

Numerical Methods for Engineers (7th Edition)

Chapter 1, Problem 19P

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Step-by-step solution

Step 1 of 10

The objective is to compute the victim's body temperature for the 5-hours period using values of $k = 0.12 / \text{hr}$ and $\Delta t = 0.5 \text{ hr}$ by using the Euler method.

Newton's law of cooling:

The temperature of body a body changes at a rate proportional to the difference between its temperature and that of the surrounding medium.

$$\frac{dT}{dt} = -k(T - T_a)$$

Here T is the temperature of the body ($^{\circ}\text{C}$), t = time (min).

The ambient temperature (room temperature), $T_a = 10^{\circ}\text{C}$.

The proportional constant, $k = 0.12 / \text{hr}$.

Substitute the values of T_a and k values in the equation, $\frac{dT}{dt} = -k(T - T_a)$.

Thus, $\frac{dT}{dt} = -0.12(T - 10)$

Assume victim's body temperature at the time of death was 37°

Thus, $T(0) = 37^{\circ}$

Comment

Step 2 of 10

Consider the initial value problem,

$$\frac{dT}{dt} = -k(T - 10), \quad T(0) = 37^{\circ}$$

Euler method for approximating the solution to the initial-value problem,

$$\frac{dT}{dt} = -0.12(T - 10), \quad T(0) = 37^{\circ}$$

at the points $t_{n+1} = t_n + n \cdot \Delta t$ is, $T_{n+1} = T_n + \Delta t \times f(t_n, T_n)$, $n = 0, 1, 2, \dots$

Here, step size $h = 0.5$

For $n = 0, t_0 = 0, T_0 = 37$

$$\begin{aligned} T_1 &= T_0 + h \times f(t_0, T_0) \\ &= 37 + \frac{1}{2} \times f(0, 37) \\ &= 37 + \frac{1}{2} \times (-0.12(37 - 10)) \\ &= 37 - \frac{1}{2} \times (0.12 \times 27) \\ T_1 &= 35.38^{\circ} \end{aligned}$$

T_1 is the approximate temperature at $t_1 = 0 + 1 \cdot 0.5 = 0.5$

Comment

Step 3 of 10

For $n = 1, T_1 = 35.38, t_1 = 0.5$

$$\begin{aligned} T_2 &= T_1 + h \times f(t_1, T_1) \\ &= 35.38 + \frac{1}{2} \times f(0.5, 35.38) \\ &= 35.38 + \frac{1}{2} \times (-0.12 \times (35.38 - 10)) \\ &= 35.38 - \frac{1}{2} \times (0.12 \times 25.38) \\ T_2 &= 33.86^{\circ} \end{aligned}$$

T_2 is the approximate temperature at $t_2 = 0 + 2 \cdot 0.5 = 1$.

Comment

Step 4 of 10

For $n = 3, T_2 = 33.86, t_2 = 1$

$$\begin{aligned} T_3 &= T_2 + h \times f(t_2, T_2) \\ &= 33.86 + \frac{1}{2} \times f(1, 33.86) \\ &= 33.86 + \frac{1}{2} \times (-0.12 \times (33.86 - 10)) \\ &= 33.86 - \frac{1}{2} \times (0.12 \times 23.86) \\ T_3 &= 32.43^{\circ} \end{aligned}$$

T_3 is the approximate temperature at $t_3 = 0 + 3 \cdot 0.5 = 1.5$.

Comment

Step 5 of 10

For $n = 3, T_3 = 64.51, t_3 = 6$

$$\begin{aligned} T_4 &= T_3 + h \times f(t_3, T_3) \\ &= 64.51 + 2 \times f(6, 64.51) \\ &= 64.51 + 2 \times (-0.019 \times (64.51 - 20)) \\ &= 64.51 - 2 \times (0.019 \times 44.51) \\ T_4 &= 62.82^{\circ} \end{aligned}$$

T_4 is the approximate temperature at $t_4 = 0 + 4 \cdot 2 = 8$.

Comment

Step 6 of 10

For $n = 4, T_4 = 62.82, t_4 = 8$

$$\begin{aligned} T_5 &= T_4 + h \times f(t_4, T_4) \\ &= 62.82 + 2 \times f(8, 62.82) \\ &= 62.82 + 2 \times (-0.019 \times (62.82 - 20)) \\ &= 62.82 - 2 \times (0.019 \times 42.82) \\ T_5 &= 61.19^{\circ} \end{aligned}$$

T_5 is the approximate temperature at $t_5 = 0 + 4 \cdot 2 = 10$.

Comment

Step 7 of 10

Use maple software to determine the volume of the droplet from $t = 0$ to $t = 5 \text{ min}$ using step size of 0.5.

Maple command:

$$DE := \text{diff}(T(t), t) = -0.12 \cdot (T(t) - 10)$$
$$\text{InitialValueProblem} \left(\begin{array}{l} DE, T(0) = 37.00, t = 5, \text{method} = \text{euler}, \\ \text{output} = \text{information, numsteps} = 10, \text{digits} = 4 \end{array} \right)$$

Maple output:

t	Approximate value T(t)
0	37
0.5	35.38
1	33.86
1.5	32.43
2	31.08
2.5	29.82
3	28.63
3.5	27.51
4	26.46
4.5	25.47
5	24.54

Comment

Step 8 of 10

(b)

Consider the initial value problem,

$$\frac{dT}{dt} = -k(T - 20), \quad T(0) = 37^{\circ}$$

Euler method for approximating the solution to the initial-value problem,

$$\frac{dT}{dt} = -0.12(T - 20), \quad T(0) = 37^{\circ}$$

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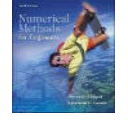
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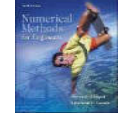
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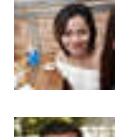
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The room temperature had actually dropped linearly from 20° to 10° .
So the room temperature decreases to 1° for every 0.5 hrs.
For $n = 0, t_n = 0, T_n = 37$
$$T_1 = T_n + h \times f(t_n, T_n)$$
$$= 37 + \frac{1}{2} \times f(0, 37)$$
$$= 37 + \frac{1}{2} \times (-0.12(37 - 20))$$
$$= 37 - \frac{1}{2} \times (0.12 \times 17)$$
$$T_1 = 35.98^{\circ}$$
$$T_1 \text{ is the approximate temperature at } t_1 = 0 + 1 \cdot 0.5 = 0.5$$

Comment

Step 9 of 10

For $n = 1, T_1 = 35.98, t_1 = 0.5$
$$T_2 = T_1 + h \times f(t_1, T_1)$$
$$= 35.98 + \frac{1}{2} \times f(0.5, 35.38)$$
$$= 35.98 + \frac{1}{2} \times (-0.12 \times (35.38 - 19))$$
$$= 35.88 - \frac{1}{2} \times (0.12 \times 16.38)$$
$$T_2 = 34.89^{\circ}$$
$$T_2 \text{ is the approximate temperature at } t_2 = 0 + 2 \cdot 0.5 = 1.$$

Comment

Step 10 of 10

Use maple software to determine the volume of the droplet from $t = 0$ to $t = 5$ min using step size of 0.5 .

Maple command:

$$DE := \text{diff}(T(t), t) = -0.12 \cdot (T(t) - (20 - 2 \cdot t))$$

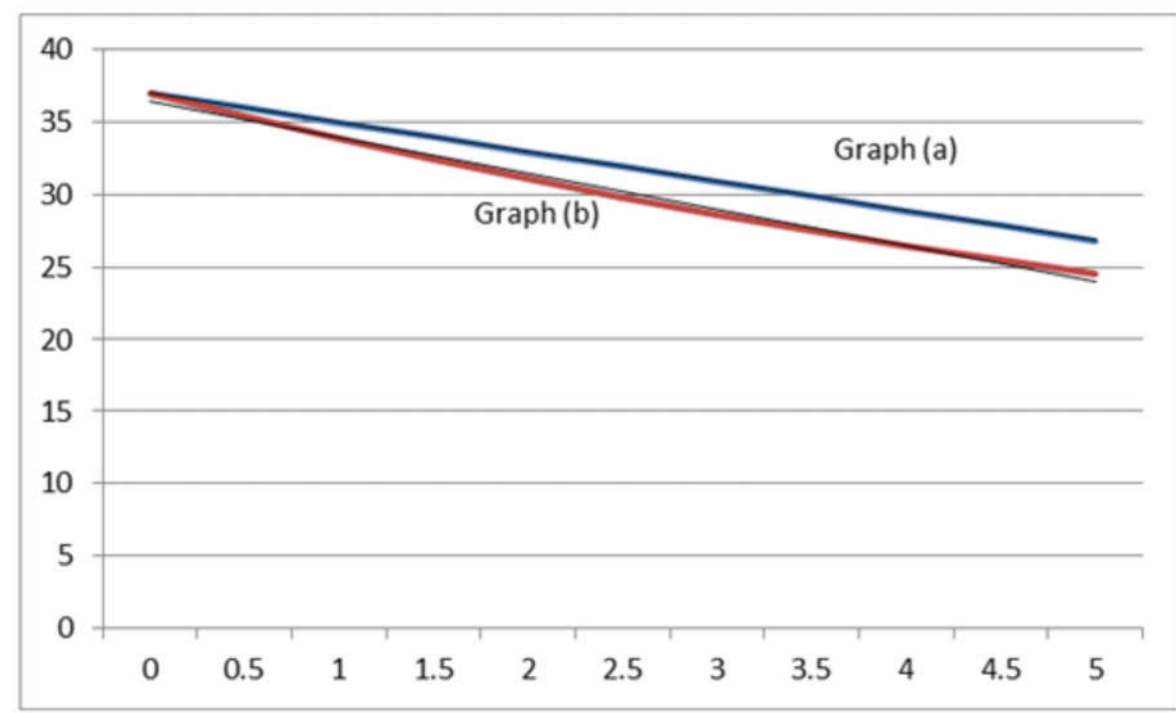
$$\text{Initial Value Problem} \left(\begin{array}{l} DE, T(0) = 37.00, t = 5, \text{method} = \text{euler}, \\ \text{output} = \text{information, numsteps} = 10, \text{digits} = 4 \end{array} \right)$$

Maple output:

t	Approximation of T(t)
0	37
0.5	35.98
1	34.96
1.5	33.94
2	32.93
2.5	31.91
3	30.90
3.5	29.88
4	28.87
4.5	27.86
5	26.85

(c)

Compare the results from (a) and (b) by plotting them on the same graph.



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