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Assignment (II).

1.) Step 1: Setting up a model;

Let $F_A(t)$ denote the amount of fresh air in the room at time t.

By Balance law;

$$\frac{\delta F_A}{\delta t} = \text{Fresh Air Inflow rate} - \text{Fresh Air Outflow rate}.$$

Input of fresh Air = $600\ ft^3/min$

Initially there was no fresh air

Hence, $F_A(0) = 0$.

Also

Output of mixture = $600\ ft^3/min$

Mixture of fresh Air & Normal Air = $20,000\ ft^3/min$

$$\frac{\delta F_A}{\delta t} = 600 - \frac{600}{20,000} \times F_A(t)$$

$$\frac{\delta F_A}{\delta t} = 600 - 0.03 F_A.$$

$\frac{\delta F_A}{\delta t} = -0.03\,(F_A - 20{,}000)$

Step 2: Solution of the Model;

$\frac{\delta F_A}{\delta t} = -0.03\,(F_A - 20{,}000)$

$\frac{\delta F_A}{F_A - 20{,}000} = -0.03\,\delta t$

Integrate both sides.

$\int \frac{\delta F_A}{F_A - 20{,}000} = \int -0.03\,\delta t$

$\ln(F_A - 20{,}000) = -0.03t + C$

Taking ln of both sides,

$F_A - 20{,}000 = C \cdot e^{-0.03t}$

where $C = e^{c}$

$F_A = 20{,}000 + Ce^{-0.03t}$ (General Soln).

Initially, there was no fresh air,

$F_A(0) = 0$

$F_A = 20{,}000 + C \cdot e^{-0.03t}$

where $t = 0$, $F_A = 0$

$0 = 20{,}000 + C \times e^{-0.03(0)}$

$C = \ldots$

$\therefore$

$F_A(t \ldots$

Force

Become

c.)

d.)

$C = -20,000$

$\therefore$

$F_A(t) = 20000 - 20,000\, e^{-0.03t}$ (Particular Solution)

Time at which 90% of the air will become fresh.

$\frac{90}{100} \times \frac{20,000}{1} = 20,000 - 20,000\, e^{-0.03t}$

$18,000 = 20,000 - 20,000\, e^{-0.03t}$

$-2,000 = -20,000\, e^{-0.03t}$

$0.1 = e^{-0.03t}$

$\ln 0.1 = -0.03t$

$-2.3026 = -0.03t$

$t = 76.75$ mins.

0.75 mins to secs.

$= 0.75 \times 60 = 45$ Seconds.

$\therefore t = 76$ minutes 45 Seconds.

c) 6 hrs to mins $= 60 \times 6 = 360$ mins.

d) Steady State Value of the amount of fresh air in the room $= 20,000$ (ft^3 of air).