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AEEM6042 Module 3 Assignment

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Problem 1

substitute temp and pressure ratios

$$\frac{T_{t0}}{T_0} = \tau_r$$

$$\frac{P_{t2}}{P_0} = \frac{P_{t0}}{P_0} \cdot \frac{P_{t2}}{P_{t0}} = \pi_r \pi_d$$

$$\pi_r = \left(1 + \frac{\gamma - 1}{2} M_0^2\right)^{\frac{\gamma}{\gamma-1}}$$

$$\tau_r = 1 + \frac{\gamma - 1}{2} M_0^2 \rightarrow \pi_r = \tau_r^{\frac{\gamma}{\gamma-1}}$$

plug in and cancel

$$\eta_d = \frac{\left(\tau_r^{\frac{\gamma}{\gamma-1}} \pi_d\right)^{\frac{\gamma-1}{\gamma}} - 1}{\tau_r - 1}$$

$$\boxed{\eta_d = \frac{\tau_r \pi_d^{\frac{\gamma-1}{\gamma}} - 1}{\tau_r - 1}}$$

Problem 2

from SL-S assumption:

$$T_0 = T_{t0} = 288.15\text{K}; \quad \gamma = 1.4$$

$$\tau_c = \pi_c^{\frac{\gamma-1}{\gamma e_c}} \rightarrow \pi_c = \tau_c^{\frac{\gamma e_c}{\gamma-1}}$$
$$\tau_c = \frac{T_{t3}}{T_{t2}}$$

assuming no inlet or fan:

$$T_{t2} = T_{t0}$$

Part A

$$T_{t3} = 900\text{K}$$

$$\pi_c = \left(\frac{900}{288.15}\right)^{\frac{1.4(0.9)}{1.4-1}}$$
$$\boxed{\pi_c = 36.15}$$

Part B

$$T_{t3} = 1300\text{K}$$

$$\pi_c = \left(\frac{1300}{288.15}\right)^{\frac{1.4(0.9)}{1.4-1}}$$
$$\boxed{\pi_c = 115.1}$$

Problem 3

In [24]:
```
import numpy as np


# given vals from table (P in psia, T in degR)
Pt2 = 14.7
Tt2 = 59. + 459.67
Pt25 = 47.5
Tt25 = 307. + 459.67
Pt13 = 47.5
Tt13 = 307. + 459.67
Pt3 = 387.7
Tt3 = 1000. + 459.67
Pt4 = 350.5
Tt4 = 2739.
Pt5 = 44.8
```

```
Pt6 = Pt5
Tt5 = 1362. + 459.67
Tt6 = Tt5
Pt16 = 42.8
Tt16 = 331. + 459.67
Pt6A = 43.7
Tt6A = 989. + 459.67
Pt7 = 39.5
Tt7 = 3167. + 459.67
alpha = 0.63                # bypass ratio
T = 23.77*1000.             # thrust (lbf)
mdot = 228.                 # mass flow (lbm/s)

# given vals for air
yc = 1.4                    # spec. heat ratio comp.
yt = 1.3                    # spec. heat ratio turb.
cp = 0.24                   # spec. heat (Btu/lbm-degR)
```

Fan and HPC

In [25]:

```
# determine temp and pres ratios
tauf = Tt13/Tt2     # fan temp ratio
tauc = Tt3/Tt25     # comp temp ratio
pif = Pt13/Pt2      # fan pres ratio
pic = Pt3/Pt25      # comp pres ratio

# calculate polytropic efficiencies from ratios and rearranged tau eqtn
ef = (yc - 1)/yc*np.log(pif)/np.log(tauf)
ec = (yc - 1)/yc*np.log(pic)/np.log(tauc)
print(f"e_f={ef:.1%}; e_c={ec:.1%}")
```

```
e_f=85.8%; e_c=93.2%
```

Turbines

In [26]:

```
# determine turbine temp and pres ratio (across both turbines)
taut = Tt5/Tt4
pit = Pt5/Pt4

# calculate polytropic efficiency from ratios and rearranged tau eqtn
et = yt/(yt - 1)*np.log(taut)/np.log(pit)
print(f"e_t={et:.1%}")
```

```
e_t=85.9%
```

Work Required

In [27]:

```
# fan power required (sees all of mdot)
Wdotf = mdot*cp*(Tt13 - Tt2)

# comp power required (sees mdot without bypass)
Wdotc = mdot/(1 + alpha)*cp*(Tt3 - Tt25)
```

```python
print(f"Wdot_f={Wdotf:.1f} Btu/s; Wdot_c={Wdotc:.1f} Btu/s")
```

```
Wdot_f=13570.6 Btu/s; Wdot_c=23264.4 Btu/s
```