SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)

COIMBATORE-35

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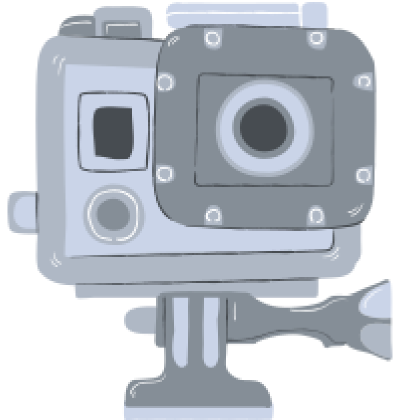
DEPARTMENT OF BIOMEDICAL ENGINEERING

COURSE NAME: 19BMT301/ BIOCONTROL SYSTEM

III YEAR / V SEMESTER

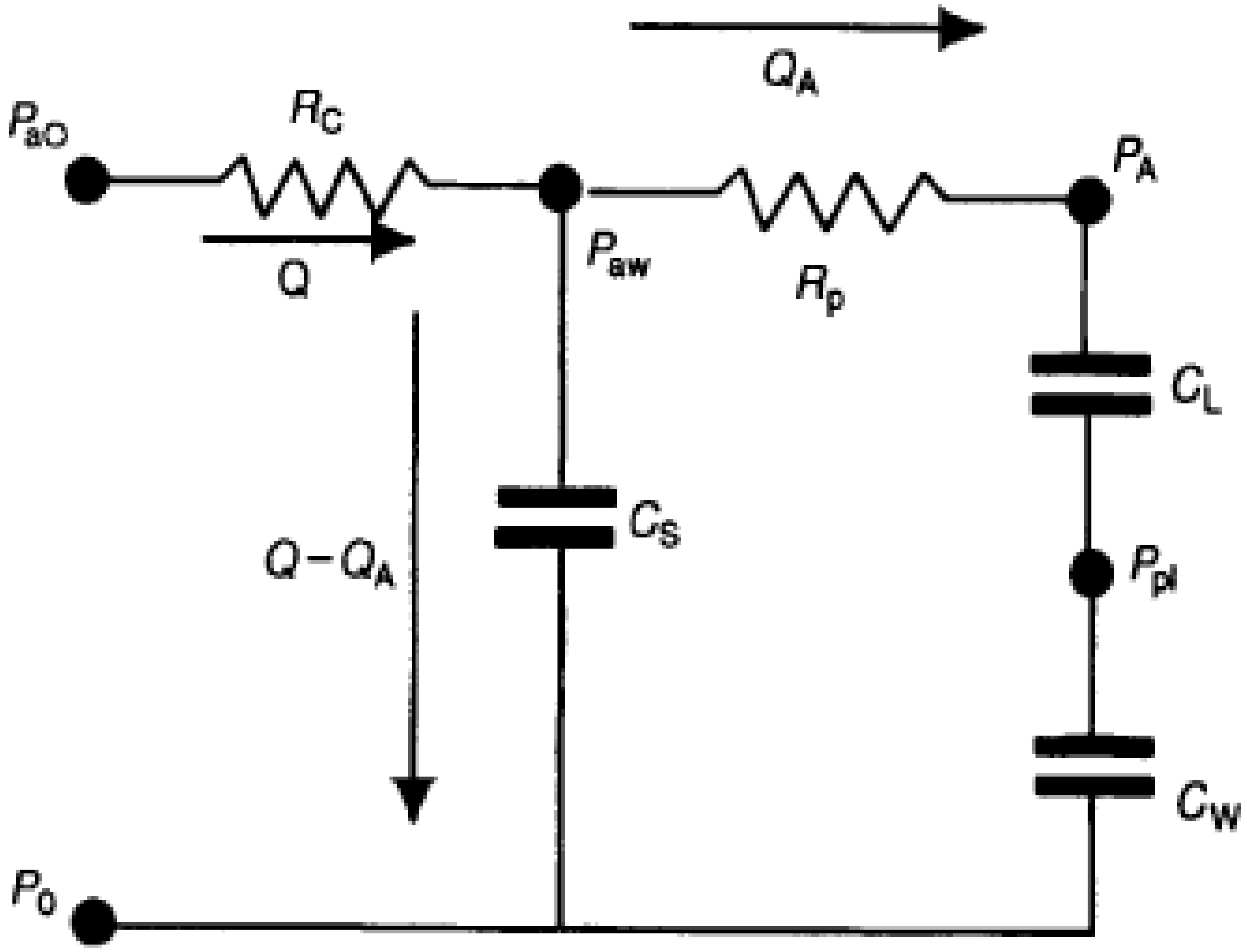
Unit 4 – Modelling of Biological System

Topic 2: Lung Model



Linear Model of Circulatory System

Linearized description of lung mechanics:



•The airways are divided into two categories: the larger or central airways and the smaller or peripheral airways, with fluid mechanical resistances equal to *Rc and Rp,* respectively.

•Air that enters the alveoli also produces an expansion of the chest-wall cavity by the same volume. This is represented by the connection of the lung (C_L) and chest-wall (C_w) compliances in series.

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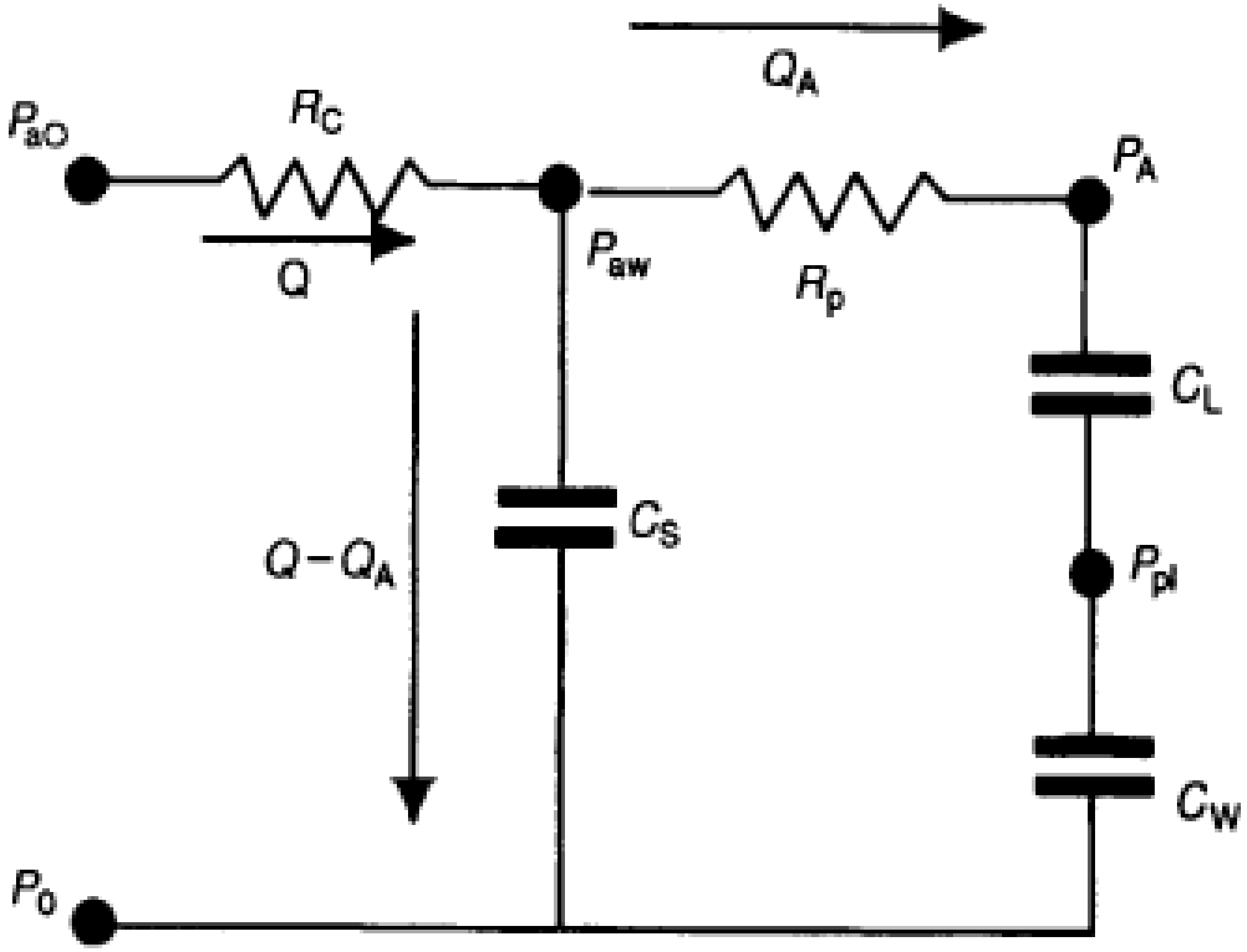


- The pressures developed at the different points of this lung model are: P_{ao} at the airway opening, P_{aw} in the central airways, P_A in the alveoli and P_{pi} in the pleural space (between the lung parenchyma and chest wall).
- These pressures are referenced to Po, the ambient pressure, which we can set to zero.

Lung Model

•A given property of the model is assumed to be "concentrated" into a single element.

•The total resistance of the central airways is "lumped" into a single quantity, Rc , even though in reality the central airways are comprised of the trachea and a few branching generations of airways, each of which has very different fluid mechanical resistance.

•Similarly, a single constant, C_L, is assumed to represent the compliance of the lungs, even though the elasticity of lung tissue varies from region to region.

•Suppose the volume flow-rate of air entering the respiratory system is *Q. Then, the objective here is to* derive a mathematical relationship between P_{ao} *and Q.*

Lung Model

- From Kirchhoff's Second Law (applied to the node P_{aw}), if the flow delivered to the alveoli is Q_A' then the flow shunted away from the alveoli must be Q - Q_A' Applying, Kirchhoff's First Law to the closed circuit containing C_s, R_p, C_L , and C_w, we have

$$R_P Q_A + \left(\frac{1}{C_L} + \frac{1}{C_W}\right)\int Q_A\, dt = \frac{1}{C_S}\int (Q - Q_A)\, dt$$

- Applying Kirchhoff's First Law to the circuit containing R_c *and* C_s, *we have*

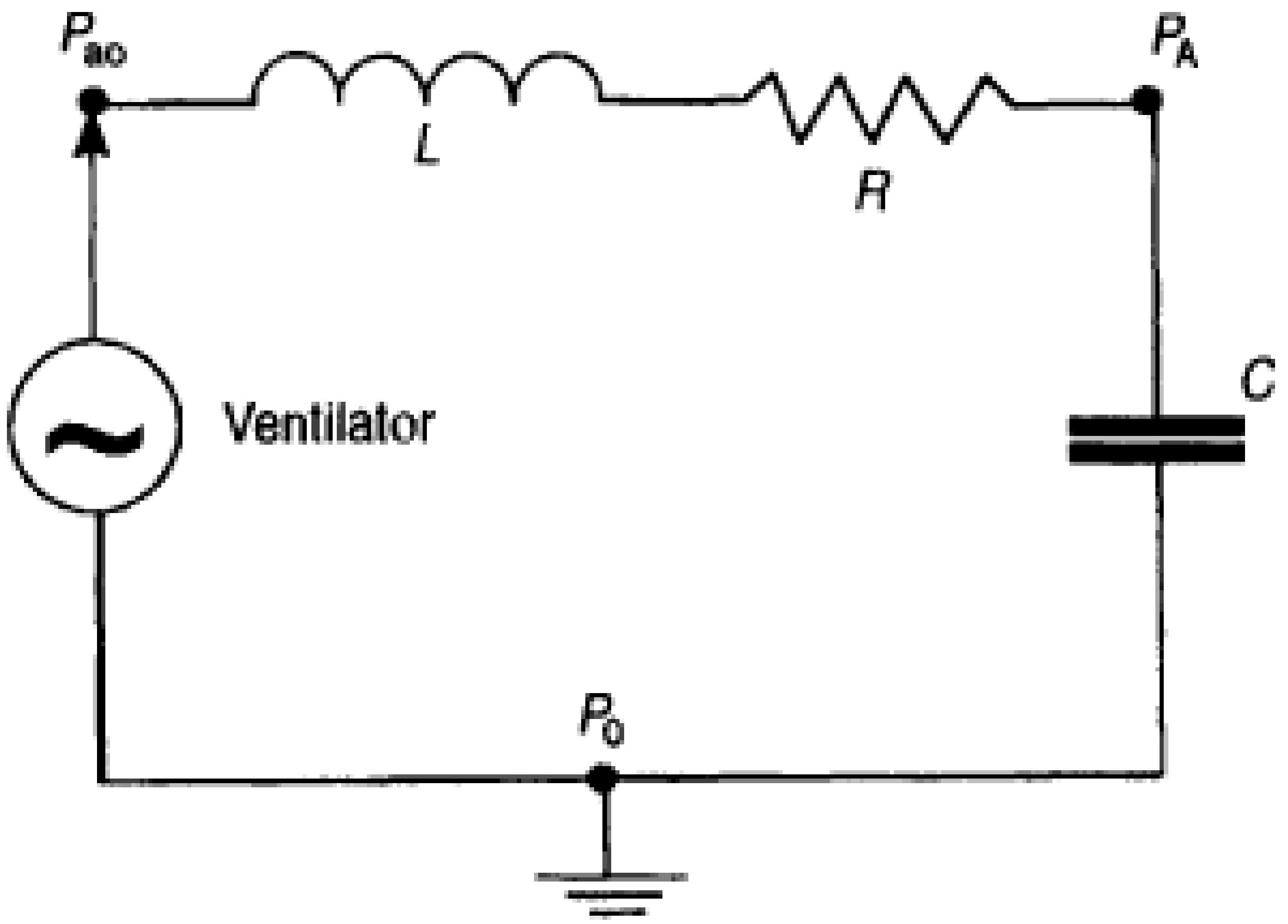
$$P_{ao} = R_C Q + \frac{1}{C_S}\int (Q - Q_A)\, dt$$

$$\frac{d^2 P_{ao}}{dt^2} + \frac{1}{R_P C_T}\frac{dP_{ao}}{dt} = R_C\frac{d^2 Q}{dt^2} + \left(\frac{1}{C_S} + \frac{R_C}{R_P C_T}\right)\frac{dQ}{dt} + \frac{1}{R_P C_S}\left(\frac{1}{C_L} + \frac{1}{C_W}\right)Q$$

$$C_T = \left(\frac{1}{C_L} + \frac{1}{C_W} + \frac{1}{C_S}\right)^{-1}$$

Analysis of Lung Model

We consider a simplified version of the linearized lung mechanics model. In addition, however, we will also add an inductance element, L, that represents fluid inertance in the airways.



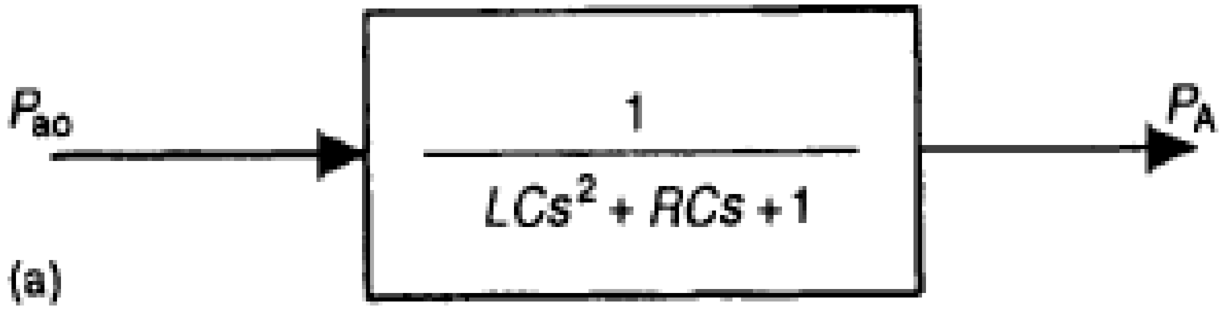
$$P_{ao} - P_0 = L\frac{dQ}{dt} + RQ + \frac{1}{C}\int Q\,dt$$

$$P_A - P_0 = \frac{1}{C}\int Q\,dt$$

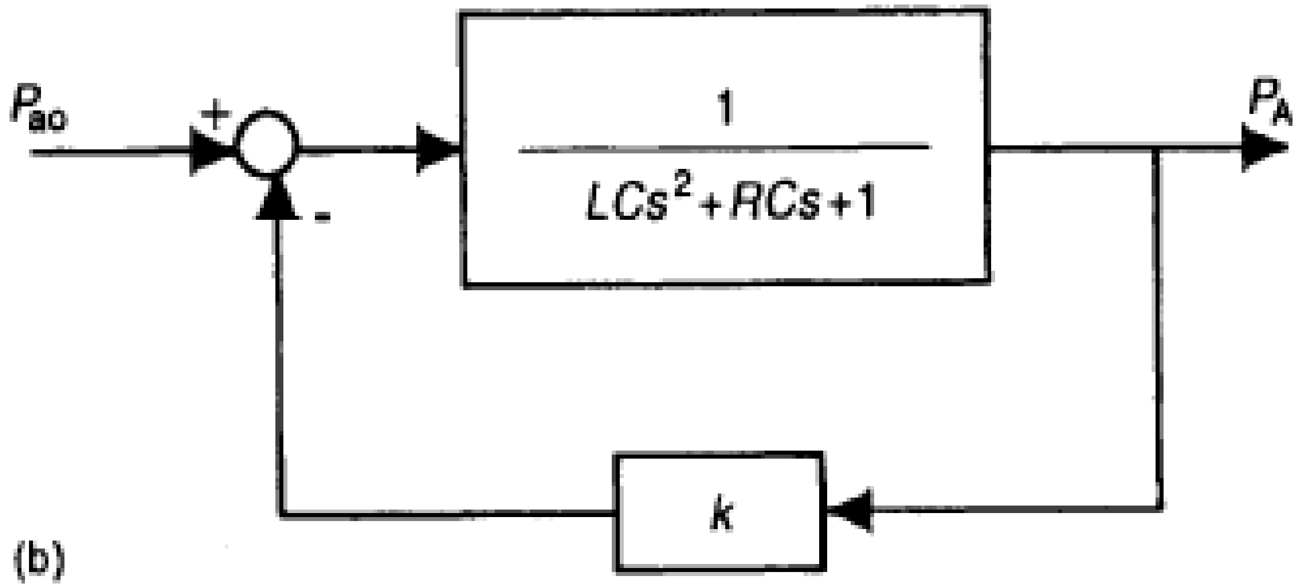
$$P_{ao} = LC\frac{d^2P_A}{dt^2} + RC\frac{dP_A}{dt} + P_A$$

$$\frac{P_A(s)}{P_{ao}(s)} = \frac{1}{LCs^2 + RCs + 1}$$

Analysis of Lung Model



(a)



(b)

$$\frac{P_A(s)}{P_{ao}(s) - kP_A(s)} = \frac{1}{LCs^2 + RCs + 1}$$

$$\frac{P_A(s)}{P_{ao}(s)} = \frac{1}{LCs^2 + RCs + (1 + k)}$$

KEEP LEARNING..

Thank u

SEE YOU IN NEXT CLASS