

3.6: Force and Rate of Change of Momentum

Theorem:

The rate of change of the total momentum of a system of particles is equal to the sum of the external forces on the system.

Thus, consider a single particle. By Newton's second law of motion, the rate of change of momentum of the particle is equal to the sum of the forces acting upon it:

$$\dot{\mathbf{P}}_i = \mathbf{F}_i + \sum_j \mathbf{F}_{ij} \quad (j \neq i) \quad (3.6.1)$$

Now sum over all the particles:

$$\begin{aligned} \dot{\mathbf{P}}_i &= \sum_i \mathbf{F}_i + \sum_i \sum_j \mathbf{F}_{ij} \quad (j \neq i) \\ \mathbf{F} + \frac{1}{2} \sum_i \sum_j \mathbf{F}_{ij} + \frac{1}{2} \sum_j \sum_i \mathbf{F}_{ij} \\ \mathbf{F} + \frac{1}{2} \sum_i \sum_j \mathbf{F}_{ji} + \mathbf{F}_{ij} \end{aligned} \quad (3.6.2)$$

But, by Newton's third law of motion, $\mathbf{F}_{ji} + \mathbf{F}_{ij} = 0$, so the theorem is proved.

Corollary:

If the sum of the external forces on a system is zero, the linear momentum is constant. (Law of Conservation of Linear Momentum.)

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