EE-321
MEDAN ELEKTROMAGNETIK I

Oleh:

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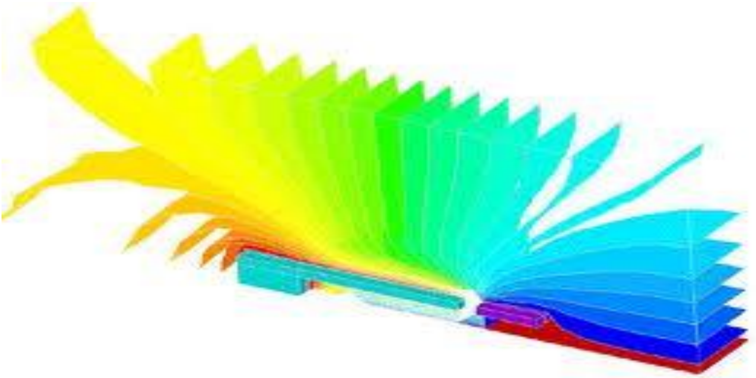

RENCANA PERKULIAHAN

MEDAN ELEKTROMAGNETIK I (EE-321)

SELASA (08.40 – 10.20) Gd. FPTK R. 01.4.11

Dosen Mata Kuliah: Wasimudin Surya S, S.T., M.T.

NO.	M A T E R I	KETERANGAN
1	ALJABAR VEKTOR	
2	SISTEM KOORDINAT & TRANSFORMASI	
3	KALKULUS VEKTOR	
4	MEDAN ELEKTROSTATIK	
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9	MEDAN ELEKTRIK DALAM BAHAN	
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12	MASALAH NILAI BATAS ELEKTROSTATIK	

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16	**UJIAN AKHIR SEMESTER**	

Pendekatan Pembelajaran

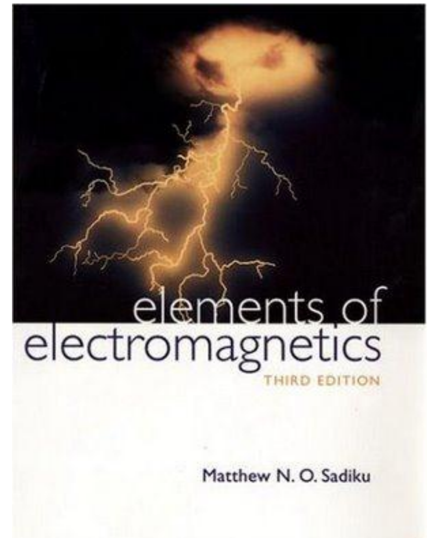
- Metode : ceramah, tanya-jawab, diskusi, *problem solving*
- Tugas : pekerjaan rumah
- Media : white board, LCD Projector

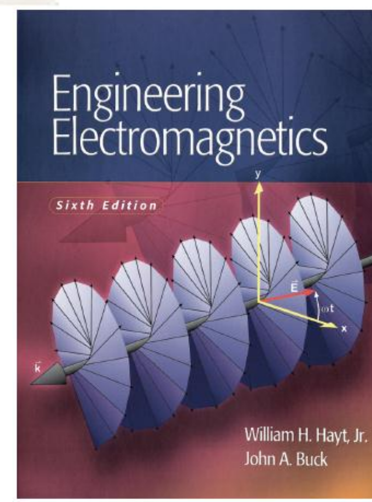
Evaluasi

- Kehadiran
- Kuis
- Tugas Rumah
- UTS
- UAS

Literatur

1. Sadiku, Matthew N.O. (2000). *Elements of Electromagnetics*. 3rd edition. Oxford University Press, USA.
2. Hayt, William H. Jr, Buck, John A. (2001). *Engineering Electromagnetics*. Sixth Edition. McGraw Hill.





1. ALJABAR VEKTOR

Electromagnetics (EM) is a branch of physics or electrical engineering in which electric and magnetic phenomena are studied.

1.1. SKALAR DAN VEKTOR

A **scalar** is a quantity that has only magnitude.

A **vector** is a quantity that has both magnitude and direction.

A **field** is a function that specifies a particular quantity everywhere in a region.

1.2. VEKTOR SATUAN

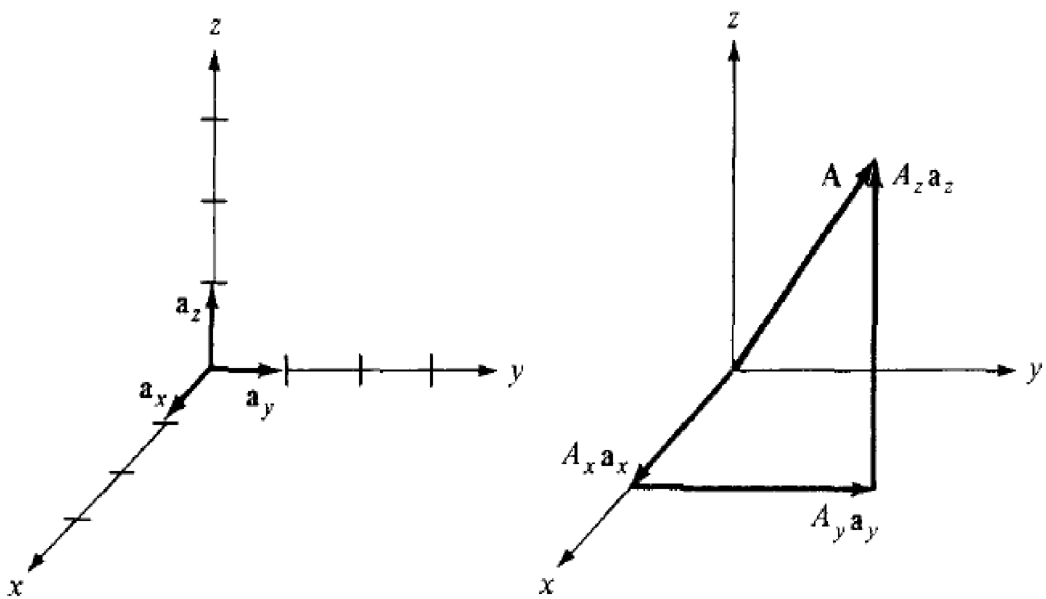
Suatu vektor **A** memiliki besar/nilai/magnitude dan arah. Besar dari **A** adalah skalar dan ditulis sebagai A atau |**A**|. Vektor satuan $\mathbf{a}_A$ sepanjang **A** didefinisikan sebagai vektor yang besarnya satu dan arahnya sepanjang **A**, yakni:

$$\mathbf{a}_A = \frac{\mathbf{A}}{|\mathbf{A}|} = \frac{\mathbf{A}}{A}$$

Catatan:
$|\mathbf{a}_A| = 1$

Jadi kita dapat menuliskan **A** sebagai **A** = A$\mathbf{a}_A$ yang secara lengkap menyatakan **A** dalam bentuk magnitude A dan arahnya $\mathbf{a}_A$.

Vektor A dalam koordinat Cartesian dapat direpresentasikan sebagai (A_x, A_y, A_z) atau $A_x\mathbf{a}_x + A_y\mathbf{a}_y + A_z\mathbf{a}_z$



$$A = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

$$\mathbf{a}_A = \frac{A_x\mathbf{a}_x + A_y\mathbf{a}_y + A_z\mathbf{a}_z}{\sqrt{A_x^2 + A_y^2 + A_z^2}}$$

(a) (b)

(a) Vektor satuan $\mathbf{a}_x$, $\mathbf{a}_y$ dan $\mathbf{a}_z$; (b) **komponen A** sepanjang $\mathbf{a}_x$, $\mathbf{a}_y$, $\mathbf{a}_z$

1.3. PENJUMLAHAN DAN PENGURANGAN VEKTOR

Dua buah vektor (misalnya **A** dan **B**) dapat dijumlahkan dan menghasilkan vektor yang lain (misalnya **C**).

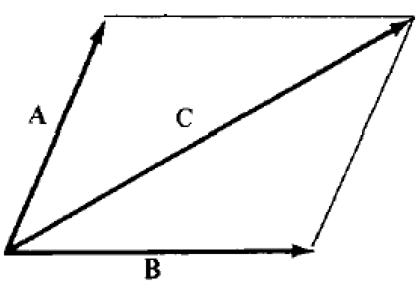
$$\mathbf{C} = \mathbf{A} + \mathbf{B}$$

$$\mathbf{A} = (A_x, A_y, A_z)$$

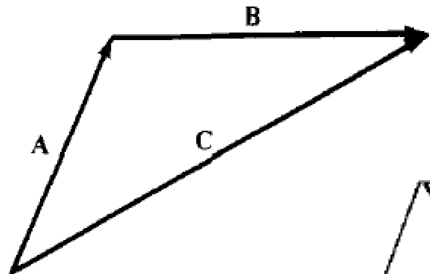
$$\mathbf{B} = (B_x, B_y, B_z)$$

$$\mathbf{C} = (A_x + B_x)\mathbf{a}_x + (A_y + B_y)\mathbf{a}_y + (A_z + B_z)\mathbf{a}_z$$

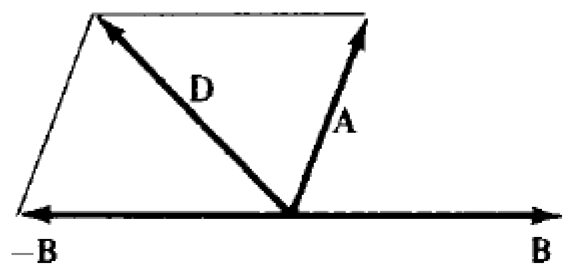
$$\begin{aligned}\mathbf{D} &= \mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B}) \\ &= (A_x - B_x)\mathbf{a}_x + (A_y - B_y)\mathbf{a}_y + (A_z - B_z)\mathbf{a}_z\end{aligned}$$



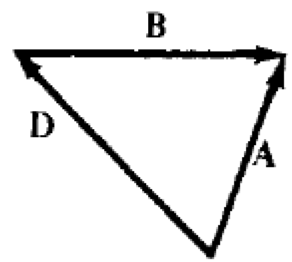
(a)



(b)



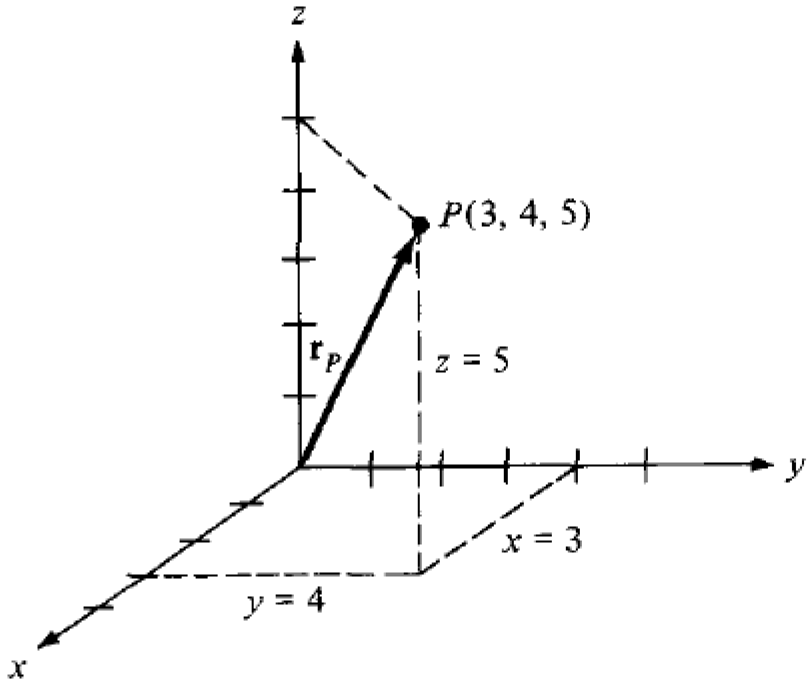
(a)



(b)

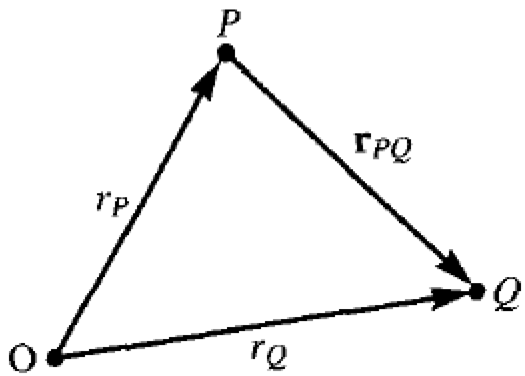
Law	Addition	Multiplication
Commutative	$\mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}$	$k\mathbf{A} = \mathbf{A}k$
Associative	$\mathbf{A} + (\mathbf{B} + \mathbf{C}) = (\mathbf{A} + \mathbf{B}) + \mathbf{C}$	$k(\ell\mathbf{A}) = (k\ell)\mathbf{A}$
Distributive	$k(\mathbf{A} + \mathbf{B}) = k\mathbf{A} + k\mathbf{B}$	

1.4. VEKTOR POSISI DAN JARAK



$$\mathbf{r}_P = OP = x\mathbf{a}_x + y\mathbf{a}_y + z\mathbf{a}_z$$

$$\mathbf{r}_P = 3\mathbf{a}_x + 4\mathbf{a}_y + 5\mathbf{a}_z.$$



$$\mathbf{r}_{PQ} = r_Q - r_P$$
$$= (x_Q - x_P)\mathbf{a}_x + (y_Q - y_P)\mathbf{a}_y + (z_Q - z_P)\mathbf{a}_z$$

Soal

Jika **A** = 10$\mathbf{a}_x$ – 4$\mathbf{a}_y$ + 6$\mathbf{a}_z$ dan **B** = 2$\mathbf{a}_x$ + $\mathbf{a}_y$, tentukan: (a) komponen **A** sepanjang $\mathbf{a}_y$, (b) magnitude dari 3**A** – **B**, (c) vektor satuan sepanjang **A** + 2**B**

(a) -4, (b) 35,74, (c) 0.9113$\mathbf{a}_x$ – 0,1302$\mathbf{a}_y$ + 0,3906$\mathbf{a}_z$

Points P and Q are located at (0, 2, 4) and (−3, 1, 5). Calculate

(a) The position vector P $2\mathbf{a}_y + 4\mathbf{a}_z$

(b) The distance vector from P to Q $(-3, -1, 1) = -3\mathbf{a}_x - \mathbf{a}_y + \mathbf{a}_z$

(c) The distance between P and Q 3.317

(d) A vector parallel to PQ with magntude of 10
$\pm(-9.045\mathbf{a}_x - 3.015\mathbf{a}_y + 3.015\mathbf{a}_z)$

1.5. PERKALIAN VEKTOR

When two vectors **A** and **B** are multiplied, the result is either a scalar or a vector depending on how they are multiplied. Thus there are two types of vector multiplication:

1. Scalar (or dot) product: $\mathbf{A} \cdot \mathbf{B}$
2. Vector (or cross) product: $\mathbf{A} \times \mathbf{B}$

Multiplication of three vectors **A**, **B**, and **C** can result in either:

3. Scalar triple product: $\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C})$ atau
4. Vector triple product: $\mathbf{A} \times (\mathbf{B} \times \mathbf{C})$

A. Dot Product

The **dot product** of two vectors **A** and **B**, written as $\mathbf{A} \cdot \mathbf{B}$, is defined geometrically as the product of the magnitudes of **A** and **B** and the cosine of the angle between them.

$$\mathbf{A} \cdot \mathbf{B} = AB \cos \theta_{AB}$$

If $\mathbf{A} = (A_x, A_y, A_z)$ and $\mathbf{B} = (B_x, B_y, B_z)$,

$$\mathbf{A} \cdot \mathbf{B} = A_xB_x + A_yB_y + A_zB_z$$

Dua vektor **A** dan **B** dikatakan tegak lurus (ortogonal) satu sama lain jika **A**.**B** = 0

Perkalian titik (*dot product*) mengikuti:

(i) *Commutative law:* $\mathbf{A} \cdot \mathbf{B} = \mathbf{B} \cdot \mathbf{A}$

(ii) *Distributive law:* $\mathbf{A} \cdot (\mathbf{B} + \mathbf{C}) = \mathbf{A} \cdot \mathbf{B} + \mathbf{A} \cdot \mathbf{C}$

$$\mathbf{A} \cdot \mathbf{A} = |\mathbf{A}|^2 = A^2$$

(iii) $\mathbf{a}_x \cdot \mathbf{a}_y = \mathbf{a}_y \cdot \mathbf{a}_z = \mathbf{a}_z \cdot \mathbf{a}_x = 0$

$$\mathbf{a}_x \cdot \mathbf{a}_x = \mathbf{a}_y \cdot \mathbf{a}_y = \mathbf{a}_z \cdot \mathbf{a}_z = 1$$

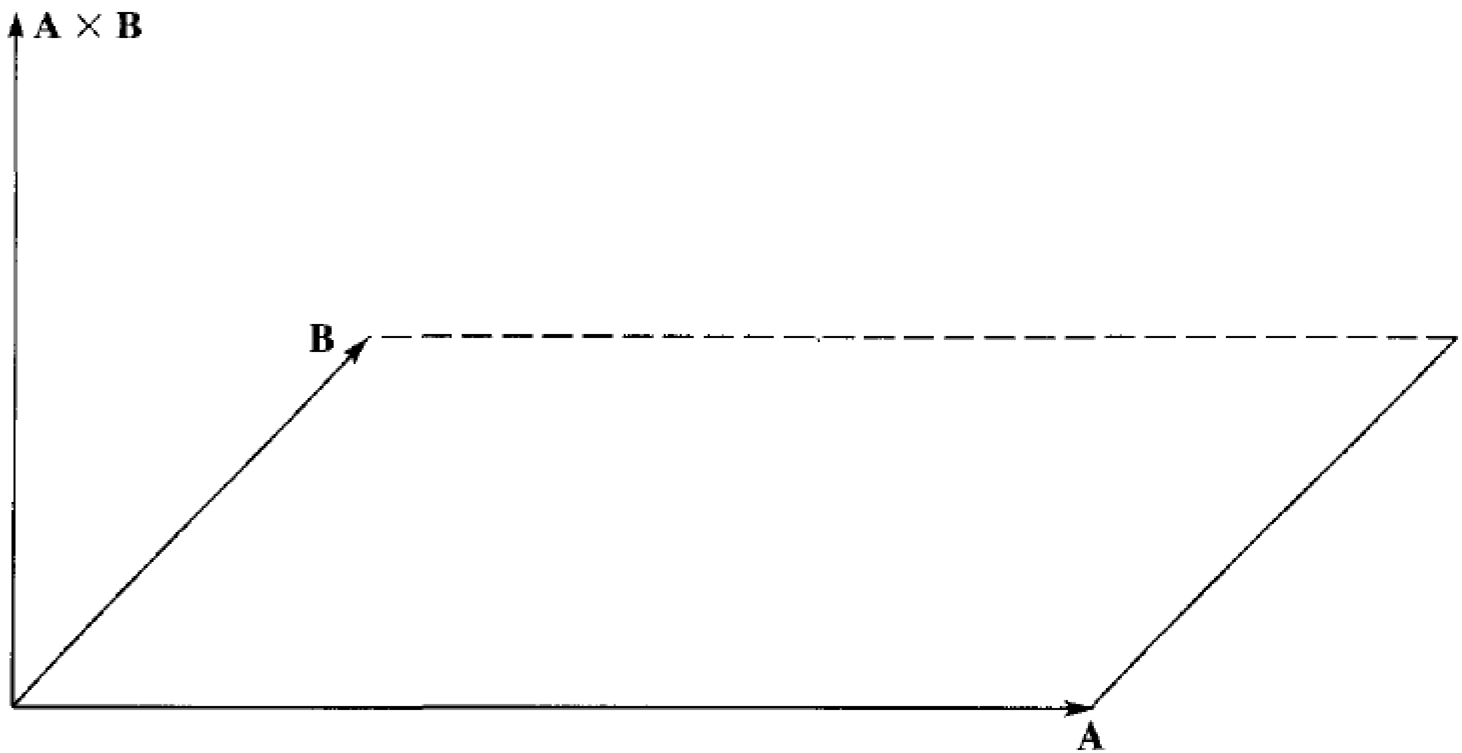
B. Cross Product

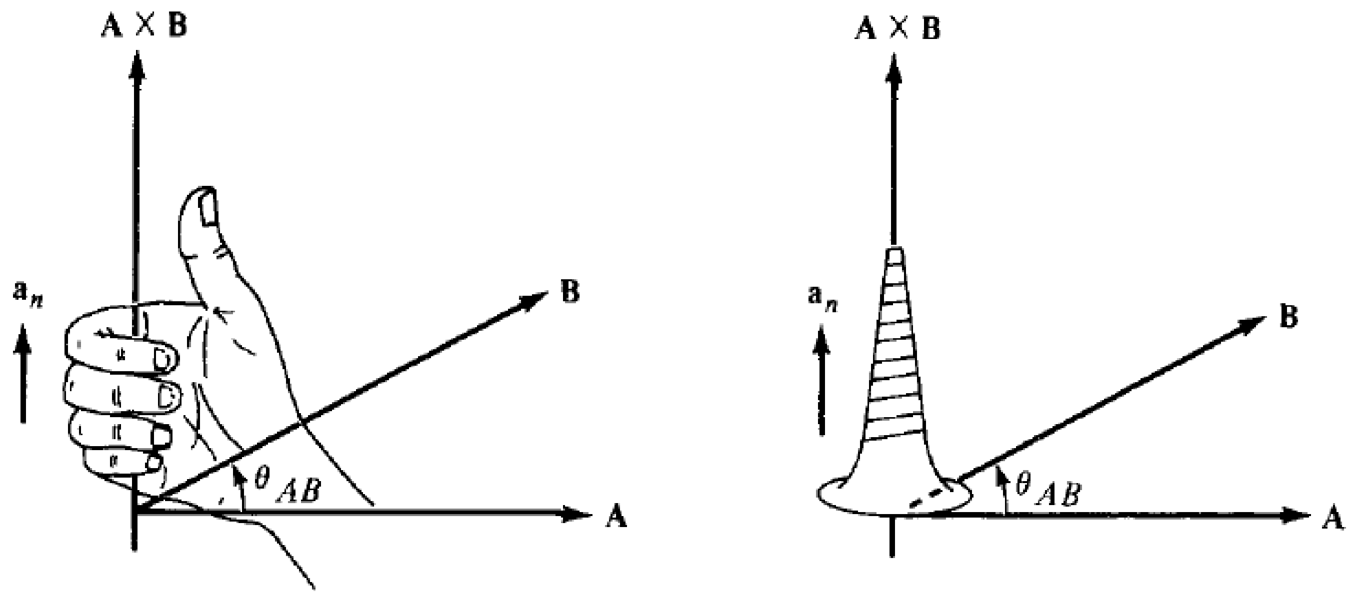
The **cross product** of two vectors **A** and **B**, written as $\mathbf{A} \times \mathbf{B}$, is a vector quantity whose magnitude is the area of the parallelopiped formed by **A** and **B** (see Figure 1.7) and is in the direction of advance of a right-handed screw as **A** is turned into **B**.

$$\boxed{\mathbf{A} \times \mathbf{B} = AB \sin \theta_{AB} \mathbf{a}_n}$$

If $\mathbf{A} = (A_x, A_y, A_z)$ and $\mathbf{B} = (B_x, B_y, B_z)$

$$\mathbf{A} \times \mathbf{B} = \begin{vmatrix} \mathbf{a}_x & \mathbf{a}_y & \mathbf{a}_z \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix} = (A_yB_z - A_zB_y)\mathbf{a}_x + (A_zB_x - A_xB_z)\mathbf{a}_y + (A_xB_y - A_yB_x)\mathbf{a}_z$$





(a) (b)

Perkalian silang (*cross product*) mengikuti sifat dasar berikut:

(i) It is not commutative:

$$\mathbf{A} \times \mathbf{B} \neq \mathbf{B} \times \mathbf{A}$$

It is anticommutative:

$$\mathbf{A} \times \mathbf{B} = -\mathbf{B} \times \mathbf{A}$$

(ii) It is not associative:

$$\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) \neq (\mathbf{A} \times \mathbf{B}) \times \mathbf{C}$$

(iii) It is distributive:

$$\mathbf{A} \times (\mathbf{B} + \mathbf{C}) = \mathbf{A} \times \mathbf{B} + \mathbf{A} \times \mathbf{C}$$

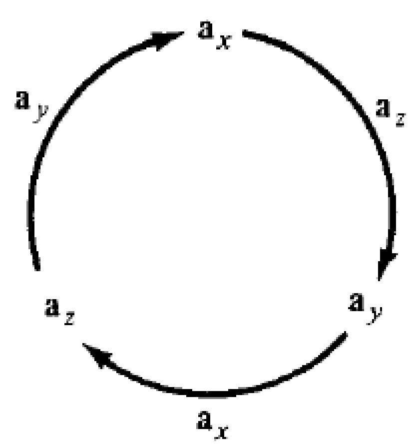
(iv)

$$\mathbf{A} \times \mathbf{A} = 0$$

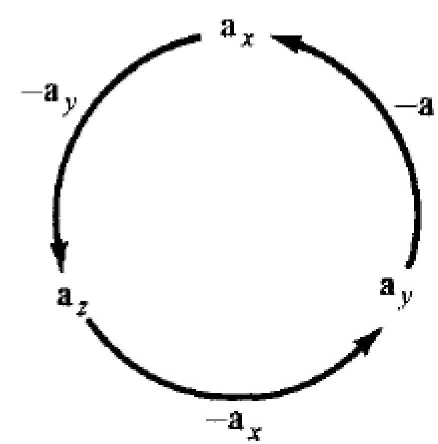
$$\mathbf{a}_x \times \mathbf{a}_y = \mathbf{a}_z$$

$$\mathbf{a}_y \times \mathbf{a}_z = \mathbf{a}_x$$

$$\mathbf{a}_z \times \mathbf{a}_x = \mathbf{a}_y$$



(a)



(b)

C. Scalar Triple Product

$$\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C}) = \mathbf{B} \cdot (\mathbf{C} \times \mathbf{A}) = \mathbf{C} \cdot (\mathbf{A} \times \mathbf{B})$$

$$\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C}) = \begin{vmatrix} A_x & A_y & A_z \\ B_x & B_y & B_z \\ C_x & C_y & C_z \end{vmatrix}$$

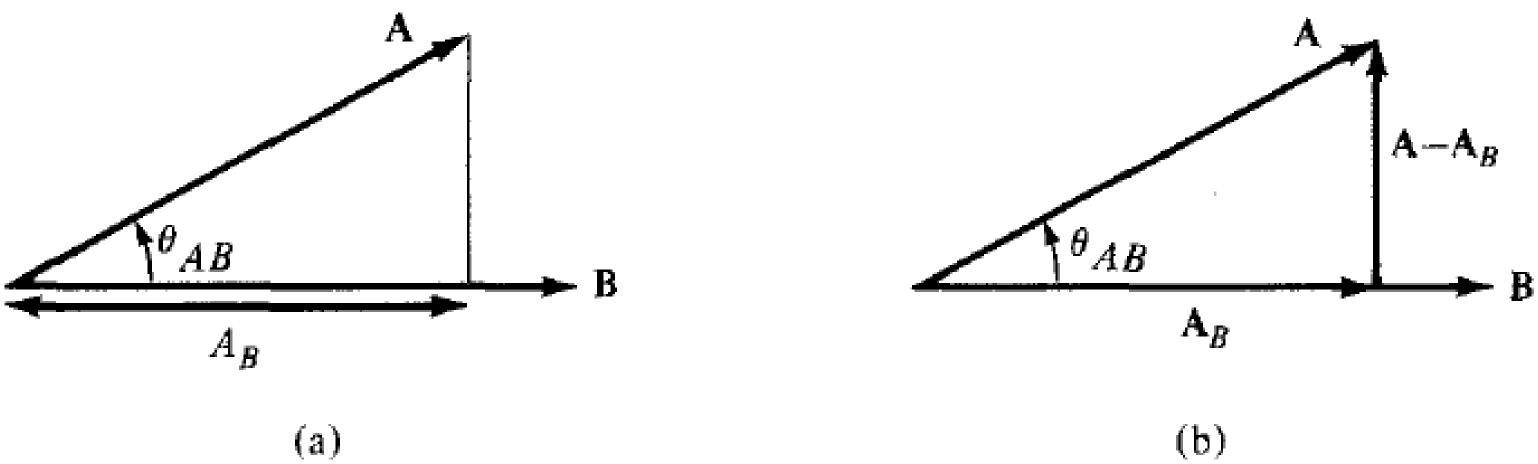
D. Vector Triple Product

$$\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) = \mathbf{B}(\mathbf{A} \cdot \mathbf{C}) - \mathbf{C}(\mathbf{A} \cdot \mathbf{B})$$

$$(\mathbf{A} \cdot \mathbf{B})\mathbf{C} \neq \mathbf{A}(\mathbf{B} \cdot \mathbf{C})$$

$$(\mathbf{A} \cdot \mathbf{B})\mathbf{C} = \mathbf{C}(\mathbf{A} \cdot \mathbf{B}).$$

1.6. KOMPONEN SUATU VEKTOR



Komponen **A** sepanjang **B**: (a) komponen skalar A_B; (b) komponen vektor $\mathbf{A}_B$

$$A_B = A\cos\theta_{AB} = |\mathbf{A}|\,|\mathbf{a}_B|\cos\theta_{AB}$$

$$\boxed{A_B = \mathbf{A}\cdot\mathbf{a}_B}$$

$$\boxed{\mathbf{A}_B = A_B\mathbf{a}_B = (\mathbf{A}\cdot\mathbf{a}_B)\mathbf{a}_B}$$

Given vectors $\mathbf{A} = 3\mathbf{a}_x + 4\mathbf{a}_y + \mathbf{a}_z$ and $\mathbf{B} = 2\mathbf{a}_y - 5\mathbf{a}_z$, find the angle between $\mathbf{A}$ and $\mathbf{B}$.

83.73°

Three field quantities are given by

$$\mathbf{P} = 2\mathbf{a}_x - \mathbf{a}_z$$

$$\mathbf{Q} = 2\mathbf{a}_x - \mathbf{a}_y + 2\mathbf{a}_z$$

$$\mathbf{R} = 2\mathbf{a}_x - 3\mathbf{a}_y + \mathbf{a}_z$$

Determine

(a) $(\mathbf{P} + \mathbf{Q}) \times (\mathbf{P} - \mathbf{Q})$ $2\mathbf{a}_x + 12\mathbf{a}_y + 4\mathbf{a}_z$

(b) $\mathbf{Q} \cdot \mathbf{R} \times \mathbf{P}$ 14

(c) $\mathbf{P} \cdot \mathbf{Q} \times \mathbf{R}$ 14

(d) $\sin \theta_{QR}$ 0.5976

(e) $\mathbf{P} \times (\mathbf{Q} \times \mathbf{R})$ (2, 3, 4)

(f) A unit vector perpendicular to both $\mathbf{Q}$ and $\mathbf{R}$ ±(0.745, 0.298, −0.596)

(g) The component of $\mathbf{P}$ along $\mathbf{Q}$ $0.4444\mathbf{a}_x - 0.2222\mathbf{a}_y + 0.4444\mathbf{a}_z$