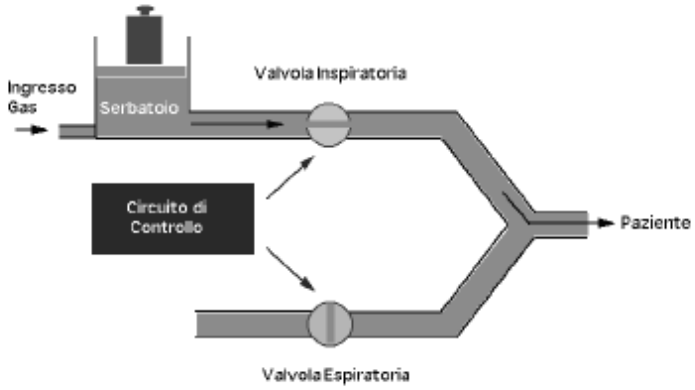
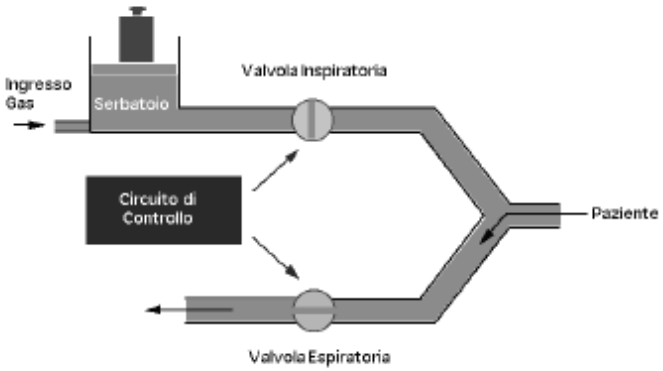
MECHATRONICS – EXAM MAY 19th 2020

Candidate Name and Surname ……..

Registration N° …….





Respiratory failure is one of the most common complications related to COVID-19, the infection triggered by the new coronavirus that emerged in China. As many as 10 percent of affected patients need intensive care treatment, basically to be treated with mechanical ventilation or artificial ventilation and support their breathing. This life-saving procedure takes place through a medical device that is present in each intensive care unit (ICU): the pulmonary ventilator.

The pulmonary ventilator is a medical device that has the purpose of integrating or replacing the activity of the muscles related to breathing, i.e. the diaphragm and the intercostals. Simply put, the mechanical ventilator is a device designed to blow air (or gas mixtures) into the patient's lungs with a specific frequency and with finely calibrated pressures; stop insufflation and allow gas exchange between the alveoli and blood capillaries; promote exhalation with the release of gas (carbon dioxide) which occurs due to the elastic nature of the lungs; start a new cycle that allows you to replicate in all respects the natural lung respiration. Modern lung ventilators automatically calculate the volume of air to be conveyed to the patient based on the recorded pressures.

The air is blown into the rib cage through instruments that are typical of the so-called "intubation". The main one is the endotracheal tube, which is inserted into the patient's mouth and which, as its name suggests, passes through the trachea. In practice, trace the path to direct the air directly into the lungs. Intubation is always practiced after having put the patient to sleep, so he does not notice the insertion and removal of the tube, considered an invasive procedure.

The passage from the forced inspiratory phase to the expiratory one is obtained through the opening and closing of suitable valves as shown in the figure. The mixed air is blown into the lungs through a bellows pump (see figure) moved by an electromagnetic actuator and by monitoring the patient's ECG the frequency of the actuator is automatically adjusted based on the heart rate acquired.

1. Draw the block scheme of the acquisition/regulation chain identifying the input and output variables in every block and in particular the process variable.
2. Calculate the transfer function of the process highlighting what variable must be known.
3. Plot the Bode diagram of the loop function (process + actuator) discussing the eventual problems in terms of stability/instability. Show the numerical implementation of the regulator if it is necessary.
4. Design the circuit the drives the actuator that pumps the air in the patient's lung.
5. Briefly answer to the following questions:
   i. How many bits are needed to the microprocessor to measure the PV with a 2% accuracy and to drive the actuator and regulate the opening/closing of the valves?
   ii. What benefits are given by the cascade control? What hypothesis?
   iii. Write an analytical expression (eventually approximated) of the induced electromotive force in the second stator of the induction generator.
   iv. Why the UJT current augments after overcoming the threshold even with voltage applied to the emitter pin lower than the threshold itself?