D'ALEMBERT'S PRINCIPLE :-

According to Newton's second law of motion, the force acting on the

$$F_i = \frac{dP_i}{dt} = \dot{P}_i$$

This can be written as

$$F_i - \dot{P}_i = 0 \quad (\text{where, } i = 1, 2, \dots N)$$

These equations mean that any particle in the system is in equilibrium under a force, which is equal to the actual force F_i plus a reversed ~~force~~ effective force $\dot{P}_i$

Therefore, for virtual displacement δr_i

$$\sum_{i=1}^{N} (F_i - \dot{P}_i) \cdot \delta r_i = 0$$

But $F_i = F_i^a + f_i$,

then,

$$\sum_{i=1}^{N} (F_i^a - \dot{P}_i) \cdot \delta r_i + \sum_{i=1}^{N} f_i \cdot \delta r_i = 0$$

Again, we restrict ourselves to the systems for which the virtual work of the constraints is zero, i.e

$$\sum_i f_i \cdot \delta r_i = 0$$

Then,

$$\sum_{i=1}^{N} (F_i^a - \dot{P}_i) \cdot \delta r_i = 0$$

This is known as D'Alembert's principle.

Since, the forces of constraints do not appear in the equation and hence, we can drop the superscript. Therefore, D'Alembert's principle written as

$$\sum_{i=1}^{N} (F_i - \dot{P}_i) \cdot \delta r_i = 0$$