# Homework 8-1

---

## Imports

[1]:
```
from thermostate import Q_, State, units
from math import pi
```

---

## Definitions

[2]:
```
# Define a four-stroke cycle
# One cycle is two revolutions of the crankshaft
units.define('rev = []')
units.define('cycle = 2*rev')
units.define('cylinder = []')

rpm = Q_(4000, 'rev/min')
bore = Q_(100, 'mm')
stroke = Q_(100, 'mm')
mep = Q_(0.6, 'MPa')
eta = Q_(0.35, 'dimensionless')
n_cyl = Q_(4, 'cylinder')
```

---

## Problem Statement

A four-cylinder four-stroke engine operates at 4000 rpm. The bore and stroke are 100 mm each, the mean effective pressure (mep) is measured as 0.6 MPa, and the thermal efficiency is 35%. Determine

1. the total power output produced, in kW,
2. the waste heat $\dot{Q}_{out}$, in kW,
3. the volumetric air intake **per cylinder**, in $\mathrm{L/(s \cdot Cylinder)}$.

## Solution

### Part 1: Total Power Output, in kW

Important Equations:

1. $\dot{W}_{net} = n_c \frac{N}{2} W_{cycle}$
2. $M_{ep} = \frac{W_{cycle}}{V_d} \Rightarrow W_{cycle} = M_{ep} \cdot V_d$
3. $V_d = \frac{\pi}{4} B^2 S$

[3]:
```
V_d = pi/4*bore**2*stroke
W_cycle = mep*V_d
W_dot_net = n_cyl * rpm/2*W_cycle
print(W_dot_net.to("kW").round(2))
```

```
62.83 kilowatt
```

**Answer:** 62.83 kW

#### Part 2: Waste Heat, in kW

Important Equations:

1. $\eta = \frac{\dot{W}_{net}}{\dot{Q}_{in}}$
2. $\Delta\dot{U} = \sum\dot{Q} - \sum\dot{W} = 0 \Rightarrow \sum\dot{Q} = \dot{W}_{net}$
3. $\sum\dot{Q} = \dot{Q}_{in} + \dot{Q}_{out}$
4. $\dot{Q}_{out} = \dot{W}_{net} - \dot{Q}_{in}$

[4]:
```
Q_in = W_dot_net/eta
Q_out = W_dot_net - Q_in
print(Q_out.to("kW").round(2))
```

```
-116.69 kilowatt
```

**Answer:** 116.69 kW out of the system

#### Part 3: Volumetric Air Intake, in L/s/cylinder

Volumetric Air intake $= \frac{4V_d\frac{N}{2}}{n_c}$

*We use $4V_d$ because the volume displaced is 4 times one cyclinders displacement*

[5]:
```
Intake = (4*V_d*(rpm/2)/n_cyl)
print(Intake.to("L/s/cylinder").round(2))
```

```
26.18 liter / cylinder / second
```

**Answer:** 26.18 L/s/cylinder

# Homework 8-2

---

## Imports

[1]:
```python
from thermostate import State, Q_, units
```

---

## Definitions

[2]:
```python
# Define a four-stroke cycle
# There are 2 revolutions per cycle
units.define('rev = []')
units.define('cycle = 2*rev')
units.define('cylinder = []')

substance = 'air'

T_1 = Q_(25, 'degC')
p_1 = Q_(95, 'kPa')
V_1 = Q_(3, 'L/cylinder')

r = Q_(18, 'dimensionless')
r_c = Q_(3, 'dimensionless')

rpm = Q_(1700, 'rev/min')
n_c = Q_(4, 'cylinder')
```

---

## Problem Statement

A four-cylinder four-stroke cold-air-standard Diesel engine has a BDC volume of 3 L/cylinder. The engine operates on the cold-air-standard Diesel cycle with a compression ratio of 18 and a cutoff ratio of 3. Air as at 25 °C, 95 kPa at the beginning of the compression process. Determine

1. the amount of power delivered by the engine at 1700 rpm, in kW,
2. the cycle's thermal efficiency.

## Solution

### Part 1: Power Delivered, in kW

*Hint:* You only need to use the `State` class once to set an ambient state. You can calculate all necessary properties using the Ideal Gas Law and the equations found in Chapter 9.3 of the textbook.

Imporant Equations:

1. $\dot{W}_{net} = n_c \cdot \frac{N}{2} \cdot W_{cycle}$
2. $W_{cycle} = W_{1-2} + W_{2-3} + W_{3-4}$

Getting $W_{1-2}$:

1. $W_{1-2} = m(u_1 - u_2) = mc_v(T_1 - T_2)$
2. $v_1 = \frac{RT_1}{p_1}$
3. $T_2 = T_1 r^{k-1}$
4. $m = \frac{V_1}{v_1}$

[3]:
```
ambient = State(substance,p=p_1,T=T_1)
c_p = ambient.cp
c_v = ambient.cv
k = c_p/c_v
R = c_p-c_v
v_1 = R*T_1/p_1
T_2 = T_1*r**(k-1)
m = V_1/v_1
W_12 = m*c_v*(T_1-T_2)
print(W_12.to("kJ").round(2))
```

```
-1.56 kilojoule
```

Getting $W_{2-3}$:

1. $W_{2-3} = mp_2(v_3 - v_2)$
2. $v_2 = v_1/r$
3. $p_2 = \frac{RT_2}{v_2}$
4. Since $(p_2 = p_3)$ Charles law says: $\frac{T_3}{T_2} = \frac{v_3}{v_2} \Rightarrow T_3 = T_2 r_c$
5. $v_3 = \frac{RT_3}{p_3}$

[4]:
```
v_2 = v_1/r
p_2 = R*T_2/v_2
p_3 = p_2
T_3 = T_2*r_c
v_3 = R*T_3/p_3
W_23 = m*p_2*(v_3-v_2)
print(W_23.to("kJ").round(2))
```

```
1.82 kilojoule
```

Getting $W_{3-4}$:

1. $W_{3-4} = mc_v(T_3 - T_4)$
2. $T_4 = T_3 \left(\frac{v_3}{v_4}\right)^{k-1}$

3. $v_4 = v_1$

[5]:
```
v_4 = v_1
T_4 = T_3*(v_3/v_4)**(k-1)
W_34 = m*c_v*(T_3-T_4)
print(W_34.to("kJ").round(2))
```

```
3.49 kilojoule
```

All Together Now:

[6]:
```
W_cycle = W_12 + W_23 + W_34
W_dot_net = n_c*(rpm/2)*W_cycle
print(W_dot_net.to("kW").round(2))
```

```
212.57 kilowatt
```

**Answer:** 212.57 kW

### Part 2: Cycle Thermal Efficiency

Important Equations:

1. $\eta = 1 - \frac{1}{r^{k-1}}\left(\frac{r_c^k - 1}{k(r_c - 1)}\right)$

[7]:
```
eta = 1-(1/r**(k-1))*((r_c**k-1)/(k*(r_c-1)))
print(eta)
```

```
0.5906465390030452 dimensionless
```

**Answer:** 59.06%