

Chapter 2 Solutions

Problem 2.1

Let $\mathbf{v} = \mathbf{a} \times \mathbf{b}$, or in index notation,

$$v_i \hat{\mathbf{e}}_i = a_j \hat{\mathbf{e}}_j \times b_k \hat{\mathbf{e}}_k = \epsilon_{ijk} a_j b_k \hat{\mathbf{e}}_i$$

Using index notation, show that,

- (a) $\mathbf{v} \cdot \mathbf{v} = a^2 b^2 \sin^2 \theta$,
- (b) $\mathbf{a} \times (\mathbf{b} \times \mathbf{a}) = \mathbf{0}$,
- (c) $\mathbf{a} \times (\mathbf{b} \times \mathbf{b}) = \mathbf{0}$.

Solution

(a) For the given vector, we have

$$\begin{aligned} \mathbf{v} \cdot \mathbf{v} &= \epsilon_{ijk} a_j b_k \hat{\mathbf{e}}_i \cdot \epsilon_{lmn} a_l b_m \hat{\mathbf{e}}_n = \epsilon_{ijk} \epsilon_{lmn} a_j a_l b_k b_m \delta_{ilm} = \epsilon_{ijk} \epsilon_{lmn} a_j a_l b_k b_m \delta_{ilm} \\ &= (\delta_{ij} \delta_{kl} - \delta_{il} \delta_{kj}) a_j b_k a_l b_m \delta_{ilm} = a_j a_l b_k b_m \delta_{ilm} - a_j b_k a_l b_m \delta_{ilm} \\ &= (\mathbf{a} \cdot \mathbf{a}) (\mathbf{b} \cdot \mathbf{b}) - (\mathbf{a} \cdot \mathbf{b}) (\mathbf{a} \cdot \mathbf{b}) = a^2 b^2 - (\mathbf{a} \cdot \mathbf{b} \cos \theta)^2 \\ &= a^2 b^2 (1 - \cos^2 \theta) = a^2 b^2 \sin^2 \theta \end{aligned}$$

(b) Again, we find

$$\mathbf{a} \times (\mathbf{b} \times \mathbf{a}) = \mathbf{v} \times \mathbf{a} = (\epsilon_{ijk} a_j b_k \hat{\mathbf{e}}_i) \times a_l \hat{\mathbf{e}}_l = \epsilon_{ijk} \epsilon_{lmn} a_j b_k a_l \delta_{ilm} \hat{\mathbf{e}}_n = \epsilon_{ijk} \epsilon_{lmn} a_j b_k a_l \delta_{ilm} \hat{\mathbf{e}}_n = \mathbf{0}$$

This is zero by symmetry in i and j .

(c) This is

$$\mathbf{a} \times (\mathbf{b} \times \mathbf{b}) = \mathbf{v} \times \mathbf{b} = (\epsilon_{ijk} a_j b_k \hat{\mathbf{e}}_i) \times b_l \hat{\mathbf{e}}_l = \epsilon_{ijk} \epsilon_{lmn} a_j b_k b_l \delta_{ilm} \hat{\mathbf{e}}_n = \epsilon_{ijk} \epsilon_{lmn} a_j b_k b_l \delta_{ilm} \hat{\mathbf{e}}_n = \mathbf{0}$$

Again, this is zero by symmetry in k and l .

Problem 2.2

With respect to the triplet of base vectors $\mathbf{u}_1$, $\mathbf{u}_2$, and $\mathbf{u}_3$ (not necessarily unit vectors), the triplet $\mathbf{u}^1, \mathbf{u}^2$, and $\mathbf{u}^3$ is said to be a reciprocal basis if $\mathbf{u}_i \cdot \mathbf{u}^j = \delta_{ij}$ ($i, j = 1, 2, 3$). Show that to satisfy these conditions,

$$\mathbf{u}^1 = \frac{\mathbf{u}_2 \times \mathbf{u}_3}{[\mathbf{u}_1, \mathbf{u}_2, \mathbf{u}_3]}, \quad \mathbf{u}^2 = \frac{\mathbf{u}_3 \times \mathbf{u}_1}{[\mathbf{u}_1, \mathbf{u}_2, \mathbf{u}_3]}, \quad \mathbf{u}^3 = \frac{\mathbf{u}_1 \times \mathbf{u}_2}{[\mathbf{u}_1, \mathbf{u}_2, \mathbf{u}_3]}$$

and determine the reciprocal basis for the specific base vectors

$$\begin{aligned} \mathbf{u}_1 &= 2\hat{\mathbf{e}}_1 + \hat{\mathbf{e}}_2, \\ \mathbf{u}_2 &= 2\hat{\mathbf{e}}_2 + \hat{\mathbf{e}}_3, \\ \mathbf{u}_3 &= \hat{\mathbf{e}}_1 + \hat{\mathbf{e}}_2 + \hat{\mathbf{e}}_3. \end{aligned}$$

Smartphysics 2 Solution Manual

**David Mills, Charles Adler, Edward
Whittaker**



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