Advanced Dynamics
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Module No # 05
Lecture No # 21
Systems with Mass Flow – I

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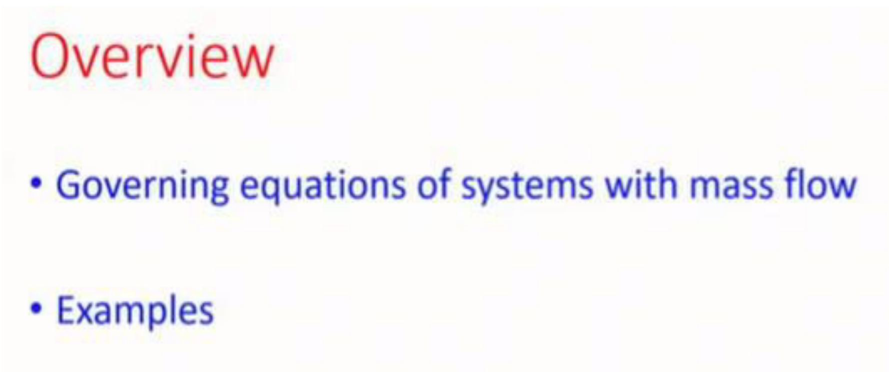

In this lecture we are going to discuss systems with mass flow.

We will start by deriving the governing equation of motion of systems with mass flow.

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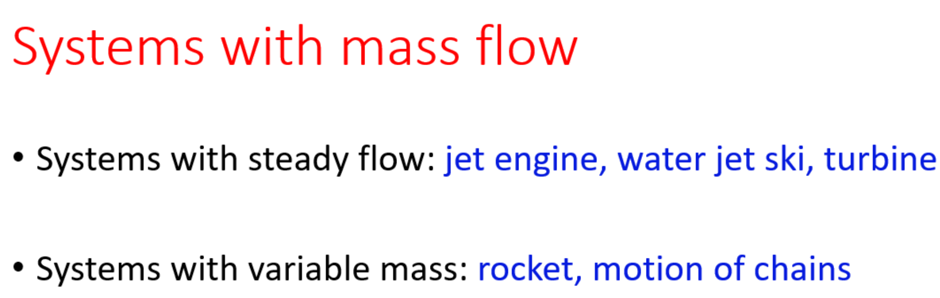

Some examples of systems with mass flow are given in the slide above.

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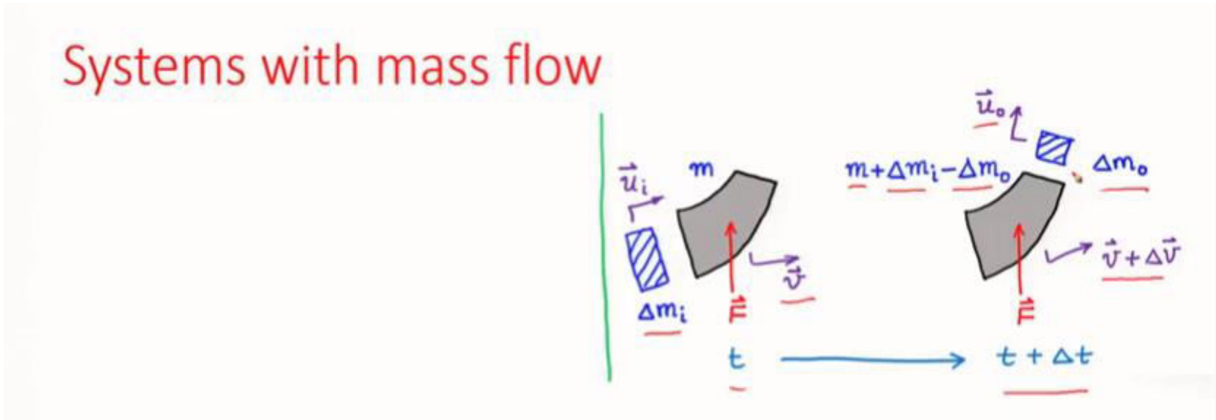

Now to derive the equation of motion of system with variable mass, we consider a body which ingests and ejects small quantities of mass as shown above in a short duration of time. The absolute velocities of the body and the two mass blobs are shown. The body is acted upon by a non-impulsive force external force F.

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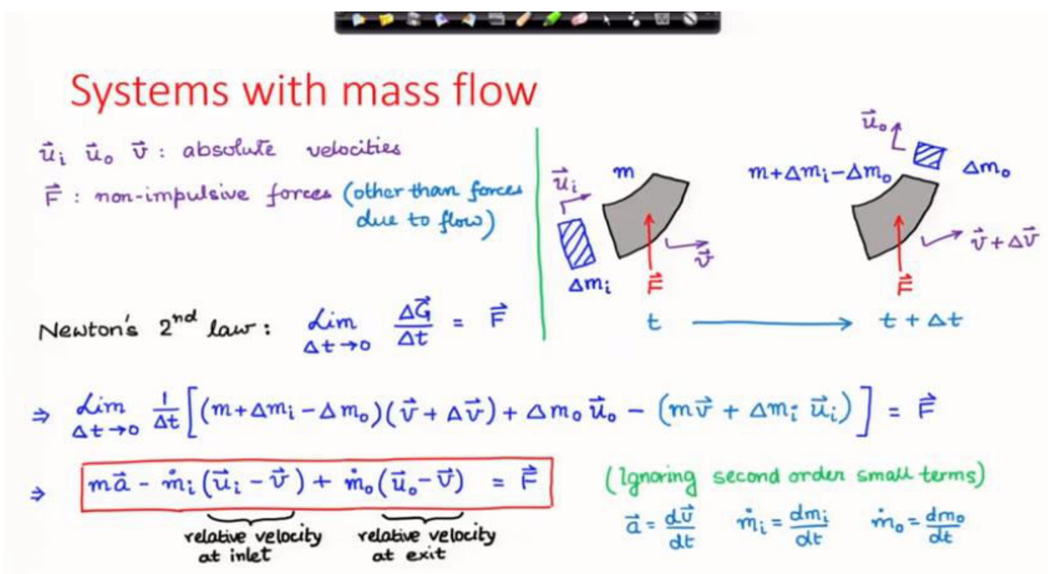

We write down Newton's second law for this system, as shown in the slide above and take the limit of the time interval to zero. Dropping second order small quantities, we obtain

$$m\vec{a} - \dot{m}_i\underbrace{(\vec{u}_i - \vec{v})}_{\text{relative velocity at inlet}} + \dot{m}_o\underbrace{(\vec{u}_o - \vec{v})}_{\text{relative velocity at exit}} = \vec{F}$$

This equation will be referred to as the master equation for mass flow systems.

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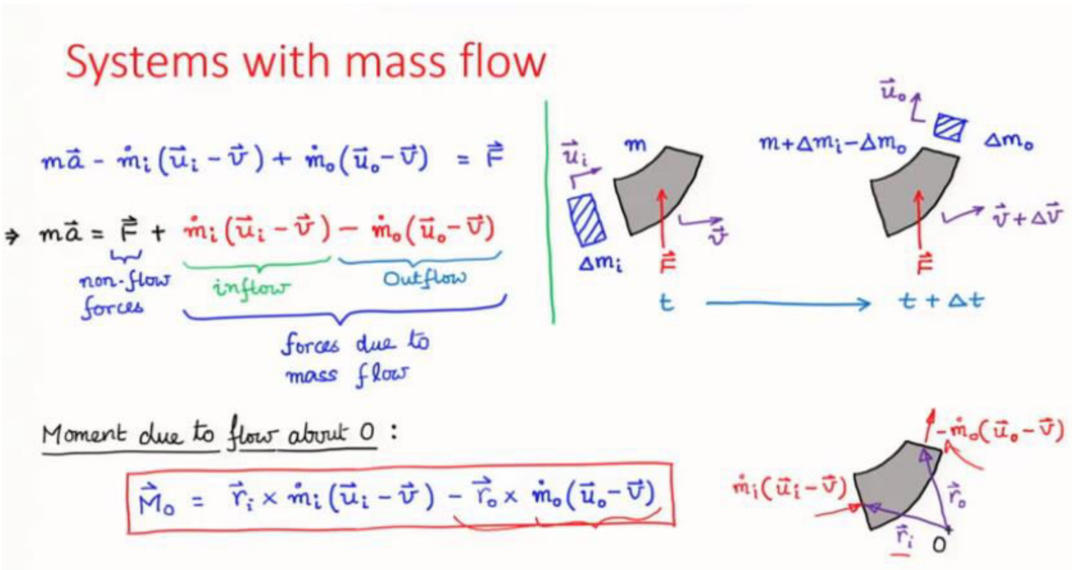

We rearrange the master equation to bring the additional terms on the left hand side to the right hand side, as shown in the slide above. These additional terms represent the flow forces due to inflow and outflow. One can also calculate the moment of the flow forces on the body about a fixed point as shown in the slide above.

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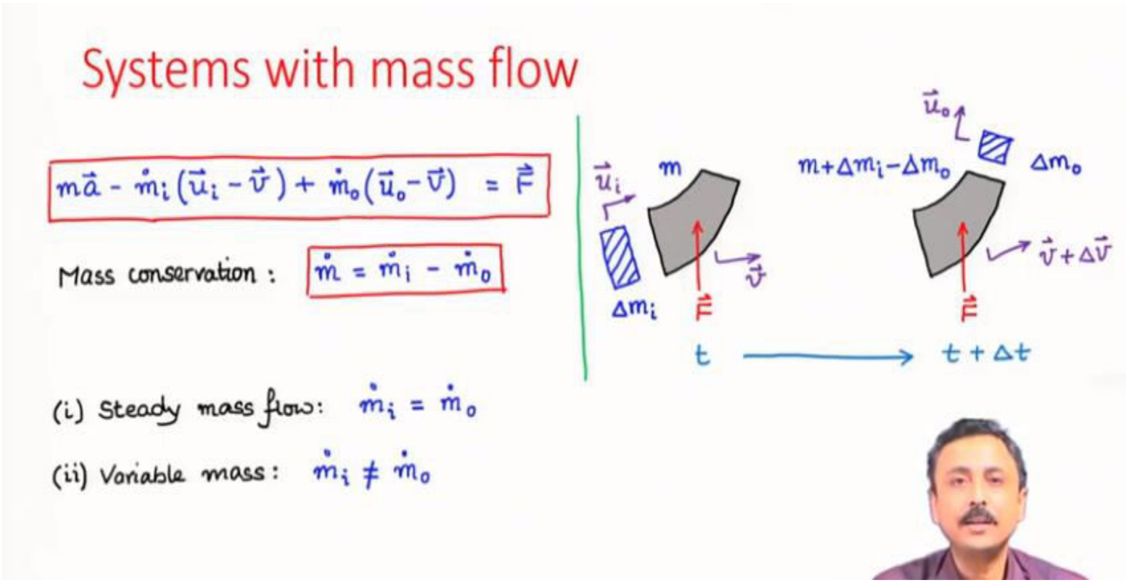

Now let us look at the mass balance of the system. This is presented in the slide above.

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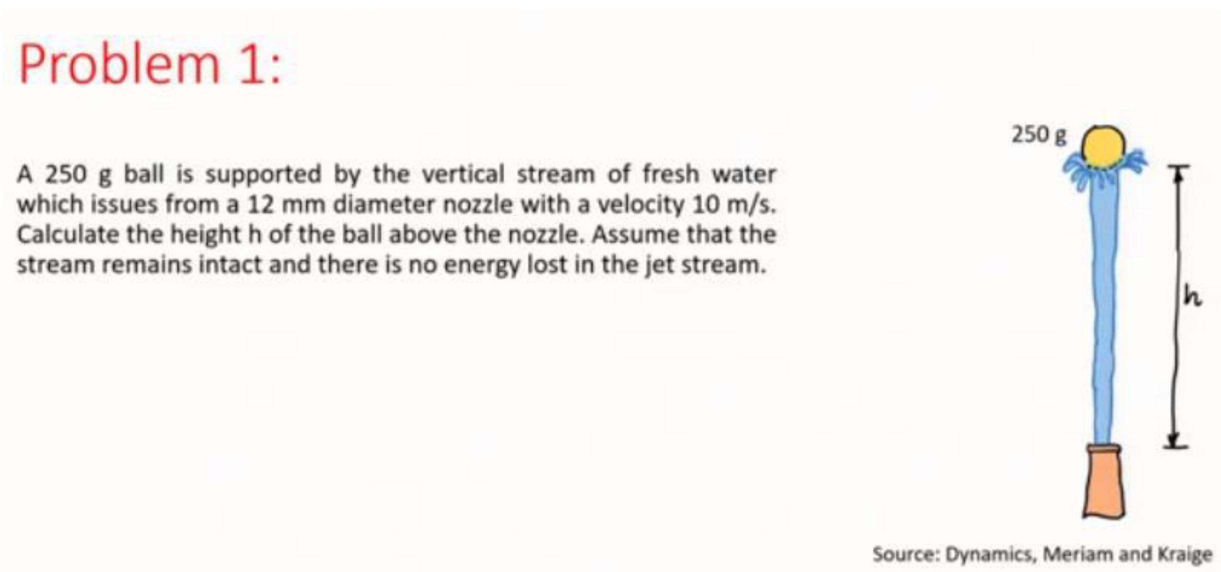

The above slide presents a problem.

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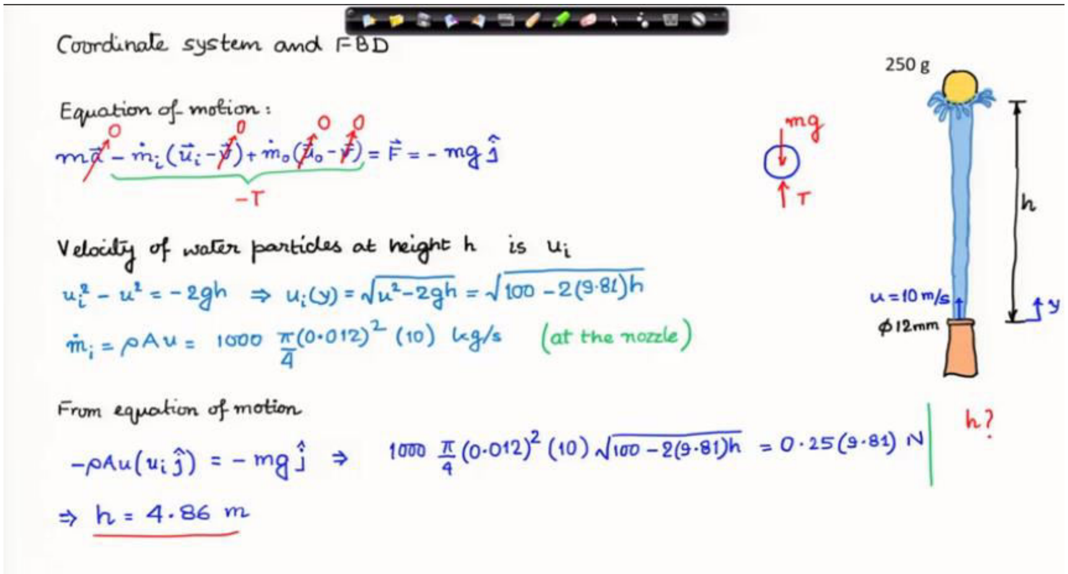

We consider our system as the ball and its surroundings. Since the ball is stationary at the balanced position, its velocity is zero. We consider that the water particles enter the system boundary at a certain velocity and come to momentary rest against the ball. This leads to some simplification of the master equation for this case, as presented in the slide above. The detailed solution is also presented in the above slide.

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A simple experiment demonstrating the balance of a small plastic ball by blowing through a straw is shown above.

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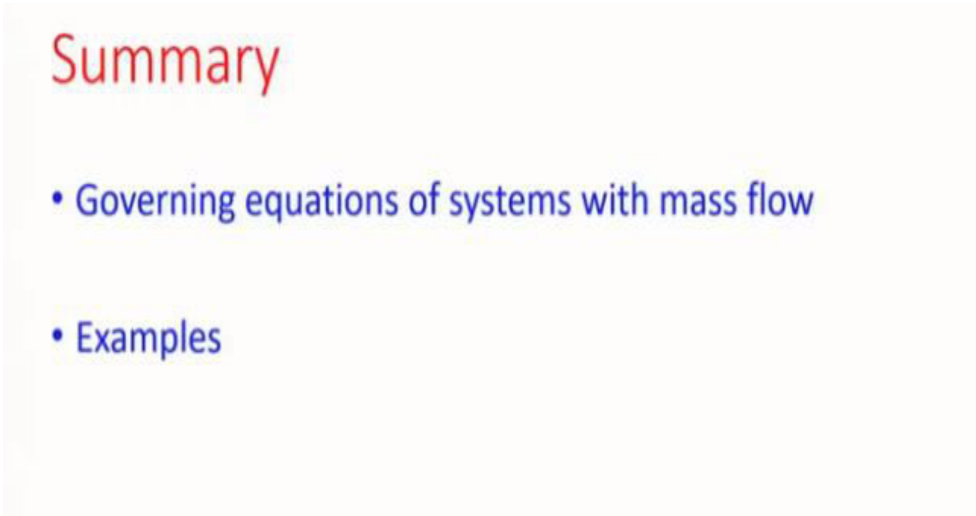

The above slide summarizes the discussions.