Part 3:

(1) $A = 1 \times 10^{-4}\ m^2$

$x = 2 \times 10^{-2}\ m$

$K = 84\ W/mK$

$d\theta = 12K$

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

Soln:

$$\frac{Q}{t} = \frac{KA\,d\theta}{x}$$

$$= \frac{84 \times 10^{-4} \times 12}{2 \times 10^{-2}}$$

$$= 5.04\,W$$

(2) $d\theta = ?$

$x = 2 \times 10^{-2}$ m

$\frac{Q}{At} = \frac{2.52 \times 10^{6}}{60}$ J/m^2.s

$K = 84$ W/mK

Soln:

$\frac{Q}{At} = K\frac{d\theta}{x}$

$\therefore \frac{2.52 \times 10^{6}}{60} = 84 \times \frac{d\theta}{2 \times 10^{-2}}$

$\therefore d\theta = \frac{2.52 \times 10^{6} \times 10^{-2}}{42 \times 60}$

$= 10$ K

(3)

$x = 2 \times 10^{-2}\ m$

$\frac{Q}{At} = 42\ J/m^2.s$

$d\theta = 20\ K$

$K = ?$

Soln :

$$\frac{Q}{At} = K\frac{d\theta}{x}$$

$$42 = K \cdot \frac{20}{2 \times 10^{-2}}$$

$$\therefore K = 0.042\ W/m.K$$

(4)

$x = 2 \times 10^{-2}\ m$

$A = 0.5\ m^2$

$d\theta = 423 - 413 = 10\ K$

$Q = ?$

$t = 60\ s$

$K = 60\ W/m \cdot K$

Soln:

$$\frac{Q}{t} = \frac{KA\, d\theta}{x}$$

$$\therefore Q = 60 \times 60 \times 0.5 \times \frac{10}{2 \times 10^{-2}}$$

$$Q = 9 \times 10^5\ J$$

(5)

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

$x = 0.5 \times 10^{-2}\ m$

$A = 1\ m^2$

$d\theta = 5^\circ C$

$K = 0.714\ W/m\cdot K$

Soln

$$\frac{Q}{t} = K \cdot A \frac{d\theta}{x}$$

$$= \frac{0.714 \times 1 \times 5}{0.5 \times 10^{-2}} = 714\ J/s$$

$$= \frac{714}{4.2} = 170\ cal$$

(6)

$d\theta = 25^\circ C$

$Q = ?$

$t = 60\ s$

$A = 2 \times 1 = 2\ m^2$

$x = 0.5 \times 10^{-2}\ m$

$K = 0.95\ W/m.K$

Soln

$$\frac{Q}{t} = KA\frac{d\theta}{x}$$

$$\therefore Q = 60 \times 0.95 \times 2 \times \frac{25}{0.5 \times 10^{-2}}$$

$$= 5.7 \times 10^5\ J$$

$$= \frac{5.7 \times 10^5}{4.2} = 1.357 \times 10^5\ cal$$

$$= 1.357 \times 10^2\ kcal$$

(7)

$d\theta = 15^{\circ}C$

$Q = ?$

$t = 600\ s$

$A = 2 \times 1 = 2\ m^2$

$x = 0.4 \times 10^{-2}\ m$

$K = 0.84\ W/m.K$

Soln

$$\frac{Q}{t} = KA\frac{d\theta}{x}$$

$$\therefore Q = 600 \times 0.84 \times 2 \times \frac{15}{0.4 \times 10^{-2}}$$

$$= 3.78 \times 10^{6}\ J$$

$$\therefore Q = \frac{3.78 \times 10^{6}}{4.2} = 9 \times 10^{5}\ cal$$

$$= 900\ Kcal$$

(8)

$Q = ?$

$t = 1\,h = 3600\,s$

$K = 2.1\ W/m\cdot K$

$A = 5 \times 3 = 15\,m^2$

$x = 0.5\,m$

$d\theta = 20^\circ C$

Soln:

$$\frac{Q}{t} = KA\frac{d\theta}{x}$$

$$\therefore Q = \frac{3600 \times 2.1 \times 15 \times 20}{0.5}$$

$$= 4.536 \times 10^4\ J$$

$$= \frac{4.536 \times 10^8}{4200}$$

$$= 1080\ kcal$$

(9) $\frac{Q}{t} = 3000 \times 4.2 \text{ J/s}$

$A = 60 \times 10^{-4} \text{ m}^2$

$x = 0.5 \times 10^{-2} \text{ m}$

$d\theta = ?$

$K = 250 \text{ W/m.K}$

$$\frac{Q}{t} = KA\frac{d\theta}{x}$$

$$3000 \times 4.2 = 250 \times 60 \times 10^{-4} \times \frac{d\theta}{0.5 \times 10^{-2}}$$

$$\therefore d\theta = \frac{3000 \times 4.2}{250 \times 120 \times 10^{-2}} = 42 \text{ K}$$

(10) $A = 5000 \times 10^{-4} m^2$

$x = 3 \times 10^{-3} m$

$d\theta = 283 - 273 = 10K$

$Q = ?$

$t = 60s$

$k = 0.63 W/m \cdot K$

Soln:

$$\frac{Q}{t} = \frac{kA\,d\theta}{x}$$

$$Q = 60 \times 0.63 \times 5000 \times 10^{-4} \times \frac{10}{3 \times 10^{-3}}$$

$$= 63000 J$$

(11)

$d\theta = 100^{\circ}C$

$A = 60 \times 60 \times 10^{-4} m^2$

$x = 10 \times 10^{-2} m$

$m = 80 \times 10^{-3}$ kg ice

$t = 60s$

$K = ?$

$L = 3.36 \times 10^5 J/kg$

$$Q = mL = 80 \times 10^{-3} \times 3.36 \times 10^5$$
$$= 2688 J$$

$$\frac{Q}{t} = K A \frac{d\theta}{x}$$

$$\frac{2688}{60} = K \cdot 60 \times 60 \times 10^{-4} \times \frac{100}{10 \times 10^{-2}}$$

$$\therefore K = \frac{2688}{6 \times 36 \times 10} = 1.24 W/m K$$

(12) m = 8 kg ice at 0°C

$A = 2(60\times10 + 40\times10 + 40\times60)\times10^{-4}$

$= 1.28\ m^2$

$t = ?$

$x = 6\times10^{-2}\ m$

$d\theta = 20 - 0 = 20°C$

$K = 0.0252\ J/mK$

$L = 80\ kcal/kg = 80\times4200\ J/kg$

Soln:

$Q = mL = 8\times80\times4200 = 2688000\ J$

$\frac{Q}{t} = \frac{KA\,d\theta}{x}$

$\frac{2688000}{t} = \frac{0.0252\times1.28\times20}{6\times10^{-2}}$

$\therefore t = 2.5\times10^{5}\ s$

(13)

$A = 0.01 m^2$

$x = 1.5 \times 10^{-3} m$

$d\theta = 100 - 0 = 100°C$

$m = ?$

$t = 60 s$

$L = 80 \times 4200 \ J/kg$

$K = 2 \times 10^{-4} \ W/m\text{-}K$

Soln

$Q = mL = m \times 80 \times 4200 \ J$

$\frac{Q}{t} = \frac{KA\,d\theta}{x}$

$\frac{m \times 80 \times 4200}{60} = \frac{2 \times 10^{-4} \times 0.01 \times 100}{1.5 \times 10^{-3}}$

$\therefore m = 0.00002381 \ kg.$

(14)

$T_1 = 352\ K$ $\quad x_1 = 3\times10^{-2}\ m$

$T_2 = 343\ K$ $\quad x_2 = 8\times10^{-2}\ m$

$T_3 = ?$ $\quad x_3 = 11\times10^{-2}\ m$

Soln

$$\left(\frac{Q}{t}\right)_{1-2} = \left(\frac{Q}{t}\right)_{2-3}$$

$$\left(\frac{KA\,d\theta}{x}\right)_{1\to2} = \left(\frac{K\,x\,d\theta}{x}\right)_{2-3}$$

$$\frac{352-343}{5\times10^{-2}} = \frac{343-T_3}{3\times10^{-2}}$$

$$\therefore \frac{9}{5}\times3 = 343 - T_3$$

$$\therefore T_3 = 337.6\ K$$

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$\frac{Q}{t} = 168\ J/s$

$A = \pi (3\times10^{-2})^2 = 9\pi\times10^{-4}\ m^2$

$d\theta = 80 - 60 = 20^\circ C$

$x = ?$

$K = 378\ W/mK$

Soln:

$\frac{Q}{t} = \frac{KA\,d\theta}{x}$

$168 = 378 \times 9\pi\times10^{-4} \times \frac{20}{x}$

$\therefore x = \frac{378\times9\pi\times10^{-4}\times20}{168}$

$= 0.1272\ m.$

$= 12.72\ cm.$

(16) $x = 31.4 \times 10^{-2}\ m$

$A = \pi (2 \times 10^{-2})^2 = 4\pi \times 10^{-4}\ m^2$

$d\theta = 100 - 0 = 100^\circ C$

$t = 60\ s$

$m = ?$

$L = 80\ cal/g = 80 \times 4200\ J/kg$

$K = 10^5\ W/m.K$

Soln.

$$\frac{Q}{t} = \frac{K A\, d\theta}{x}$$

$$Q = \frac{60 \times 10^5 \times 4\pi \times 10^{-4} \times 100}{31.4 \times 10^{-2}}$$

$$= \frac{60 \times 10^5 \times 4 \times 10^{-4} \times 100}{10 \times 10^{-2}}$$

$$= 24 \times 10^5\ J$$

$$mL = 24 \times 10^5$$

$$m = \frac{24 \times 10^5}{80 \times 4200} = 7.143\ kg$$

(14)

$r = 25 \times 10^{-2}$ m

$d\theta = 100 - 0 = 100^\circ C$

$m = 12 \times 10^{-3}$ kg

$t = 60$ s

$K = ?$

$A = 25 \times 10^{-4}$ m^2

$L = 80$ kcal/kg $= 80 \times 4200$ J/kg

$\Rightarrow$ In

$Q = mL = 12 \times 10^{-3} \times 80 \times 4200$

$= 4032$ J

$$\frac{Q}{At} = K\frac{d\theta}{r}$$

$$\frac{4032}{25 \times 10^{-4} \times 60} = \frac{K \times 100}{25 \times 10^{-2}}$$

$$\therefore K = \frac{672 \times 25}{25 \times 10^{-3} \times 10^4}$$

$= 67.2$ W/m·K

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$x = 50 \times 10^{-2}\ m$

$A = \pi (1 \times 10^{-2})^2 = \pi \times 10^{-4}\ m^2$

$d\theta = 100 - 0 = 100^\circ C$

$m = 23.5 \times 10^{-3}\ kg$ i.e.

$t = 10 \times 60 = 600\ s$

$K = ?$

$L = 80\ cal/g = 80 \times 4200\ J/kg$

Soln

$Q = ml = 23.5 \times 10^{-3} \times 80 \times 4200$

$= 7896\ J$

$\frac{Q}{t} = K A \frac{d\theta}{x}$

$\frac{7896}{600} = K \times \frac{\pi \times 10^{-4} \times 100}{50 \times 10^{-2}}$

$\therefore K = \frac{1316 \times 50}{100 \times \pi} = 209.5\ W/m.K$

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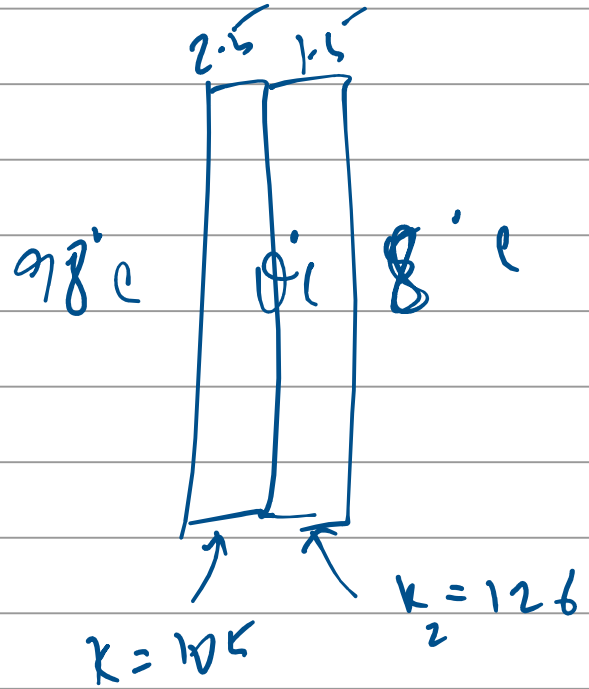


$$\left(\frac{\theta}{t}\right)_1 = \left(\frac{\theta}{t}\right)_2$$

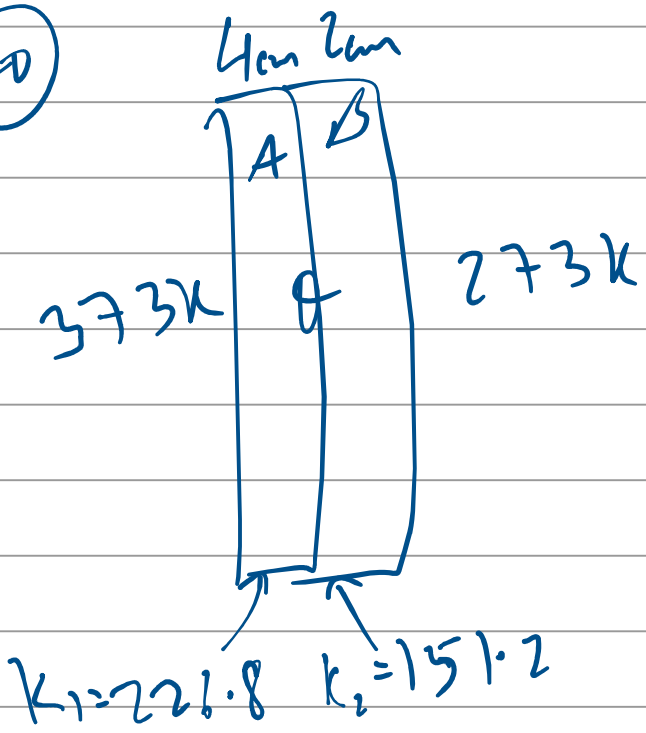
$$\left(\frac{KA\,d\theta}{x}\right)_1 = \left(\frac{KA\,d\theta}{x}\right)_2$$

$$105 \times A \times \frac{(98-\theta)}{2.5} = 126 \times A \times \frac{(\theta-8)}{1.5}$$

$$315(98-\theta) = 630(\theta-8)$$

$$\therefore \theta = 38°C$$

(20)



$$\left(\frac{Q}{T}\right)_1 = \left(\frac{Q}{T}\right)_2$$

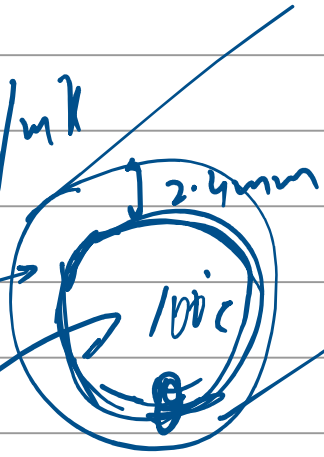
$$\left(\frac{K A d\theta}{x}\right)_1 = \left(\frac{K A d\theta}{x}\right)_2$$

$$\frac{226.8 \times (373-\theta)}{4} = \frac{151.2\,(\theta-273)}{2}$$

$$226.8(373-\theta) = 302.4(\theta-273)$$

$$\therefore \theta = 315.9\ K$$

27



$K_1 = 378\ W/mK$ (Cu)

T_{in} 700°C

0.2mm

$K_2 = 63\ W/mK$

$A = 100 \times 10^{-4}\ m^2$

$t = 1h = 3600\ s$

$m = ?$

$l = 2268000\ J/kg$

$$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2$$

$$\left(K \frac{A\,d\theta}{x}\right)_1 = \left(K \frac{A\,d\theta}{x}\right)_2$$

$$\frac{378\,(700-\theta)}{2.4} = \frac{63\,(\theta-100)}{0.2}$$

$$\therefore \theta = 300^\circ C$$

$$\left(\frac{Q}{t}\right)_{Cu} = \left(\frac{Q}{t}\right)_{fin} = \left(\frac{Q}{t}\right)_{steam}$$

$$\left(\frac{K_1 A\,d\theta}{x}\right)_1 = \left(\frac{ml}{t}\right)_{steam}$$

$$\frac{378 \times 100 \times 10^{-4} \times (700-300)}{2.4 \times 10^{-3}} = m \times 2268000/3600$$

$$\therefore m = 1000$$

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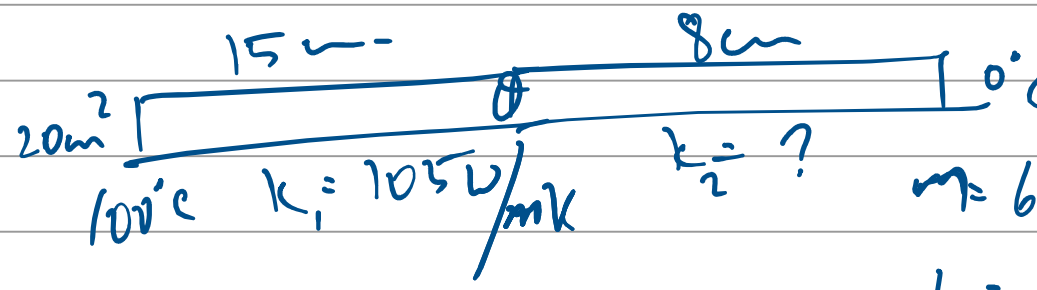


$m = 630 \times 10^{-3}$ kg in 1 h

$t = 3600$ s

$L = 80 \times 4200$ J/kg

$$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2 = \left(\frac{Q}{t}\right) \text{ in}$$

$$\left(\frac{KA\,d\theta}{x}\right)_1 = \left(\frac{KA\,d\theta}{x}\right)_2 = \frac{630 \times 10^{-3} \times 80 \times 4200}{3600}$$

$$\therefore \frac{105 \times 20 \times 10^{-4} \times (100 - \theta)}{75 \times 10^{-2}} = \frac{630 \times 10^{-3} \times 80 \times 4200}{3600}$$

$\therefore \theta = 58°C$

$$\left(\frac{Q}{t}\right)_2 = \left(\frac{Q}{t}\right) \text{ in}$$

$$k_2 \times \frac{20 \times 10^{-4} \times (58 - 0)}{8 \times 10^{-2}} = \frac{630 \times 10^{-3} \times 80 \times 4200}{3600}$$

$\therefore k_2 = 40.55 W/mK$

(23) $-20^\circ C$ ——— $x = 3\ cm$ $\quad t = ?$

$0^\circ C$ ////////// 1mm

$K = 0.005\ cal/s \cdot cm^\circ K$

$\rho = 0.91\ g/cc$

$L = 80\ cal/g$

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

$= A \times 10^{-3} \times 0.91 \times \frac{80}{t}$

$\frac{Q}{t} = \frac{KA\,d\theta}{x}$

$= \frac{0.005 \times A \times 20}{\left(\frac{3+3.1}{2}\right)}$

NOTE : mass = Volume × density

$= A \times h \times \rho$

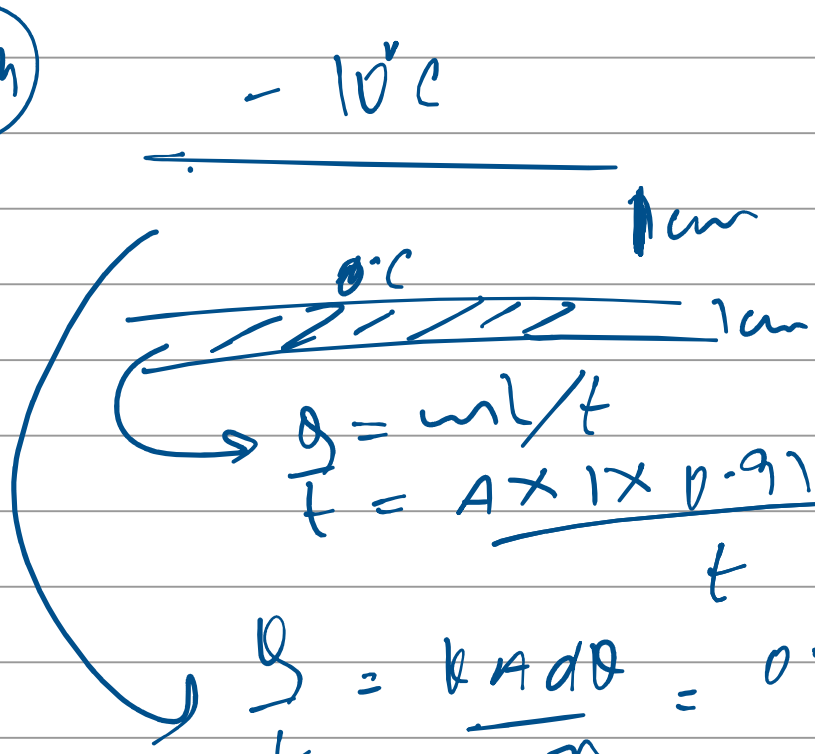
$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2$

$A \times 10^{-3} \times 0.91 \times 80 = 0.005 \times A \times 20$

$\frac{\qquad\qquad\qquad\qquad}{t} \qquad\qquad \frac{\qquad\qquad\qquad}{3.05}$

$\therefore t = 222.0\ s$

(24)



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

$$\frac{Q}{t} = \frac{A \times 1 \times 0.91 \times 80}{t} \text{ cal}$$

$$\frac{Q}{t} = \frac{kA\,d\theta}{x} = \frac{0.005 \times A \times 10}{\left(\frac{1+2}{2}\right)}$$

$$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2$$

$$\frac{4 \times 1.5 \times 0.91 \times 80}{t} = \frac{0.005 \times A \times 10}{1}$$

$$\therefore t = 2184\text{s}$$

(25) $\left(\frac{d\theta}{dt}\right)_1 = 3°C/min$ at $50°C$

$\left(\frac{d\theta}{dt}\right)_2 = ?$ at $40°C$

$\theta_0 = 25°C$

Soln $\frac{d\theta}{dt} \propto \theta - \theta_0$

$$\frac{\left(\frac{d\theta}{dt}\right)_1}{\left(\frac{d\theta}{dt}\right)_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$$

$$\frac{3}{\left(\frac{d\theta}{dt}\right)_2} = \frac{50 - 25}{40 - 25}$$

$$\therefore \left(\frac{d\theta}{dt}\right)_2 = \frac{3 \times 15}{25} = 1.8°C/min$$

(26)

$\theta_0 = 30°C$

$\theta_2 = ?$ $\left(\frac{d\theta}{dt}\right)_2 = \frac{1}{2}\left(\frac{d\theta}{dt}\right)_1$

$\therefore \left(d\theta/dt\right)_2 / \left(\frac{d\theta}{dt}\right)_1 = 1/2$

$$\frac{\theta_2 - \theta_0}{\theta_1 - \theta_0} = \frac{1}{2}$$

$$\frac{\theta_2 - 30}{50 - 30} = \frac{1}{2}$$

$\therefore \theta_2 = 40°C$

(27)

75°C

10 min | $\frac{d\theta}{dt} = \frac{75-55}{10} = 2°C/min$ at 65°C ← θ_1

55°C

$\theta_0 = 31°C$

75°C

? | $\frac{d\theta}{dt} = \frac{2}{4} = \frac{1}{2}°C/min$

55°C

$\theta_0 = ?$

$$\frac{\left(\frac{d\theta}{dt}\right)_1}{\left(\frac{d\theta}{dt}\right)_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$$

$$4 = \frac{65 - 31}{65 - \theta_0}$$

$$\therefore \theta_0 = 56.5°C$$

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60°C

5 min $\left(\frac{d\theta}{dt}\right)_1$ = 2°C/min at 55°C
θ_1

50°C

$\left(\frac{d\theta}{dt}\right)_2 = \frac{6}{dt}$ at 47°C
θ_2

44°C

$\theta_0 = 32°C$

$$\frac{\left(\frac{d\theta}{dt}\right)_1}{\left(\frac{d\theta}{dt}\right)_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$$

$$\frac{2}{6/dt} = \frac{55-32}{47-32}$$

$$\therefore dt = 4.6 \text{ min.}$$