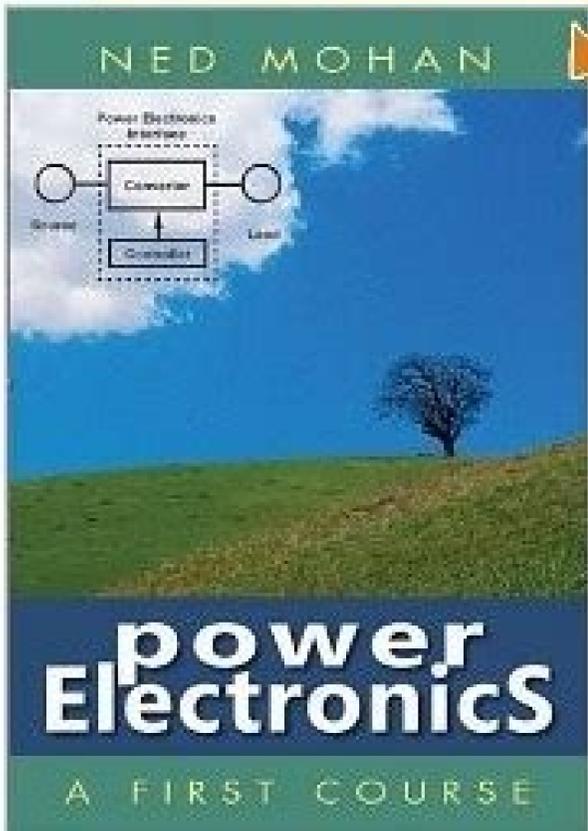


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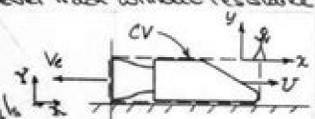
**FOX MCDONALD FLUID
MECHANICS SOLUTION MANUAL
8TH EDITION**

JNMFNRNOXY | PDF | 74 (385.54) | 14 Jul, 2014



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Given: Rocket sled moving on level track without resistance
 Initial mass, $M_0 = 2000 \text{ kg}$
 (includes $M_{fuel} = 1000 \text{ kg}$)
 $V_e = 2500 \text{ m/s}$; $P_e = P_{atm}$
 Fuel consumption, $\dot{m} = 75 \text{ kg/s}$



Find: Acceleration and speed of sled at $t = 10 \text{ s}$.
 Plot: sled speed and acceleration as functions of time.

Solution:
 Apply x component of momentum to linearly accelerating CV; use continuity to find $M(t)$

Basic equations: $0 = \frac{\partial}{\partial t} \int_{CV} \rho u_x dV + \int_{CS} \rho u_x u_x dA$
 $F_x + F_{ex} - \int_{CS} \rho u_x u_x dA = \frac{\partial}{\partial t} \int_{CV} \rho u_x dV + \int_{CS} \rho u_x u_x dA$

- Assumptions: (1) $F_x = 0$, no resistance (given)
 (2) $F_{ex} = 0$, horizontal
 (3) neglect $\frac{\partial}{\partial t}$ inside CV
 (4) uniform flow at nozzle exit
 (5) $P_e = P_{atm}$ (given)

From continuity, $0 = \frac{\partial M}{\partial t} + \dot{m} = \frac{dM}{dt} + \dot{m}$ or $dM = -\dot{m} dt$
 Integrating, $\int_{M_0}^M dM = M - M_0 = \int_0^t -\dot{m} dt = -\dot{m}t$ or $M = M_0 - \dot{m}t$

From the momentum equation
 $-a_x M = -a_x (M_0 - \dot{m}t) = u_e \dot{m} = -V_e \dot{m}$ ($u_e = -V_e$)

Plus $a_x = \frac{dV}{dt} = \frac{V_e \dot{m}}{M_0 - \dot{m}t}$ (1)

At $t = 10 \text{ s}$
 $\frac{dV}{dt} = \frac{2500 \text{ m/s} \cdot 75 \text{ kg/s}}{2000 \text{ kg} - 75 \text{ kg/s} \cdot 10 \text{ s}} = 83.3 \text{ m/s}^2$ a.c.

From Eq. 1, $dV = V_e \frac{\dot{m} dt}{M_0 - \dot{m}t}$

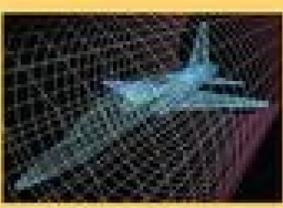
Integrating from $V = 0$ at $t = 0$ to V at $t = t$
 $V = -V_e \ln \left(\frac{M_0 - \dot{m}t}{M_0} \right) = -V_e \ln \left(\frac{M_0 - \dot{m}t}{M_0} \right)$

$V = -V_e \ln \left(\frac{M_0}{M_0 - \dot{m}t} \right)$ (2)

Engineering Fluid Mechanics

Donald F. Elger • Barbara A. LeBret • Clayton T. Crowe • John A. Roberson

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