

## 2.5 Multiplication of Vectors:

We saw that we can add or subtract vectors of the same type to get resultant vectors of the same type. However, when we multiply vectors of the same or different types, we get a new physical quantity which may either be a scalar (scalar product) or a vector (vector product). Also note that the multiplication of a scalar with a scalar is always a scalar and the multiplication of scalar with a vector is always a vector. Let us now study the characteristics of a scalar product and vector product of two vectors.

### 2.5.1 Scalar Product (Dot Product):

The scalar product or dot product of two nonzero vectors  $\vec{P}$  and  $\vec{Q}$  is defined as the product of magnitudes of the two vectors and the cosine of the angle  $\theta$  between the two vectors.

The scalar product of  $\vec{P}$  and  $\vec{Q}$  is written as,

$$\vec{P} \cdot \vec{Q} = PQ \cos \theta, \quad \text{--- (2.17)}$$

where  $\theta$  is the angle between  $\vec{P}$  and  $\vec{Q}$ .

#### Characteristics of scalar product

(1) The scalar product of two vectors is equivalent to the product of magnitude of one vector with the magnitude of the component of the other vector in the direction of the first.

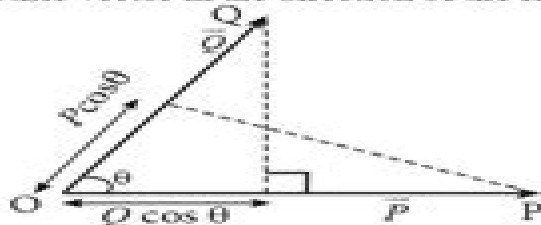


Fig. 2.9: Projection of vectors.

From Fig. 2.9,

$$\begin{aligned} \vec{P} \cdot \vec{Q} &= PQ \cos \theta \\ &= P (Q \cos \theta) \\ &= P (\text{component of } \vec{Q} \text{ in the direction of } \vec{P}) \end{aligned}$$

$$\begin{aligned} \text{Similarly } \vec{P} \cdot \vec{Q} &= Q (P \cos \theta) \\ &= Q (\text{component of } \vec{P} \text{ in the direction of } \vec{Q}) \end{aligned}$$

(2) Scalar product obeys the commutative law of vector multiplication.

$$\vec{P} \cdot \vec{Q} = PQ \cos \theta = QP \cos \theta = \vec{Q} \cdot \vec{P}$$

(3) Scalar product obeys the distributive law of multiplication

$$\vec{P} \cdot (\vec{Q} + \vec{R}) = \vec{P} \cdot \vec{Q} + \vec{P} \cdot \vec{R}$$

(4) Special cases of scalar product  $\vec{P} \cdot \vec{Q} = PQ \cos \theta$

(i) If  $\theta = 0$ , i.e., the two vectors  $\vec{P}$  and  $\vec{Q}$  are parallel to each other, then

$$\vec{P} \cdot \vec{Q} = PQ \cos \theta = PQ$$

$$\text{Thus, } \hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1$$



#### Do you know ?

Scalar and vector products are very useful in physics. They make mathematical formulae and their derivation very elegant.

Figure below shows a toy car pulled through a displacement  $\vec{S}$ . The force  $\vec{F}$  responsible for this is not in the direction of  $\vec{S}$  but is at an angle  $\theta$  to it. Component of displacement along the direction of force  $\vec{F}$  is  $S \cos \theta$ . According to the definition, the work done by a force is the product of the force and the displacement in the direction of force.  $\therefore W = FS \cos \theta$ . According to the definition of scalar product,

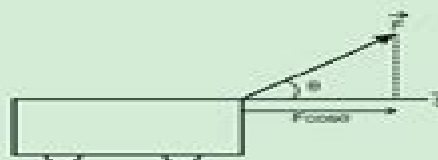
$$\vec{F} \cdot \vec{S} = FS \cos \theta$$

$$\therefore W = \vec{F} \cdot \vec{S}$$

$$\text{Also } W = F (S \cos \theta) = (F \cos \theta) S$$

Hence dot or scalar product is the product of magnitude of one of the vectors and component of the other vector in the direction of the first.

Power is the rate of doing work on a body by an external force  $\vec{F}$  assumed to be constant in time. If  $\vec{v}$  is the velocity of the body under the action of the force then power  $P$  is given by the scalar product of  $\vec{F}$  and  $\vec{v}$  i.e.,  $P = \vec{F} \cdot \vec{v}$ .



# State Board 11 Standard Physics Golden Guide

**Thomas Griffiths**



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