text{ kNm} \checkmark \end{aligned}$$

BM at C (from the left)

$$\begin{aligned} &= (-30 \times 6) + (55 \times 5) + (-5 \times 6 \times 3) \\ &= 5 \text{ kNm} \checkmark \end{aligned}$$

OR

BM at C (from the right)

$$\begin{aligned} &= (-40 \times 2) + (85 \times 1) \\ &= 5 \text{ kNm} \checkmark \end{aligned}$$

BM at D (from the left)

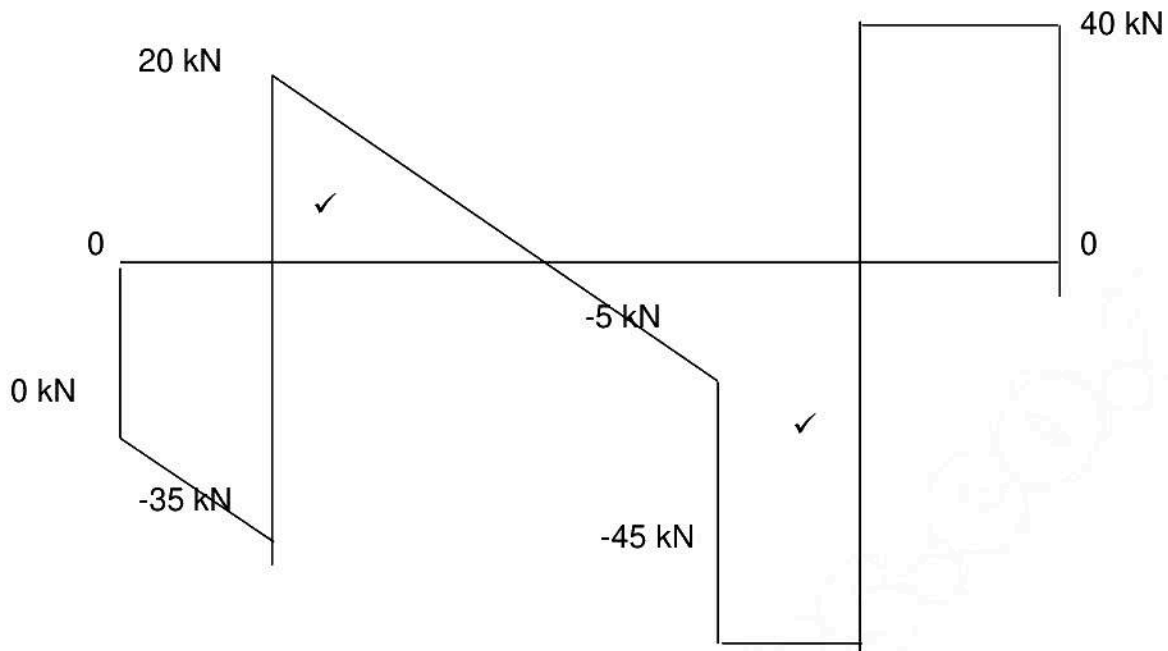
$$\begin{aligned} &= (-40 \times 1) + (-5 \times 6 \times 4) + (-30 \times 7) + (55 \times 6) \\ &= -40 \text{ kNm} \checkmark \end{aligned}$$

OR

BM at D (from the right)

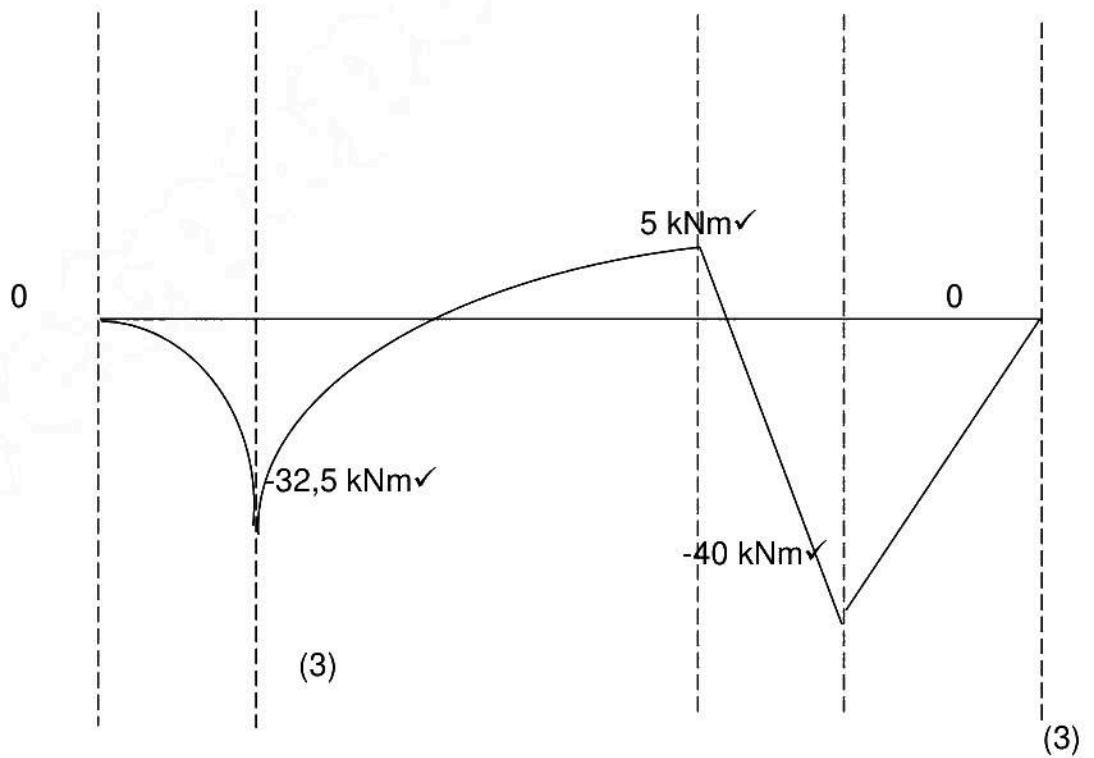
$$\begin{aligned} &= (-40 \times 1) \\ &= -40 \text{ kNm} \checkmark \end{aligned}$$

4.1.4



(2)

4.1.5



(3)

(3)

4.1.6 Maximum bending moment = 40 kNm (sagging)

Or

Maximum bending moment = -40 kNm

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

Or

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

(2)
[16]

QUESTION 5: HYDRAULICS

5.1 $w = mg = 4,6 \times 10^3 \times 9,8$
 $= 45080 \text{ N}$
 $D = 450 \text{ mm} = 0,45 \text{ m}$
 $D = 100 \text{ mm} = 0,1 \text{ m}$
 $SL = 120 \text{ mm} = 0,12 \text{ m}$
 $MA = 20$

$$\begin{aligned} 5.1.1 \quad \frac{w}{F} &= \frac{D^2}{d^2} \\ F &= \frac{d^2 \times w}{D^2} \\ F &= \frac{0,1^2 \times 45080}{0,45^2} \checkmark \\ &= 2226,173 \text{ N} \checkmark \end{aligned}$$

$$\begin{aligned} MA &= \frac{L}{E} \\ E &= \frac{L}{MA} \\ E &= \frac{2226,173}{20} \\ &= 111,309 \text{ N} \checkmark \end{aligned}$$

$$\begin{aligned} \text{For 90\% efficiency } E &= 111,309 \times \frac{100}{90} \checkmark \\ &= 123,677 \text{ N} \checkmark \end{aligned}$$

(5)

$$\begin{aligned} 5.1.2 \quad V_R &= V_P \\ A_R \times H &= A_P \times SL \times n \checkmark \\ \frac{\pi \times 0,45^2}{4} \times H \checkmark &= \frac{\pi \times 0,1^2}{4} \times 0,12 \times 160 \checkmark \\ H &= 0,948 \text{ m} \checkmark \end{aligned}$$

(4)

5.2 $N = 250 \text{ r/min}$
 $d = 85 \text{ mm} = 0,085 \text{ m}$
 $SL = 590 \text{ mm} = 0,59 \text{ m}$
 $C = 3$
 $\text{Slip} = 1,7\%$
 $\text{Efficiency} = 100 - \text{Slip}\% = 100 - 1,7 = 98,3\%$
 $V_a = \text{actual volume in l/s}$
$$V_p = A \times SL \times C \times \frac{N}{60}$$
$$= \frac{\pi \times 0,085^2}{4} \times 0,590 \times 3 \times \frac{250}{60}$$
$$= 0,041849 \text{ m}^3 \checkmark$$
$$V_a = V_p \times \frac{\eta}{100}$$
$$= 0,041849 \times \frac{98,3}{100} \checkmark$$
$$= 0,041137567 \text{ m}^3/\text{s} \times (1000 \text{ l/s})$$
$$= 41,138 \text{ l/s} \checkmark$$

(3)

5.3 m
 $V_a = 320 \text{ l/min}$
 $\eta = 80\%$

$$P = \rho \times g \times h$$
$$= 1000 \times 9,8 \times 70$$
$$= 686000 \text{ Pa}$$
$$= 686 \text{ kPa} \checkmark$$
$$V_a = 320000 \times \frac{1}{60}$$
$$= 5333,333 \text{ m}^3/\text{s}$$
$$P_{out} = (686000)(5333,333)$$
$$= 3658666438 \text{ W} \checkmark$$
$$\eta = \frac{P_{out}}{P_{in}} \times 100$$
$$P_{in} = \frac{P_{out}}{\eta} \times 100$$
$$= \frac{3658666,438}{80} \times 100$$
$$= 4573333,048 \text{ kW} \checkmark$$

(3)

[15]

QUESTION 6: STRESS AND STRAIN

6.1 Limit of proportionality is that point at which the strain is no longer proportional to stress. (2)

6.2 $D = 1,8d$
 $L_0 = 700 \text{ mm} = 0,7 \text{ m}$
 $F = 315 \text{ kN} = 315\,000 \text{ N}$
 $X = 0,319$
 $E = 200 \text{ GPa}$

$$E = \frac{F \times L_0}{A \times X}$$

$$A = \frac{F \times L_0}{E \times X} \checkmark$$

$$= \frac{315\,000 \times 0,7}{200 \times 10^9 \times 0,319 \times 10^{-3}} \checkmark$$

$$= 0,00793 \text{ m}^2$$

$$= 7,932 \times 10^{-3} \text{ m}^2 \checkmark$$

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

$$= \frac{\pi[(1,8d)^2 - (d)^2]}{4} \checkmark$$

$$\frac{4(7,932 \times 10^{-3})}{\pi} = 2,24d^2$$

$$d = 0,0671 \text{ m} \checkmark$$

$$D = 1,8d$$

$$D = 1,8 \times 0,0671 \checkmark$$

$$= 0,121 \text{ m} \checkmark$$

(7)

6.3 $F = 9,5 \text{ kN} = 9\,500 \text{ N}$
 $S = 195 \text{ mm} = 0,195 \text{ m}$
 $X = 0,213 \text{ mm}$

6.3.1 $\text{Stress} = \frac{F}{A}$

$$= \frac{9\,500}{0,195^2} \checkmark$$

$$= 249\,835,6345 \text{ Pa}$$

$$= 249,836 \text{ kPa} \checkmark$$

(2)

6.3.2 $\text{Strain} = \frac{X}{L}$

$$= \frac{0,213}{4\,500} \checkmark$$

$$= 4,733 \times 10^{-5} \checkmark$$

(2)

6.3.3 $E = \frac{249\,835,6345}{4,733 \times 10^{-5}}$

$$= 5,279 \text{ GPa} \checkmark$$

(4)

QUESTION 7: HEAT

- 7.1
- Isochoric
 - Isobaric
 - Isothermal
- (3)

- 7.2 Isothermal (1)

- 7.3 $L \times B \times H = 75 \text{ cm} \times 35 \text{ cm} \times 20 \text{ cm} = 750 \text{ mm} \times 350 \text{ mm} \times 200 \text{ mm}$
 $T_1 = 38 \text{ }^\circ\text{C}$
 $T_2 = 400 \text{ }^\circ\text{C}$
 $\alpha = 17 \times 10^{-6} / ^\circ\text{C}$

7.3.1 $\Delta L = L_0 \times \alpha \times (t_2 - t_1)$
 $= 75 \times 17 \times 10^{-6} (400 - 38) \checkmark$
 $= 0,462 \text{ cm} \checkmark$ (2)

7.3.2 $A_f = A_0 + A_0 \times 2\alpha \times (t_2 - t_1)$
 $= (750 \times 350) + (750 \times 350) \times 2 \times 17 \times 10^{-6} (400 - 38) \checkmark \checkmark$
 $= 265730,85 \text{ mm}^2 \checkmark$ (3)

7.3.2 $\Delta V = V_0 \times 3\alpha \times (t_2 - t_1)$
 $= 0,75 \times 0,35 \times 0,2 \times 3 \times 17 \times 10^{-6} (400 - 38) \checkmark \checkmark$
 $= 0,969 \times 10^{-3} \text{ m}^3 \checkmark$ (3)

- 7.4 $P_1 = 750 \text{ kPa}$
 $P_2 = 1300 \text{ kPa}$
 $V_1 = 0,495 \text{ m}^3$
 $V_2 = 0,0749 \text{ m}^3$

$$\begin{aligned} \frac{P_1 V_1}{T_1} &= \frac{P_2 V_2}{T_2} \\ &= \frac{P_2 V_2 T_1}{P_1 V_1} \checkmark \\ &= \frac{1000 \times 0,0639 \times 348}{750 \times 0,495} \checkmark \\ &= 59,89 \text{ }^\circ\text{K} \checkmark \end{aligned}$$

(3)
[15]

TOTAL: 100