EA429 Fall AY2008 **Name(s):**_____

Classroom Exercise 2 **Section:**_____

All work must be checked before you leave the laboratory period. You may work in groups of 2-3 and you should generate a common solution sheet. Show all your work and write up your solutions in an organized, legible format. It may or may not be collected.

1. An aircraft is traveling at 550 mph at an altitude where the ambient pressure is 6.5 psia. The exit area of the jet engine is 1.65 ft^2 and the exit jet has a relative velocity of 1500 ft/sec. The pressure at the exit plane is found to be 10 psia. Air flow is measured at 175 lbm/sec. Neglecting the weight of fuel added, determine the net propulsive thrust of this engine.

2. The air flow through a jet engine is 30 kg/sec and the fuel flow rate is 1 kg/sec. The exhaust gases leave with a relative velocity of 610 m/sec. Pressure equilibrium exists over the exit plane. Compute the velocity of the aircraft if the thrust power is 1.12 MW.

3. A boat is propelled by an hydraulic water jet. The inlet scoop has an area of 0.5 ft^2 and the exit nozzle has an area of 0.2 ft^2. Since the exit velocity will always be subsonic, pressure equilibrium exists at the exit plane. No spillage occurs at the inlet as the craft is moving through fresh water at 50 mph.

    a. Calculate the net propulsive thrust being developed.

    b. What is the propulsive efficiency?

    c. How much energy is added to the water as it passes through the device (assume no losses)?

4. A ramjet missile flies at Mach 4 at 30,000 ft altitude. The exhaust nozzle diameter is 18 in. The exhaust jet velocity is 5000 ft/sec relative to the missile, and is 1800°R and 850 psf (absolute). Neglecting the weight of the fuel added, determine the net propulsive thrust of this engine. How much thrust power is developed (in HP)?

5. A twinjet requires a total propulsive thrust of 6,000 lbs. Each engine consumes air at 120 lbm/sec when traveling 650 ft/sec. Fuel is added to each engine at 3.0 lbm/sec. The nozzle exit diameter is 20″ and there is a 3.5 psi overpressure at the exit plane. Compute the relative velocity of the exhaust stream. What is this in the absolute (i.e., earth) frame of reference?

$\boxed{1}$ $V_1 = 550 \text{ mph} = 806.7 \text{ fps}$

$P_1 = P_{amb} = 6.5 \text{ psia}$

$V_3 = 1500 \text{ fps}$

$\dot{m} = 175 \text{ lbm/sec} = 5.435 \text{ slug/sec.}$

$$T_{net} = \dot{m}_3 V_3 - \dot{m}_1 V_1 + (P_3 - P_1) A_3$$

$$= \dot{m}(V_3 - V_1) + (P_3 - P_1) A_3$$

$$= 5.435 \frac{\text{slug}}{\text{sec}} (1500 - 806.7 \text{ fps})$$

$$+ (10 - 6.5 \text{ psia})(144 \text{ in}^2/\text{ft}^2)(1.65 \text{ ft}^2)$$

$$= 3{,}768 + 832 = \boxed{4{,}600 \text{ lbs}}$$

$\boxed{2}$

$\dot{m}_1 = 30$ kg/sec

$\dot{m}_f = 1$ kg/sec

$\dot{m}_3 = \dot{m}_1 + \dot{m}_f = 31$ kg/sec

$V_3 = 610$ m/sec

$P_3 = P_{amb} = P_1$

$$T_{net} = \dot{m}_3 V_3 - \dot{m}_1 V_1 + \cancelto{0}{(P_3 - P_1)} A_3$$

$$T_{net} V_1 = \dot{m}_3 V_3 V_1 - \dot{m}_1 V_1^2 = 1.12 \times 10^6 \text{ W}$$

$$\left(31 \frac{kg}{s}\right)\left(610 \frac{m}{s}\right) V_1 - \left(30 \frac{kg}{s}\right) V_1^2 = 1.12 \times 10^6 \text{ W}$$

OR $\quad 30 V_1^2 - 18{,}910 V_1 + 1.12 \times 10^6 = 0$

$$\boxed{V_1 = \begin{cases} 66 \text{ m/sec} \\ 564 \text{ m/sec} \end{cases}}$$

Two possible velocities at the same thrust power level.

$\boxed{3}$ Water is incompressible!

$A_2 = 0.5\ ft^2$ $\quad \rho = 1.94\ slug/ft^3$

$A_3 = 0.2\ ft^2$

Assume $V_2 = V_1 = 50\ mph = 73.33\ fps$

$$V_3 = V_2 \frac{A_2}{A_3} = 73.33\left(\frac{0.5}{0.2}\right) = 183.33\ fps$$

$$\dot{m} = \rho_2 V_2 A_2 = (1.94)(73.33)(0.5) = 71.13\ \frac{slug}{sec}$$

a) $T_{net} = \dot{m}_3 V_3 - \dot{m}_1 V_1 + \underbrace{(p_3 - p_1)}_{0} A_3$

$$= \dot{m}(V_3 - V_1) = (71.13)(183.33 - 73.33)$$

$$= \boxed{7{,}824\ lbs}$$

b) $\nu = V_1/V_3 = \dfrac{73.33}{183.33} = 0.400$

$$\eta_p = \frac{2\nu}{1+\nu} = 0.57 \rightarrow \boxed{57\%}$$

c) Pressure-Energy Eqn...

$$\cancel{\frac{p_2}{\rho}} + \frac{1}{2}V_2^2 + \cancel{gh_2} + \Delta e = \cancel{\frac{p_3}{\rho}} + \frac{1}{2}V_3^2 + \cancel{gh_3}$$

$$\Delta e = \frac{1}{2}(V_3^2 - V_2^2) = \boxed{14{,}116\ ft\text{-}lb/slug}$$

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$\boxed{4}$ $d_3 = 18\text{ in} = 1.5\text{ ft.}$

$A_3 = \pi d_3^2/4 = 1.767\text{ ft}^2$

$V_3 = 5000\text{ fps}$

At $h = 30{,}000\text{ ft}$, $p_1 = 4.364\text{ psia}$

$T_1 = 411.7\,°R$

$a_1 = \sqrt{\gamma R T_1} = 994.5\text{ fps}$

$V_1 = M_1 a_1 = 4(994.5) = 3{,}978\text{ fps}$

$$\rho_3 = \frac{p_3}{RT_3} = \frac{850\text{ psf}}{(1716)(1800\,°R)} = 2.752\times10^{-4}\ \frac{\text{slug}}{\text{ft}^3}$$

$$\dot{m}_1 \approx \dot{m}_3 = \rho_3 V_3 A_3 = (2.752\times10^{-4})(5000)(1.767)$$

$$= 2.431\text{ slug/sec}$$

$$T_{net} = \dot{m}_3 V_3 - \dot{m}_1 V_1 + (p_3 - p_1) A_3$$

$$= \dot{m}(V_3 - V_1) + (p_3 - p_1) A_3$$

$$= 2.431(5000 - 3978) + (850 - 4.364\times144)(1.767)$$

$$= 2{,}484 + 392 = \boxed{2{,}876\text{ lbs}}$$

$$THP = \frac{TV_1}{550} = \frac{(2876)(3978)}{550} = \boxed{20{,}810\text{ HP}}$$

$\boxed{5}$ $T_{net} = 3000$ lbs per engine.

$\dot{m}_1 = 120$ lbm/sec $= 3.727$ slug/sec

$V_1 = 650$ fps

$\dot{m}_3 = \dot{m}_1 + \dot{m}_f = 120 + 3 = 123$ lbm/sec

$= 3.820$ slug/sec

$d_3 = 20$ in $= 1.667$ ft

$A_3 = \frac{\pi d_3^2}{4} = 2.182$ ft^2

Exit overpressure: $p_3 - p_1 = 3.5$ psi

$$T_{net} = \dot{m}_3 V_3 - \dot{m}_1 V_1 + (p_3 - p_1) A_3$$

$$3000 = 3.820 V_3 - 3.727(650) + (3.5 \times 144)(2.182)$$

$$\boxed{V_3 = 1{,}132 \text{ fps}}$$

Absolute frame of reference: $1{,}132 - 650$

$= \underline{482 \text{ fps}}$