1.81.1

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MECHANICAL ENGINEERING

Soln

let $y(t)$ be the amount of air at any time t in ft^3 in the room

$\frac{dy}{dt}$ → fresh air inflow rate − fresh air outflow rate

fresh air inflow → 600 ft^3/min

fresh air outflow → Note: the amount flowing out of the room is a function of the amount in the room

$\frac{600}{2000} = 0.03m$

i.e 0.03 of $y(t)$ to the outflow = 0.03 yft^3

$\frac{dy}{dt} = 600 - 0.03y$

$= -0.03y + 600$ —— (1)

$= 0.03(y - 2000)$ —— (1)

this equ can be separated & integrated

$\frac{dy}{(y-2000)} = -0.03dt$

find the integral of both sides

$\ln(y-2000) = -0.03t + c$

$y - 20000 = e(-0.03t + c)$

$y = 2000 = e^{-0.03t} \cdot e^c$

Recall $c = e^c$ = initial equation

$\therefore y - 20000 = e^{-0.03t} \cdot c$ ... (1)

At $t = 0$, $y(t) = 0$ since the room contained no fresh air initially

Put $y = 0$; $t = 0$ in equ (1)

$y - 20000 = e^{-(0.03t)} \cdot c$

$0 - 20000 = e^0 \cdot c$

$0 - 20000 = 1(c)$

$c = -20000$ —— (2)

Put (1) into (2)

$y = 20000 - 20000 e^{-0.03t}$

$y = 20000 (1 - e^{-0.03t}) \quad \ldots (3)$

In (3) above is the model for the amount of fresh air in the room

Calculate the time at which 90% of the air in the room will become fresh

$$90\% = \frac{90}{100} = 0.9$$

$y = 0.9 \times 20,000$, is 90% of air in the room = 18000 ft³

$y = 20,000 (1 - e^{-0.03t})$

$18000 = 20,000 (1 - e^{-0.03t})$

$0.9 = 1 - e^{-0.03t}$

$e^{-0.03t} = 1 - 0.9$

$-0.03t = 0.1$

$0.03t = \ln(0.1)$

$$t = \frac{\ln(0.1)}{-0.03}$$

$$t = \frac{2.303}{-0.03}$$

$t = 76.77$ mins

≈ 77 mins

(c) with the aid of matlab, plot the dynamic response of the amount of fresh air in the room for $t = 24$ hrs

Note: $t = 6$ hrs to mins

$= 6 \times 60$ s

$= 360$ mins

Soln:

```
Command window
clear all
clc
close all
syms y,t
y= 20000 * (1- exp(-0.03*t))
t= 0:5:360
yn= subs(y)
plot(t, yn)
xlabel ('time (min)')
ylabel ('flowrate of fresh air (ft^3/min)')
Grid on
Grid minor
Axis height
```

d) Determine the steady-state value of the amount of fresh air in the room

Ans

-the steady-state value is 20,000 ft^3 at 215min, (3hr and 35min). If exponential approach.

Comment on answer in (d)

-the functions shows an exponential approach to the limit of 20000 ft^3 as y increases with time. Also, when the steady state value approaches 20000 ft^3 at 215mins and continues till 360min (6hrs). -the model discussed becomes more realistic in pneumatic technology although maybe difficult because mixing maybe imperfect