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1

Answers to the exercises of chapter 1

Exercises

- 1.1 (a) $|\vec{e}_i| = 1$
(b) $\vec{e}_i \cdot \vec{e}_j = 0$ if $i \neq j$
 $\vec{e}_i \cdot \vec{e}_j = 1$ if $i = j$
(c) $\vec{e}_x \cdot (\vec{e}_y \times \vec{e}_z) = 1$
(d) Definition of a right-handed orthonormal basis.

1.2 $\vec{F}_z = \vec{e}_x - 3\vec{e}_y - 5\vec{e}_z$

- 1.3 (a)

$$\vec{a} = \begin{bmatrix} 0 \\ 0 \\ 4 \end{bmatrix} \quad \vec{b} = \begin{bmatrix} 0 \\ -3 \\ 4 \end{bmatrix} \quad \vec{c} = \begin{bmatrix} 1 \\ 0 \\ 2 \end{bmatrix}$$

- (b)

$$\begin{aligned} \vec{a} + \vec{b} &= -3\vec{e}_y + 8\vec{e}_z \\ 3(\vec{a} + \vec{b} + \vec{c}) &= 3\vec{e}_x - 9\vec{e}_y + 30\vec{e}_z \end{aligned}$$

- (c)

$$\begin{aligned} \vec{a} \cdot \vec{b} &= \vec{b} \cdot \vec{a} = 16 \\ \vec{a} \times \vec{b} &= 12\vec{e}_x \\ \vec{b} \times \vec{a} &= -12\vec{e}_x \end{aligned}$$

- (d)

$$\begin{aligned} |\vec{a}| &= 4 \\ |\vec{b}| &= 5 \end{aligned}$$

$$\begin{aligned} |\vec{a} \times \vec{b}| &= 12 \\ |\vec{b} \times \vec{a}| &= 12 \end{aligned}$$

- (e) $\phi = \arccos(\frac{4}{5})$
 (f) \vec{e}_x or $-\vec{e}_x$
 (g)

$$\begin{aligned} \vec{a} \times \vec{b} \cdot \vec{c} &= 12 \\ \vec{a} \times \vec{c} \cdot \vec{b} &= -12 \end{aligned}$$

(h)

$$\begin{aligned} \vec{a}\vec{b} \cdot \vec{c} &= 32\vec{e}_z \\ (\vec{a}\vec{b})^T \cdot \vec{c} &= -24\vec{e}_y + 32\vec{e}_z \\ \vec{b}\vec{a} \cdot \vec{c} &= -24\vec{e}_y + 32\vec{e}_z \end{aligned}$$

- (i) The vectors are independent, but not perpendicular. So the vectors \vec{a} , \vec{b} and \vec{c} form a suitable but non-orthogonal basis.

1.4

$$\begin{aligned} \vec{d} + \vec{e} &= 3\vec{a} + 2\vec{b} - 3\vec{c} \\ \vec{d} \cdot \vec{e} &= 24 \end{aligned}$$

- 1.5 (a) $\vec{a}_z = -25\vec{e}_z$
 (b) $|\vec{a}_x| = |\vec{a}_y| = 5$; $|\vec{a}_z| = 25$
 (c) $\vec{a}_x \times \vec{a}_y \cdot \vec{a}_z = 625$
 (d) $\phi = \frac{\pi}{2}$
 (e)

$$\begin{aligned} \vec{\alpha}_x &= 4/5 \vec{e}_x + 3/5 \vec{e}_y \\ \vec{\alpha}_y &= 3/5 \vec{e}_x - 4/5 \vec{e}_y \\ \vec{\alpha}_z &= -\vec{e}_z \end{aligned}$$

So the basis $\{\vec{\alpha}_x, \vec{\alpha}_y, \vec{\alpha}_z\}$ is right-handed and orthogonal.

(f)

$$\begin{aligned} \vec{b} &= 2\vec{e}_x + 3\vec{e}_y + \vec{e}_z \\ \text{so with respect to } \{\vec{e}_x, \vec{e}_y, \vec{e}_z\}, \quad \underline{b} &= [2 \ 3 \ 1]^T \end{aligned}$$

$$\vec{b} = \frac{17}{25} \vec{a}_x - \frac{6}{25} \vec{a}_y - \frac{1}{25} \vec{a}_z$$

so with respect to $\{\vec{a}_x, \vec{a}_y, \vec{a}_z\}$, $\vec{b} = \frac{1}{25} [17 \ -6 \ -1]^T$

$$\vec{b} = \frac{17}{5} \vec{\alpha}_x - \frac{6}{5} \vec{\alpha}_y - \vec{\alpha}_z$$

so with respect to $\{\vec{\alpha}_x, \vec{\alpha}_y, \vec{\alpha}_z\}$, $\vec{b} = \frac{1}{5} [17 \ -6 \ -1]^T$

- 1.6 The triple product is zero. This means that the vectors are not independent. The vector \vec{a} is lying in the plane, that is defined by the vectors \vec{b} and \vec{c} . Relation: $2\vec{a} - \vec{b} - \vec{c} = \vec{0}$.
- 1.7 Both operators are associated with a rotation.
- 1.8 (a) $a_x \vec{e}_x$
 (b) $a_x \vec{e}_x + a_y \vec{e}_y$
 (c) no effect
 (d) $a_y \vec{e}_x - a_x \vec{e}_y + a_z \vec{e}_z$
 (e) $a_x \vec{e}_x - a_y \vec{e}_y + a_z \vec{e}_z$

2

Answers to the exercises of chapter 2

Exercises

- 2.1 (a) $\vec{F} = \frac{5}{2}\sqrt{2} \vec{e}_1 + \frac{1}{2}\sqrt{2} \vec{e}_2 - 4 \vec{e}_3$
(b) $|\vec{F}| = \sqrt{29}$
- 2.2 (a) $\vec{M}_P = \vec{0}$; $\vec{M}_R = -2 \vec{e}_z$
(b) $\vec{M}_P = [0 \ 0 \ 0]^T$; $\vec{M}_R = [0 \ 0 \ -2]^T$
- 2.3 (a) 0
(b) $2F\ell$ positive if counterclockwise
(c) $F\ell$ positive if counterclockwise
(d) $2F\ell$ positive if counterclockwise
(e) $2F\ell$ positive if counterclockwise
- 2.4 $f = \frac{R}{r} F$
- 2.5 $\vec{M}_P = 6\vec{e}_x - 9\vec{e}_y$
- 2.6 $\vec{M}_S = 12\vec{e}_z$; $\vec{M}_E = 3\vec{e}_z$
- 2.7 (a) $\vec{M}_S = 3\vec{e}_y + 3\vec{e}_z$
(b) $\vec{M}_O = -2\vec{e}_x + 22\vec{e}_y + 13\vec{e}_z$