# ECE309 Project: Spring 2014

Assigned date: June 23, 2014 Due date: July 23, 2014

The project must be completed individually. The report should be typed and be accompanied by a CD including your code. It should not exceed 11 pages, appendices extra, if needed.

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The Compressed Air Car (Air Car) has been claimed as the true car of tomorrow, with the same mileage and zero emissions as a fuel-cell car without the dangers currently associated with hydrogen. Air Cars are powered by air turbines and driven by compressed air, which is stored in a tank under high pressure, typically $30\ MPa$ ($4500\ psi$ or $300\ bar$). A schematic of the compressor unit and the Air Car is shown in Fig. 1.

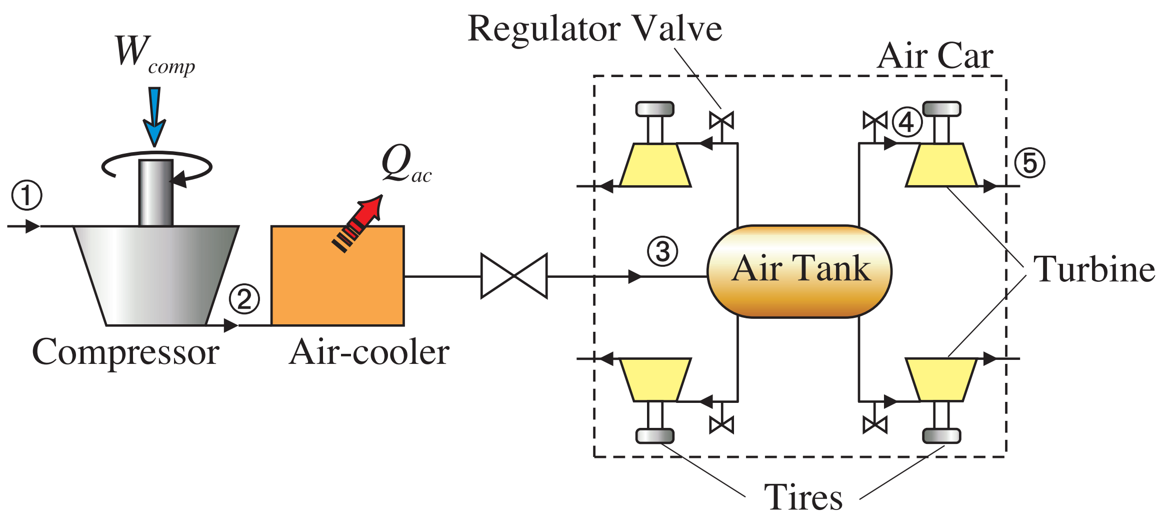



Figure 1: Schematic of the Air Car and Air Compression Process

The compressor unit (compressor and air-cooler) is not a part of the car.

The overall process can be described as follows:

> Air is compressed from the ambient condition (state 1) under a polytropic process, $PV^n = const$ in a compressor. The pressure ratio ($r_p = P_2/P_1$ ) of the compressor varies from $10$ to $300$ and the ambient temperature can vary from $0\ °C$ to $40\ °C$. Air is cooled to the ambient temperature (state 3) in an air-cooler and then stored in the vehicle's air tank. The volume of the air tank is $300\ L$ and it is thermally isolated. Once the air car is disconnected from the air supplier, the compressed air is transferred to the turbines to produce work and is discharged to the atmosphere. As a result of this expansion, the car starts moving and the pressure in the tank drops.

Expansion stops when the tank pressure drops to atmospheric pressure. At this point $99\%$ of the air in the tank has been discharged.

Your job is to determine:

1. The amount of work needed to fill the tank, $W_{comp}$ $[kJ]$, the heat transfer in the air-cooler, $Q_{ac}$ $[kJ]$, the amount of work produced in the turbines to move the car, $W_{turb}$ $[kJ]$ , the mass of air stored in the tank, $m_{tank}$, and the total efficiency of the Air Car, $\eta$. Consider constant ambient temperature and pressure, $T_1 = 25\ °C,\ P_1 = 100\ kPa$ and a pressure ratio, $r_p = 300$ in this part. Also consider $n = 1.51$ for the polytropic processes in the compressor.

2. If the mass of the car is $m_{car} = 380\ kg$ when the air tank is empty, the maximum possible speed is $V_{max} = 100\ km/hr$ (along a flat road), and it requires $12\ seconds$ to reach the maximum speed, calculate the maximum distance ($\Delta X_{max}$), this car can travel with one tank of air. Consider a constant friction coefficient, $f = 0.2$ for the friction resistance between the tires and the road.

   Hint: You can consider an average mass of $m_{tank}/2$ for the air tank over the duration of $\Delta X_{max}$.

3. Let the ambient temperature vary from $0\ °C$ to $40\ °C$, while the ambient pressure, $100\ kPa$ and $r_p = 300$ are constant. Plot $W_{comp},\ Q_{ac},\ W_{turb},\ \eta$ and $\Delta X_{max}$ vs. ambient temperature and discuss your results.

4. Perform the same analysis as part (3.) when the ambient temperature remains constant ($T_1 = 25\ °C$) and the pressure ratio varies from $10$ to $300$. Plot $W_{comp},\ Q_{ac},\ W_{turb},\ \eta$ and $\Delta X_{max}$ vs. pressure ratio and discuss your results.

Present your results using both tables and figures. Elaborate on your results; make recommendations based on your observations and draw conclusions. What would be the optimum working conditions for the Air Car? For parts (3.) and (4.) you should write a program to extract data and plot the results. You can use any of the popular software tools, such as Maple, Mathematica, Excel, Matlab, C++, Java, etc.

Figure 2: Air Car

## Useful Equations

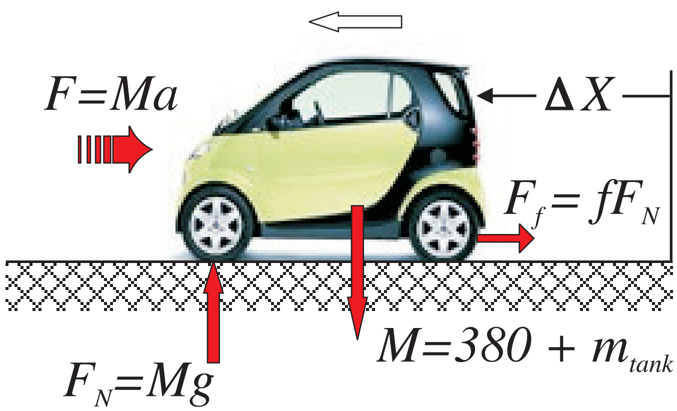



Figure 3: Force Balance

### Compressor and Turbine

$$W_{comp} = \frac{n\, m_{tank}\, R\, T_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right]$$

### Efficiency

$$\eta = \frac{\text{Benefit}}{\text{Cost}} = \frac{W_{turb}}{W_{comp}}$$

**Acceleration**

$$a = \Delta V / \Delta t$$

**Maximum Distance**

$$W_{turb} = (F + F_f)\Delta X_{max}$$

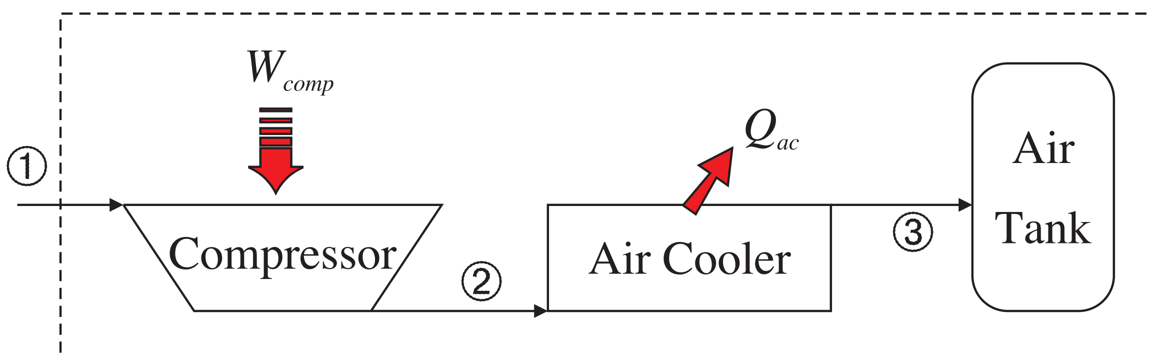
**Note (1):** When cruising, acceleration is zero, $a = 0$ .

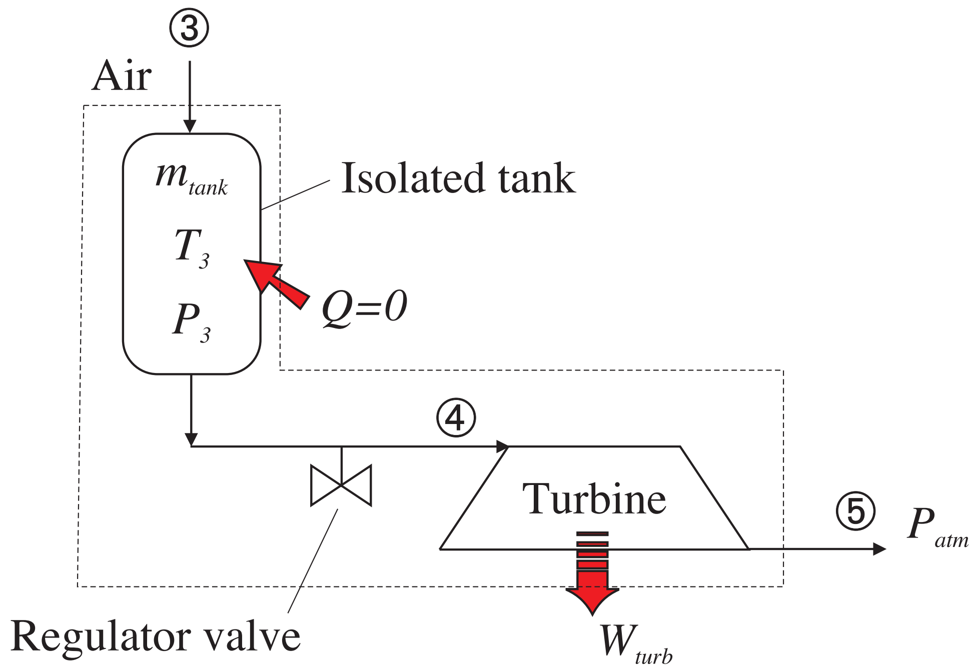
**Note (2):** Neglect the final deceleration in $\Delta X_{max}$ calculation.

Some assumptions you may consider:

- Negligible mechanical losses.
- Air is an ideal gas.
- Negligible pressure losses in pipes, joints and the air-cooler.

Suggested control volumes:



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**Report Structure**

This is an engineering report and should adhere the following structure:

**Introduction:**

- A brief description of how the Air Car works.
- A summary listing advantages and disadvantages of the Air Car.

**Analysis:**

- Justify the assumptions and simplifications.
- Control volumes and calculations.
- Plots and tables.
- Discussions of the results.
- Recommendations and suggestions.

**Conclusions and Summary:**