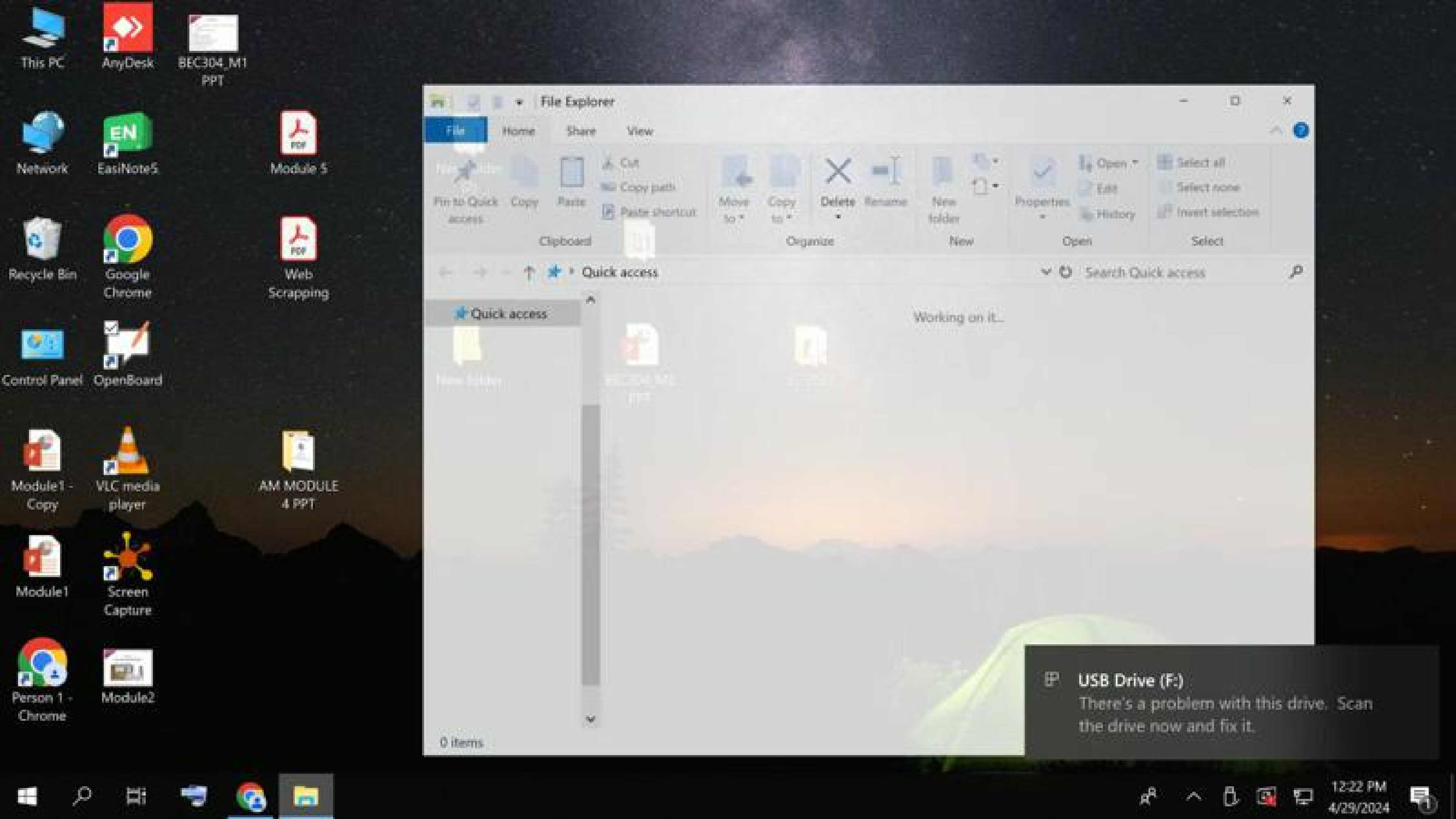
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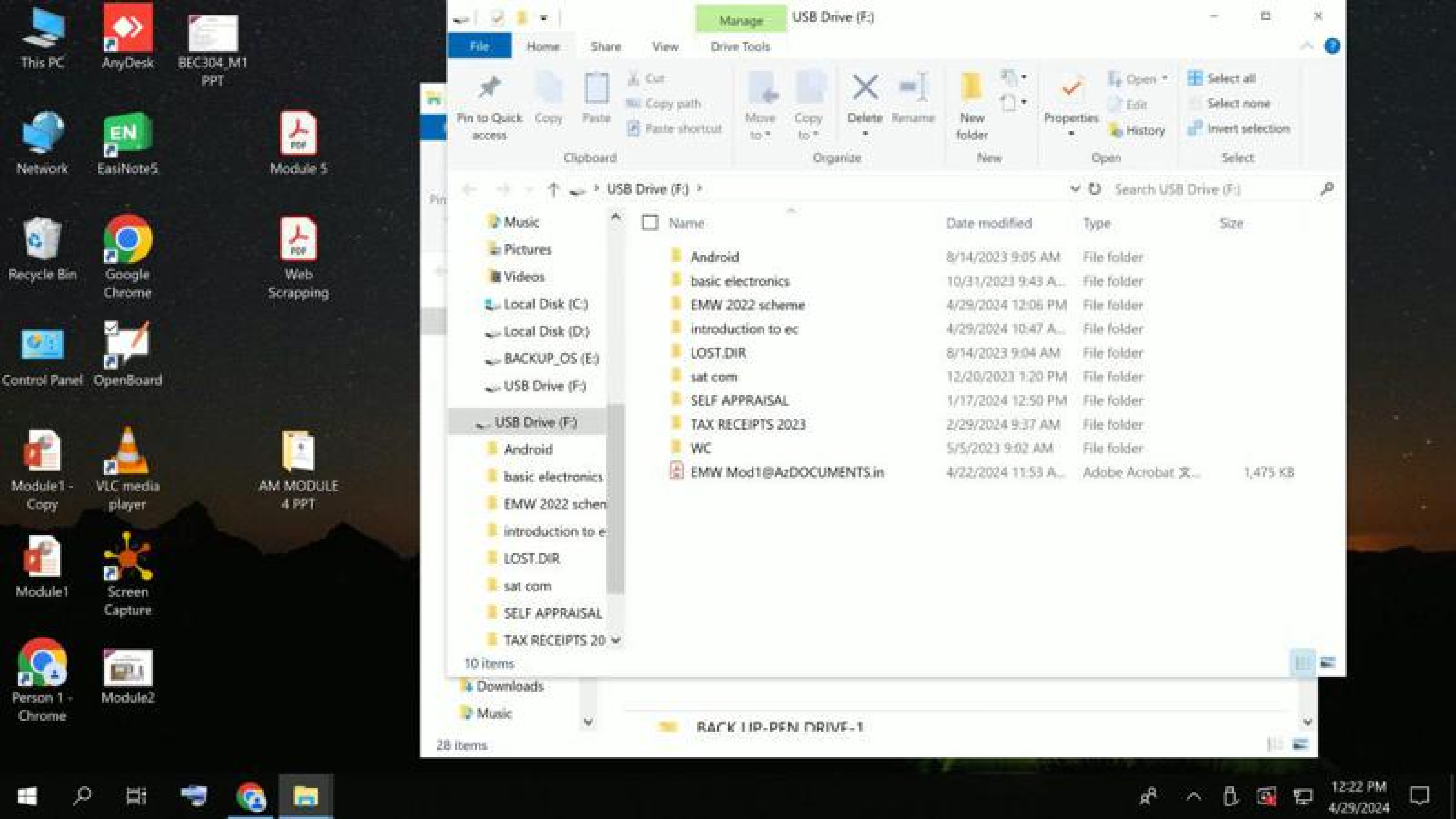
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...Technology and Management

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Engineering Electromagnetics		Semester	4
Course Code	**BEC401**	CIE Marks	50
Teaching Hours/Week (L:T:P: S)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	3
Examination type (SEE)	Theory		

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Teaching-Learning Process (General Instructions)

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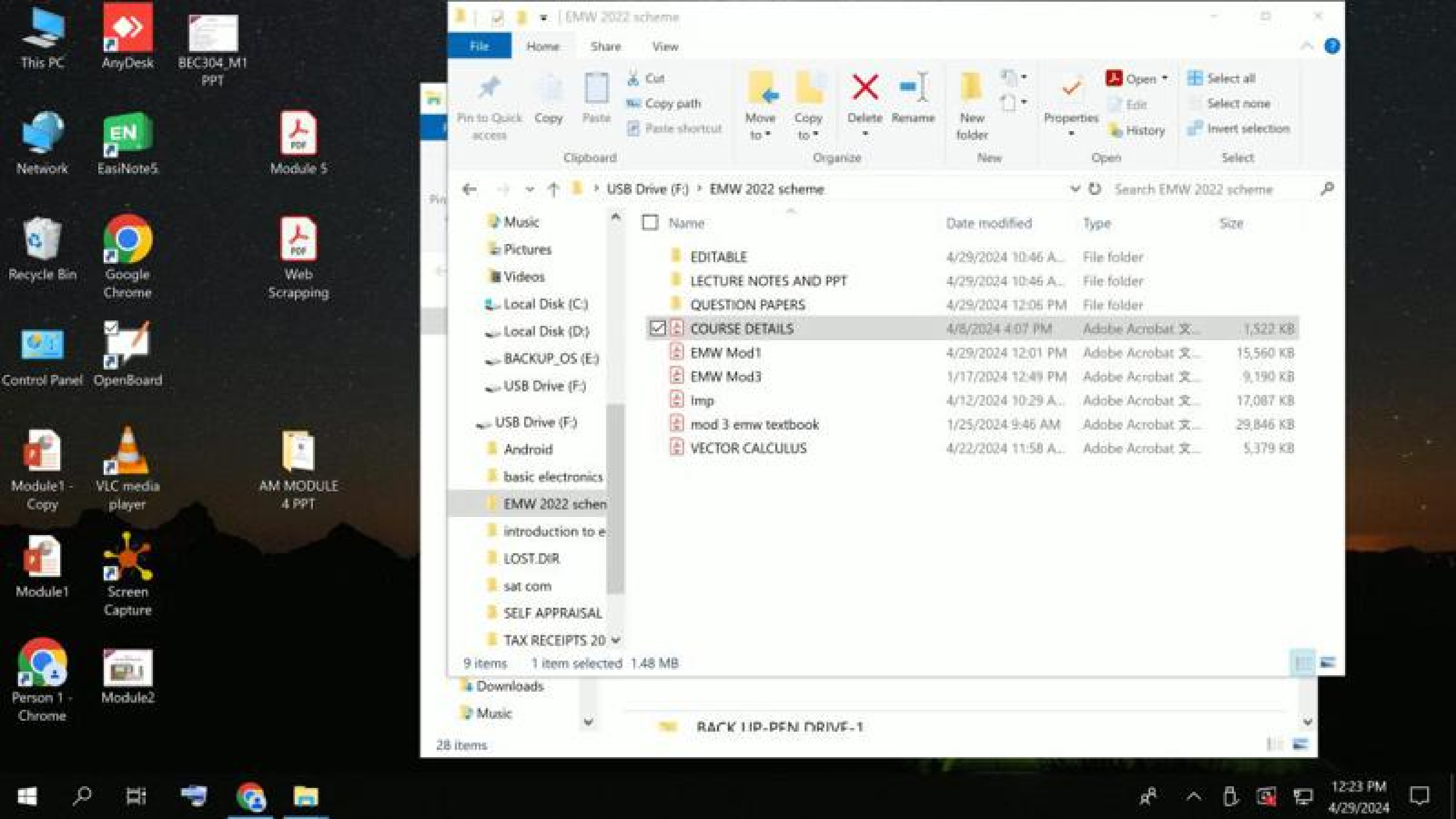
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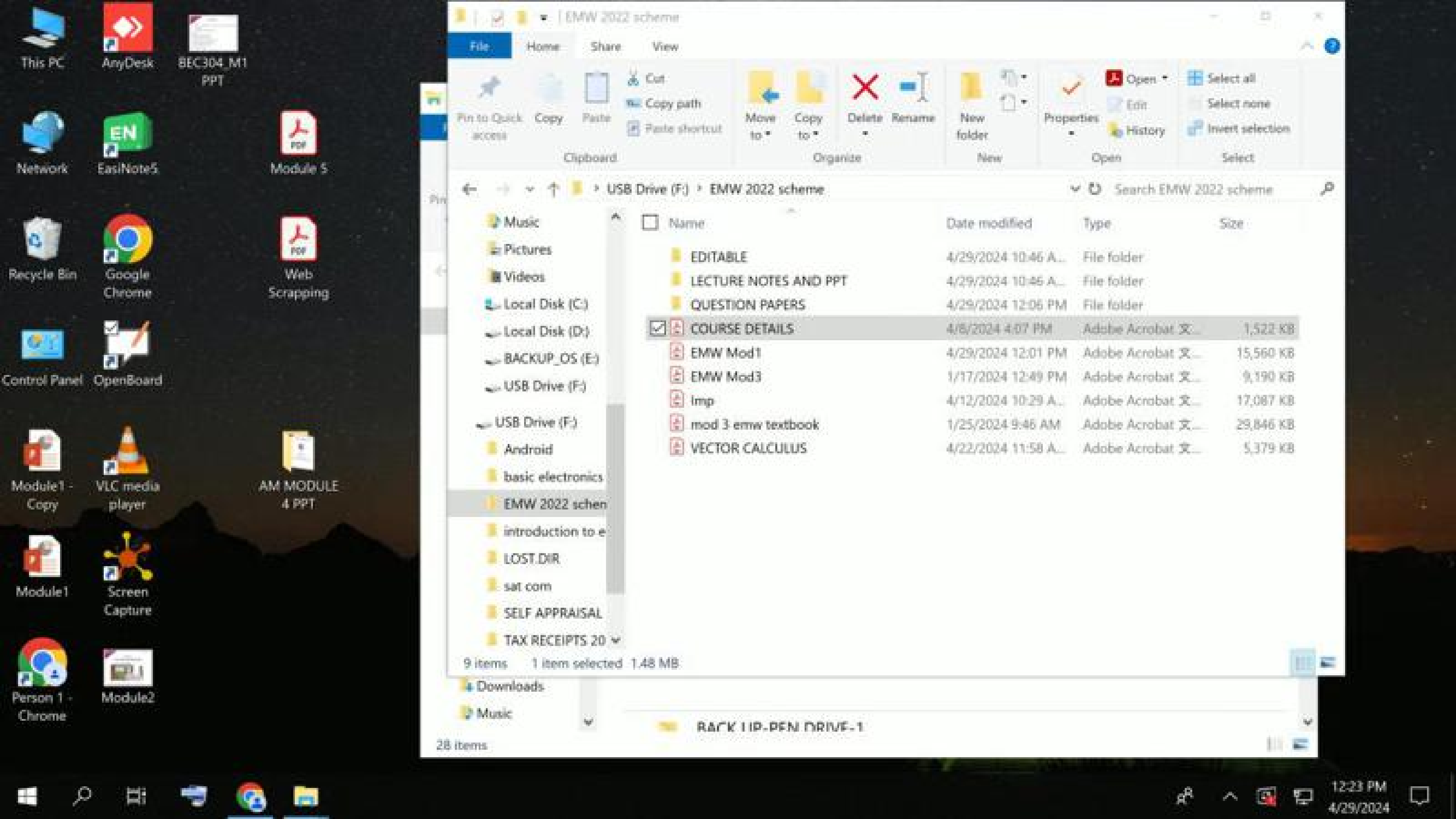
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are Studied.

Scalar and Vector

A Scalar Quantity has a magnitude only. It is a Quantity that can be described by a Simple number.

Thus mass, length, Temperature, volume, Electric potential, Current and Energy, time, Entropy, distance are Scalars.

Vector Quantities has both Magnitude and Direction.

Thus velocity, Force, displacement and Electric Field Intensity are examples for Vectors.

Note:- To distinguish b/w a Scalar and vector, It is customary to represent a vector by a letter with an Arrow ($\rightarrow$) on top of it, Such as $\vec{A}, \vec{B}, \vec{C} \ldots \vec{Z}$ or by a boldface type Such as **A**, **B** .... **Z**

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$\boxed{A = A\hat{a}_A}$

A Vector $\vec{A}$ in Cartesian (or rectangular) Co-ordinates may be represented as

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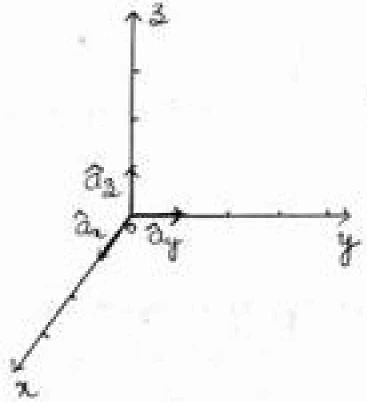

fig ②:- unit vectors $\hat{a}_x, \hat{a}_y, \hat{a}_z$

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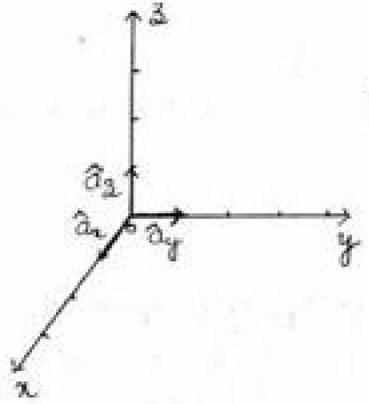

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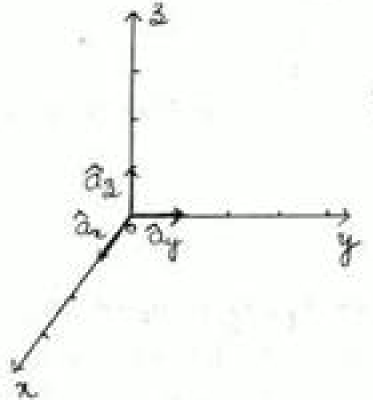

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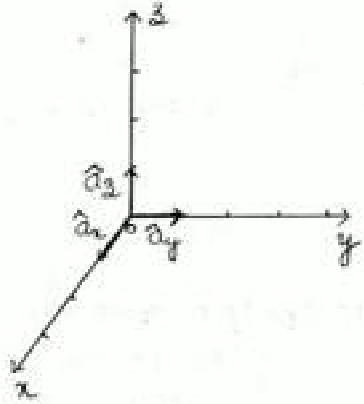

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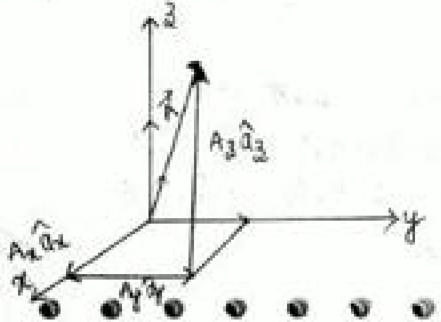

electric charges at rest and in motion. It entails the analysis, synthesis, physical interpretation and application of electric and magnetic fields.

Electromagnetics (EM) is a branch of physics or Electrical Engineering in which Electric and Magnetic phenomena are studied.

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A unit vector $\hat{a}_A$ along $\vec{A}$ is defined as a vector whose magnitude is unity (1) and its direction is along $\vec{A}$ that is

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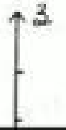

fig (2):- unit vectors

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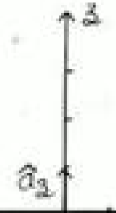

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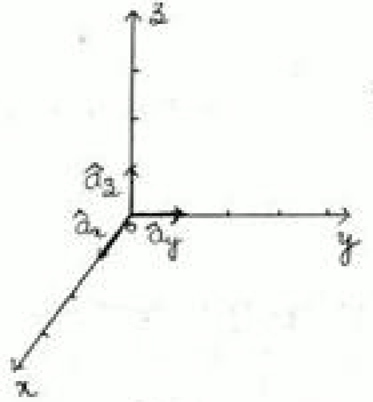

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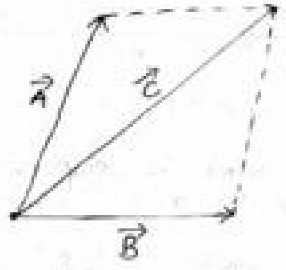
Vector Addition and Subtraction

Two vectors $\vec{A}$ and $\vec{B}$ can be added together to give another vector $\vec{C}$; that is

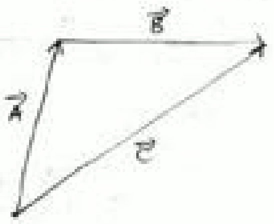
$$\boxed{\vec{C} = \vec{A} + \vec{B}}$$

The vector addition is carried out component by component. Thus, if $\vec{A} = (A_x, A_y, A_z)$ and $\vec{B} = (B_x, B_y, B_z)$

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



(a) parallelogram rule
$\vec{C} = \vec{A} + \vec{B}$



(b) Head to tail rule.

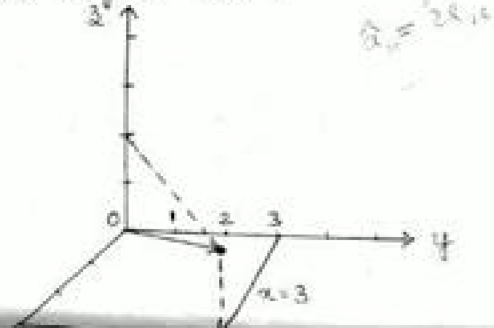
Position and Distance Vectors

The position vector $\vec{R}_P$ (or radius vector) of point P is defined as the directed distance from the origin 'O' to 'P', that is $\vec{R}_P = \vec{OP} = A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z$

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

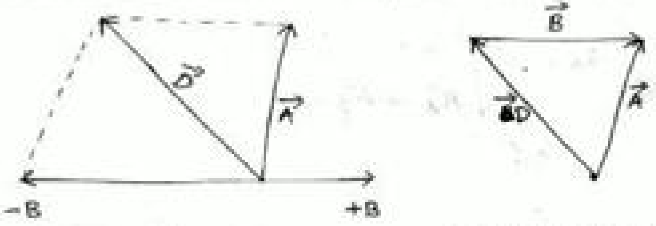
The position vector of point 'p' is useful in defining its position in space.

Consider point (3, 4, 2) and its position vector $3\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$ can be represented in ~~vector~~ Diagram as



(a) parallelogram rule (b) Head to tail rule.

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



(a) parallelogram Rule. (b) Head to tail rule

Vector Subtraction.

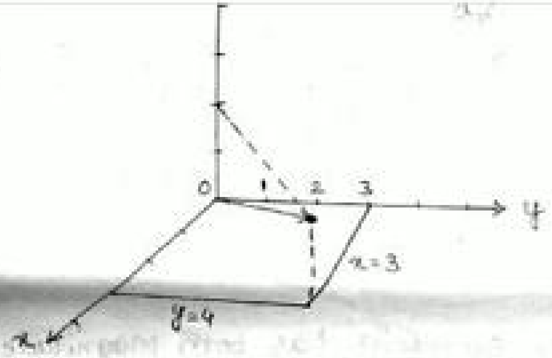
$\vec{D} = \vec{A} - \vec{B} = A + (-B)$

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

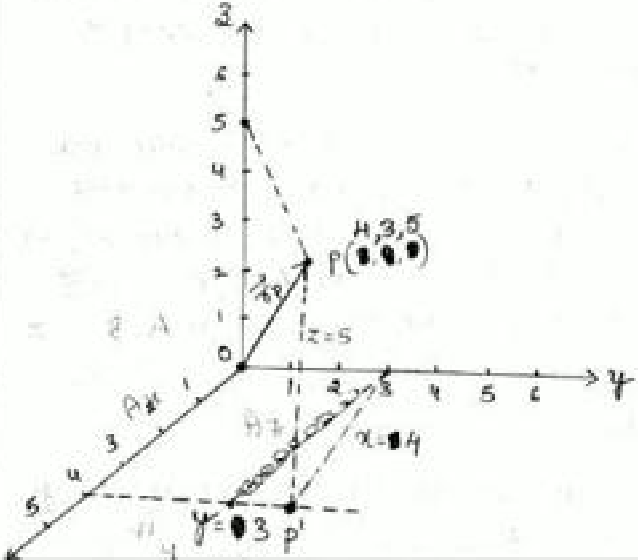
The three basic laws of algebra obeyed by any given vectors, $\vec{A}$, $\vec{B}$ and $\vec{C}$ are summarised as follows.

Commutative law $\Rightarrow$ $\vec{A} + \vec{B} = \vec{B} + \vec{A}$

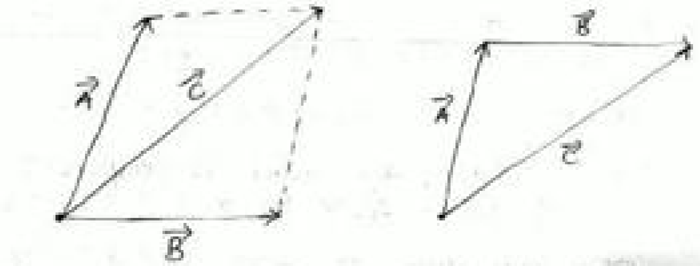
Associative law $\Rightarrow$ $\vec{A} + (\vec{B} + \vec{C}) = (\vec{A} + \vec{B}) + \vec{C}$



(4, 3, 5)

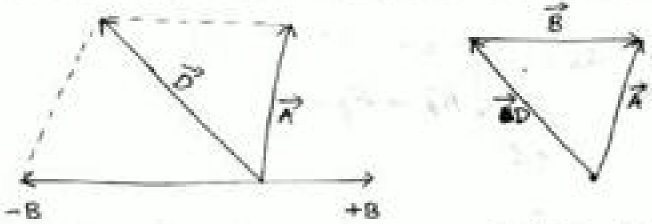


$$\boxed{\vec{C} = (A_x + B_x)\hat{a}_x + (A_y + B_y)\hat{a}_y + (A_z + B_z)\hat{a}_z}$$



(a) parallelogram rule $\quad$ (b) Head to tail rule.

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



(a) parallelogram Rule. $\quad$ (b) Head to tail rule

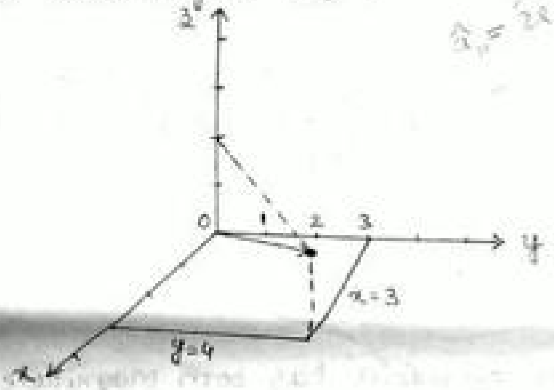
Vector Subtraction.

$\vec{D} = \vec{A} - \vec{B} = A + (-B)$

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

The Three basic laws of algebra obeyed by

in defining its position in space. Consider point $(3, 4, 2)$ and its position Vector $3\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$ can be represented in ~~vector~~ Diagram as.



$(4, 3, 5)$

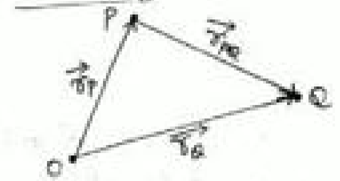
the position vector of point 'P'. Its distance from the origin is $\sqrt{3^2+4^2+5^2} = 7.071$

The distance can also be calculated as follows. The projection of the position vector in the xy plane $(z=0)$ is

$$r_{p'} = 3\hat{a}_x + 4\hat{a}_y$$

$$|r_{p'}| = OP' = \sqrt{3^2+4^2} = \sqrt{25} = 5$$

Distance Vector



$$\vec{r}_Q = \vec{r}_P + \vec{r}_{PQ}$$
$$\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$$

$\vec{r}_{PQ}$ = distance vector.

The distance vector is the displacement from one point to another.

(c) Let $\vec{C} = \vec{A} + 2\vec{B}$

$$\vec{C} = (10,-4,6) + 2(2,1,0)$$
$$\vec{C} = (10,-4,6) + (4,2,0)$$
$$\vec{C} = (14,-2,6)$$

$$\hat{a}_c = \frac{\vec{C}}{|C|} = \frac{(14,-2,6)}{\sqrt{14^2+(-2)^2+6^2}} = \frac{(14,-2,6)}{15.36}$$

$$\hat{a}_c = 0.911\hat{a}_x - 0.130\hat{a}_y + 0.390\hat{a}_z$$

Ex (2)

Given vectors $\vec{A} = \hat{a}_x + 3\hat{a}_z$ and $\vec{B} = 5\hat{a}_x + 2\hat{a}_y - 6\hat{a}_z$, determine

(a) $|A+B|$

(b) $5A - B$

(c) the component of $\vec{A}$ along $\hat{a}_y$

(d) A unit vector parallel to $3\vec{A}+\vec{B}$

Answer :- (a) 7 (c) 0

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The distance can also be calculated as follows. The projection of the position vector in the xy plane (z=0) is

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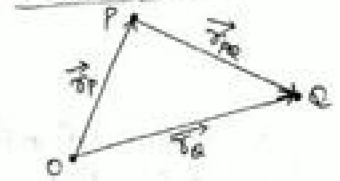
Distance Vector



$$\vec{r}_Q = \vec{r}_P + \vec{r}_{PQ}$$
$$\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$$

$\vec{r}_{PQ}$ = distance vector.

The distance vector is the displacement from one point to another.

If two points P and Q are given by (x_P, y_P, z_P) and (x_Q, y_Q, z_Q), the distance

(c) Let $\vec{C} = \vec{A} + 2\vec{B}$

$$\vec{C} = (10,-4,6) + 2(2,1,0)$$
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$$\vec{C} = (14,-2,6)$$

$$\hat{a}_c = \frac{\vec{C}}{|C|} = \frac{(14,-2,6)}{\sqrt{14^2+(-2)^2+6^2}} = \frac{(14,-2,6)}{15.36}$$

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Ex (2)

Given vectors $\vec{A} = \hat{a}_x + 3\hat{a}_z$ and $\vec{B} = 5\hat{a}_x + 2\hat{a}_y - 6\hat{a}_z$, determine

(a) $|A+B|$

(b) $5A - B$

(c) The component of $\vec{A}$ along $\hat{a}_y$

(d) A unit vector parallel to $3\vec{A}+\vec{B}$

Answer:- (a) 7 (c) 0

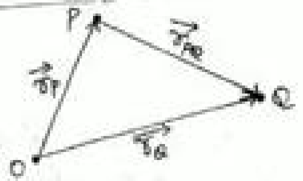
(b) $(0,-2,21)$ (d) $\pm(0.9117, 0.2279, 0.3419)$

Vector Multiplication

$OP' = 3a_x + 4a_y$

$$|r_{P'}| = OP' = \sqrt{3^2+4^2} = \sqrt{25} = 5$$

Distance Vector



$$\vec{r}_Q = \vec{r}_P + \vec{r}_{PQ}$$
$$\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$$

$\vec{r}_{PQ}$ = distance vector.

The distance vector is the displacement from one point to another.

If two points P and Q are given by (x_P, y_P, z_P) and (x_Q, y_Q, z_Q), the distance vector or seperation vector is the displacement vector from P to Q as shown in figure above.

i.e $\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$

$$\boxed{\vec{r}_{PQ} = (x_Q - x_P)\hat{a}_x + (y_Q - y_P)\hat{a}_y + (z_Q - z_P)\hat{a}_z}$$

$$\vec{R}_{PQ} = (R_{Qx} - R_{Px})\hat{a}_x + (R_{Qy} - R_{Py})\hat{a}_y + (R_{Qz} - R_{Pz})\hat{a}_z$$

Problems

1) If $\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$ find (a) The component of $\vec{A}$ along $\hat{a}_y$

(b) The magnitude of $3\vec{A} - \vec{B}$

$$\hat{a}_c = 0.911\hat{a}_x - 0.130\hat{a}_y + 0.390\hat{a}_z$$

Ex (2)

Given vectors $\vec{A} = \hat{a}_x + 3\hat{a}_z$ and $\vec{B} = 5\hat{a}_x + 2\hat{a}_y - 6\hat{a}_z$, determine

(a) $|A+B|$

(b) $5A - B$

(c) The component of $\vec{A}$ along $\hat{a}_y$

(d) A unit vector parallel to $3\vec{A} + \vec{B}$

Answer:- (a) 7 (b) $(0, -2, 21)$ (c) 0 (d) $\pm(0.9117, 0.2279, 0.3419)$

Vector Multiplication

When two vectors $\vec{A}$ and $\vec{B}$ are multipli the result is either a scalar or a vect depending on how they are multiplied. Thus there are two types of vector multipli-cation.

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

Multiplication of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ can ~~either~~ result in either.

(1) Scalar triple product : $\vec{A} \cdot (\vec{B} \times \vec{C})$

The distance vector is the displacement from one point to another.

If two points P and Q are given by (x_P, y_P, z_P) and (x_Q, y_Q, z_Q), the distance vector or seperation vector is the displacement from P to Q as shown in figure above.

i.e $\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$

$$\boxed{\vec{r}_{PQ} = (x_Q - x_P)\hat{a}_x + (y_Q - y_P)\hat{a}_y + (z_Q - z_P)\hat{a}_z}$$

$$\vec{R}_{PQ} = (R_{Qx} - R_{Px})\hat{a}_x + (R_{Qy} - R_{Py})\hat{a}_y + (R_{Qz} - R_{Pz})\hat{a}_z$$

Problems

1) If $\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$ find (a) the component of $\vec{A}$ along $\hat{a}_y$

(b) the magnitude of $3\vec{A} - \vec{B}$

(c) A unit vector along $\vec{A} + 2\vec{B}$

Solution

(a) The component of $\vec{A}$ along $\hat{a}_y$ is (-4)

(b) $3\vec{A} - \vec{B} = 3(10, -4, 6) - (2, 1, 0)$

$= (30, -12, 18) - (2, 1, 0)$

$= (28, -13, 18)$

Answer:- (a) 7 (b) $(0, -2, 21)$ (c) 0 (d) $\pm(0.9117, 0.2279, 0.3419)$

Vector Multiplication

When two vectors $\vec{A}$ and $\vec{B}$ are multipli[ed] the result is either a scalar or a vect[or] depending on how they are multiplied. Thus there are two types of vector multipli-cation.

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2) Vector (or cross) product :- $\vec{A} \times \vec{B}$

Multiplication of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ can ~~either~~ result in either.

(3) Scalar triple product : $\vec{A} \cdot (\vec{B} \times \vec{C})$

(4) Vector triple product: $\vec{A} \times (\vec{B} \times \vec{C})$

If two points P and Q are given by (x_P, y_P, z_P) and (x_Q, y_Q, z_Q), the distance vector or seperation vector is the displacement from P to Q as shown in figure above.

i.e. $\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$

$$\boxed{\vec{r}_{PQ} = (x_Q - x_P)\hat{a}_x + (y_Q - y_P)\hat{a}_y + (z_Q - z_P)\hat{a}_z}$$

$$\vec{R}_{PQ} = (R_{Qx} - R_{Px})\hat{a}_x + (R_{Qy} - R_{Py})\hat{a}_y + (R_{Qz} - R_{Pz})\hat{a}_z$$

Problems

1) If $\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$ find (a) the component of $\vec{A}$ along $\hat{a}_y$

(b) the magnitude of $3\vec{A} - \vec{B}$

(c) A unit vector along $\vec{A} + 2\vec{B}$

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$= (30, -12, 18) - (2, 1, 0)$

$= (28, -13, 18)$

$|3\vec{A} - \vec{B}| = \sqrt{28^2 + (-13)^2 + 18^2} = \sqrt{1277} = 35.74$

Vector Multiplication

When two vectors $\vec{A}$ and $\vec{B}$ 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 :- $\vec{A} \cdot \vec{B}$

2) Vector (or cross) product :- $\vec{A} \times \vec{B}$

Multiplication of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ can ~~either~~ result in either.

(3) Scalar triple product : $\vec{A} \cdot (\vec{B} \times \vec{C})$

(4) Vector triple product : $\vec{A} \times (\vec{B} \times \vec{C})$

vector or seperation vector is the displacement from P to Q as shown in figure above.

$$\boxed{\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P}$$

$$\boxed{= (x_Q - x_P)\hat{a}_x + (y_Q - y_P)\hat{a}_y + (z_Q - z_P)\hat{a}_z}$$

$$\vec{R}_{PQ} = (R_{Qx} - R_{Px})\hat{a}_x + (R_{Qy} - R_{Py})\hat{a}_y + (R_{Qz} - R_{Pz})\hat{a}_z$$

Problems

If $\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$

find (a) The component of $\vec{A}$ along $\hat{a}_y$

(b) The magnitude of $3\vec{A} - \vec{B}$

(c) A unit vector along $\vec{A} + 2\vec{B}$

Solution

(a) The component of $\vec{A}$ along $\hat{a}_y$ is (-4)

(b) $3\vec{A} - \vec{B} = 3(10, -4, 6) - (2, 1, 0)$

When two vectors $\vec{A}$ and $\vec{B}$ are multipli- the result is either a scalar or a vect- depending on how they are multiplied. Thus there are two types of vector multipli-cation.

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(3) Scalar triple product : $\vec{A} \cdot (\vec{B} \times \vec{C})$

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Problems

$\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$

(a) The component of $\vec{A}$ along $\hat{a}_y$

(b) The magnitude of $3\vec{A} - \vec{B}$

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a) The component of $\vec{A}$ along $\hat{a}_y$ is (-4)

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$= (30, -12, 18) - (2, 1, 0)$

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$|3\vec{A} - \vec{B}| = \sqrt{28^2 + (-13)^2 + 18^2} = \sqrt{1277} = 35.74$

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distance vector is the displacement from point to another.

If two points P and Q are given by (x_P, y_P, z_P) and (x_Q, y_Q, z_Q), the distance or seperation vector is the displacement from P to Q as shown in figure above.

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Answer :- (a) 7 (c) 0

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(6)

...e position vector of point 'p'. Its ...ance from the origin is $\sqrt{3^2+4^2+5^2} = 7.071$

The distance can also be calculated as follows. The projection of the position vector in the xy plane (Z=0) is

$$r_{p'} = 3\hat{a}_x + 4\hat{a}_y$$

$$|r_{p'}| = OP' = \sqrt{3^2+4^2} = \sqrt{25} = 5$$

Distance Vector

(c) Let $\vec{C} = \vec{A} + 2\vec{B}$

$$\vec{C} = (10,-4,6) + 2(2,1,0)$$

$$\vec{C} = (10,-4,6) + (4,2,0)$$

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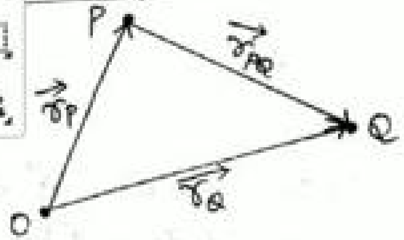
Ex (2)

Given vectors $\vec{A} = \hat{a}_x + 3\hat{a}_z$ and $\vec{B} = 5\hat{a}_x + 2\hat{a}_y - 6\hat{a}_z$

$\vec{r}_{p'} = 3\hat{a}_x + 4\hat{a}_y$

$|\vec{r}_{p'}| = OP' = \sqrt{3^2 + 4^2} = \sqrt{25} = 5$

...tance Vector



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$|C| \quad \sqrt{14^2 + (-2)^2 + 6^2} \quad 15.36$

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(b) $5A - B$

(c) The component of $\vec{A}$ along $\hat{a}_y$

(d) A unit vector parallel to $3\vec{A} + \vec{B}$

Answer:- (a) 7
(b) $(0, -2, 21)$
(c) 0
(d) $\pm(0.9117, 0.2279, 0.3419)$

Vector Multiplication.

When two vectors $\vec{A}$ and $\vec{B}$ are multipli... the result is either a scalar or a vect... depending on how they are multiplied.

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$$\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$$

$$\boxed{= (x_Q - x_P)\hat{a}_x + (y_Q - y_P)\hat{a}_y + (z_Q - z_P)\hat{a}_z}$$

$$\vec{R}_{PQ} = (R_{Qx} - R_{Px})\hat{a}_x + (R_{Qy} - R_{Py})\hat{a}_y + (R_{Qz} - R_{Pz})\hat{a}_z$$

Problems

If $\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$ find (a) The component of $\vec{A}$ along $\hat{a}_y$

(b) The magnitude of $3\vec{A} - \vec{B}$

(c) A unit vector along $\vec{A} + 2\vec{B}$

Answer:- (a) 7 (c) 0

(b) $(0, -2, 21)$ (d) $\pm(0.9117, 0.2279, 0.3419)$

Vector Multiplication.

When two vectors $\vec{A}$ and $\vec{B}$ are multipli[ed] the result is either a scalar or a vect[or] depending on how they are multiplied. Thus there are two types of vector multipli-cation.

1) Scalar (or dot) product :- $\vec{A} \cdot \vec{B}$

2) Vector (or cross) product :- $\vec{A} \times \vec{B}$

Multiplication of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ can ~~either~~ result in either.

(3) Scalar triple product : $\vec{A} \cdot (\vec{B} \times \vec{C})$

(4) Vector triple product : $\vec{A} \times (\vec{B} \times \vec{C})$

If two points P and Q are given by (x_P, y_P, z_P) and (x_Q, y_Q, z_Q), the distance vector or seperation vector is the displacement from P to Q as shown in figure above.

$$\vec{r}_{PQ} = \vec{r}_Q - \vec{r}_P$$

$$\boxed{= (x_Q - x_P)\hat{a}_x + (y_Q - y_P)\hat{a}_y + (z_Q - z_P)\hat{a}_z}$$

$$\vec{R}_{PQ} = (R_{Qx} - R_{Px})\hat{a}_x + (R_{Qy} - R_{Py})\hat{a}_y + (R_{Qz} - R_{Pz})\hat{a}_z$$

Problems

If $\vec{A} = 10\hat{a}_x - 4\hat{a}_y + 6\hat{a}_z$ and $\vec{B} = 2\hat{a}_x + \hat{a}_y$

find (a) The component of $\vec{A}$ along $\hat{a}_y$

(b) The magnitude of $3\vec{A} - \vec{B}$

(c) A unit vector along $\vec{A} + 2\vec{B}$

Solution

(a) The component of $\vec{A}$ along $\hat{a}_y$ is (-4)

(b) $(0, -2, 21)$ (c) $\pm(0.[illegible], 0.[illegible], 0.[illegible])$

Vector Multiplication.

When two vectors $\vec{A}$ and $\vec{B}$ are multipli[illegible] the result is either a scalar or a vect[illegible] depending on how they are multiplied. Thus there are two types of vector multipli-cation.

1) Scalar (or dot) product :- $\vec{A} \cdot \vec{B}$

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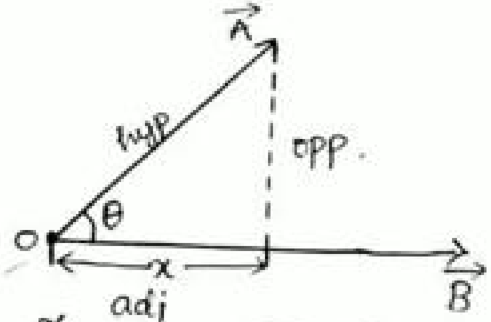
Multiplication of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ can ~~either~~ result in either.

(3) Scalar triple product : $\vec{A} \cdot (\vec{B} \times \vec{C})$

(4) Vector triple product : $\vec{A} \times (\vec{B} \times \vec{C})$

...t product

...e Dot product of two vectors $\vec{A}$ and $\vec{B}$ ...ten as $\vec{A}\cdot\vec{B}$, is defined geometrically a... the product of the magnitudes of $\vec{A}$ and $\vec{B}$ ...and the cosine of the smaller angle b...een them, when they are drawn Tail to tail".

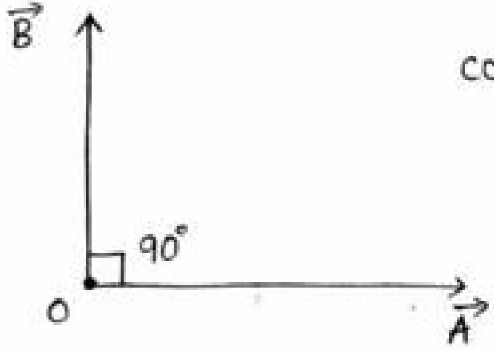


$$\cos\theta = \frac{adj}{hyp} = \frac{x}{A}$$

$$\boxed{x = A\cos\theta}$$

Orthogonal Vectors

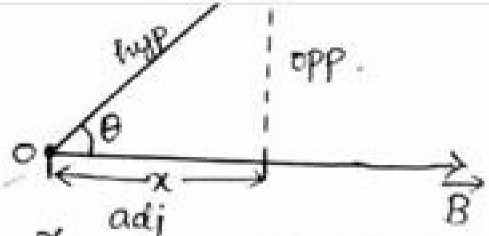
If the angle b/w the two vectors is 90 or $\left(\frac{\pi}{2}\right)$ then the vectors are orthogonal for any orthogonal vectors $\vec{A}\cdot\vec{B}=0$ because $\cos 90^\circ = 0$



$\cos 90^\circ = 0$

Cross product

The cross product of two vectors $\vec{A}$ and $\vec{B}$ written as $\vec{A}\times\vec{B}$ is a vector quantity ... is the area of parallelogram



$\cos\theta = \frac{adj}{hyp} = \frac{x}{A}$ $\boxed{x = A\cos\theta}$

$\vec{B} = |A||\vec{B}|\cos\theta$

$\cos\theta = \frac{x}{A}$

$\cos\theta = \frac{\vec{A}\cdot\vec{B}}{|A||B|}$

Ex:- $\vec{A} = (A_1, A_2, A_3)$ $\vec{B} = (B_1, B_2, B_3)$

$\cdot\vec{B} = (A_1 \cdot B_1) + (A_2 \cdot B_2) + (A_3 \cdot B_3)$

Problems

what is the angle b/w these vectors.

$\vec{A} = (2, 2, -1)$ $\vec{B} = (5, -3, 2)$

Cross product

The cross product of two vectors $\vec{A}$ and $\vec{B}$ written as $\vec{A}\times\vec{B}$ is a vector Quantity whose magnitude is the area of parallelogram formed by $\vec{A}$ and $\vec{B}$ and is in the direction of advance of a right-handed screw as A is turned into B.

Thus

$$\vec{A}\times\vec{B} = AB\sin\theta\,\hat{a}_n$$

where $\hat{a}_n$ = unit vector normal to plane containing $\vec{A}$ and $\vec{B}$

Note:- The direction of $\hat{a}_n$ is taken as the direction of the right thumb when the fingers of the right hand rotate from $\vec{A}$ to $\vec{B}$ as

$$\cos\theta = \frac{adj}{hyp} = \frac{x}{A} \qquad \boxed{x = A\cos\theta}$$

$$\vec{A}\cdot\vec{B} = |A||\vec{B}|\cos\theta \qquad \cos\theta = \frac{x}{A}$$

$$\cos\theta = \frac{\vec{A}\cdot\vec{B}}{|A||B|}$$

Ex:- $\vec{A} = (A_1, A_2, A_3)$ $\vec{B} = (B_1, B_2, B_3)$

$$\vec{A}\cdot\vec{B} = (A_1 \cdot B_1) + (A_2 \cdot B_2) + (A_3 \cdot B_3)$$

Problems

what is the angle b/w these vectors.

$\vec{A} = (2, 2, -1)$ $\vec{B} = (5, -3, 2)$

$\theta = ?$ $\cos\theta = \frac{2}{\ldots} = 0.1081$

Cross product

The cross product of two vectors $\vec{A}$ and $\vec{B}$ written as $\vec{A}\times\vec{B}$ is a vector quantity whose magnitude is the area of parallelogram formed by $\vec{A}$ and $\vec{B}$ and is in the direction of advance of a right-handed screw as A is turned into B.

Thus

$$\vec{A}\times\vec{B} = AB\sin\theta \, \hat{a}_n$$

Where $\hat{a}_n$ = unit vector normal to plane containing $\vec{A}$ and $\vec{B}$

Note:- The direction of $\hat{a}_n$ is taken as the direction of the right thumb when the fingers of the right hand rotate from $\vec{A}$ to $\vec{B}$ as shown in figure below.

Problems

What is the angle b/w these vectors.

$\vec{A} = (2, 2, -1)$ $\qquad$ $\vec{B} = (5, -3, 2)$

$\theta = ?$

$$\cos\theta = \frac{\vec{A}\cdot\vec{B}}{|A|\,|B|}$$

$\vec{A}\cdot\vec{B} = 10 - 6 - 2 = 2$

$$\cos\theta = \frac{2}{(3)(\sqrt{38})} = 0.1081$$

Ans: $\theta = 83.79$

$|A| = \sqrt{2^2 + 2^2 + (-1)^2} = 3$

$|B| = \sqrt{25 + 9 + 4} = \sqrt{38}$

$$\cancel{|A||B| = \sqrt{(2^2 + 2^2 + (-1)^2) + (5^2 + (-3^2) + (2^2))}}$$

$$\cancel{= \sqrt{(4 + 4 + 1) + (25 + 9 + 4)}}$$

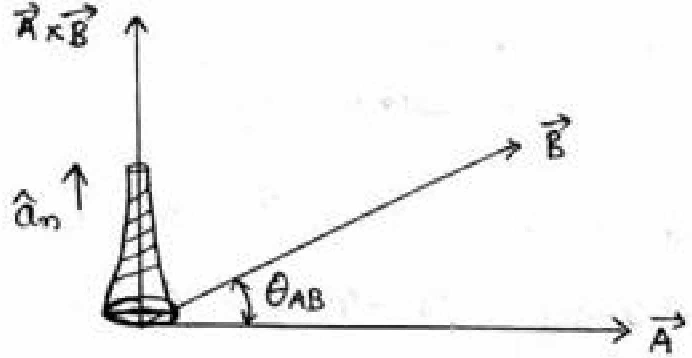
$$\cancel{= \sqrt{9 + 38}} = \sqrt{47} = 6.85$$

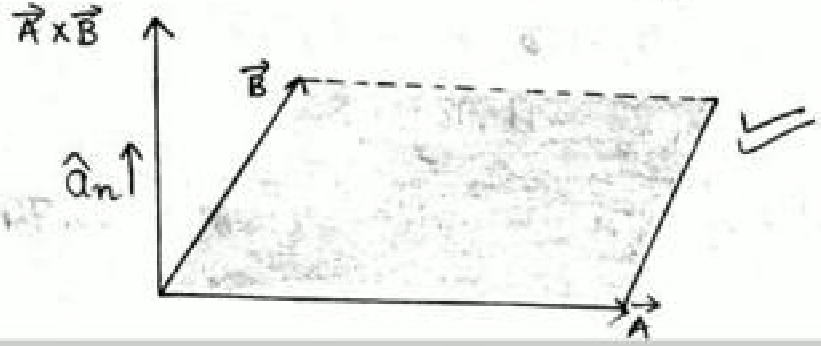
$29 + 9 = 38$

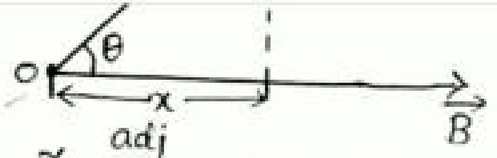
$$\cancel{\cos\theta = \frac{2}{\sqrt{47}}} \quad \cancel{\cos\theta = \frac{2}{6.85} = 0.2919}$$

A and B

Note:- The direction of $\hat{a}_n$ is taken as the direction of the right thumb when the fingers of the right hand rotate from $\vec{A}$ to $\vec{B}$ as shown in figure below.







$\cos\theta = \frac{adj}{hyp} = \frac{x}{A}$

$\boxed{x = A\cos\theta}$

$\vec{A}\cdot\vec{B} = |A||\vec{B}|\cos\theta$ $\qquad \cos\theta = \frac{x}{A}$

$\cos\theta = \frac{\vec{A}\cdot\vec{B}}{|A||B|}$

Ex:- $\vec{A} = (A_1, A_2, A_3)$ $\qquad \vec{B} = (B_1, B_2, B_3)$

$\vec{A}\cdot\vec{B} = (A_1 \cdot B_1) + (A_2 \cdot B_2) + (A_3 \cdot B_3)$

Problems

what is the angle b/w these vectors

$\vec{A} = (2, 2, -1)$ $\qquad \vec{B} = (5, -3, 2)$

$\theta = ?$ $\qquad \cos\theta = \frac{2}{(3)(\sqrt{38})} = 0.1081$

Cross product

The cross product of two vectors $\vec{A}$ and $\vec{B}$ written as $\vec{A}\times\vec{B}$ is a vector Quantity whose magnitude is the area of parallelogram formed by $\vec{A}$ and $\vec{B}$ and is in the direction of advance of a right-handed screw as A is turned into B.

Thus

$$\vec{A}\times\vec{B} = AB\sin\theta\,\hat{a}_n$$

where $\hat{a}_n$ = unit vector normal to plane containing $\vec{A}$ and $\vec{B}$

Note:- The direction of $\hat{a}_n$ is taken as the direction of the right thumb when the fingers of the right hand rotate from $\vec{A}$ to $\vec{B}$ as shown in figure below.

$$\ldots B_z - B_y A_z)\hat{a}_x - (A_x B_z - A_z B_x)\hat{a}_y + (A_x B_y - B_x A_y)\hat{a}_z$$

P...erties of Scalar product or Dot product.

1) If vector $\vec{A}$ is perpendicular to $\vec{B}$, then the Scalar product $\vec{A}\cdot\vec{B} = 0$

2) If vector $\vec{A}$ is parallel to $\vec{B}$, then
$$\vec{A}\cdot\vec{B} = AB$$

3) Commutative law
$$\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$$

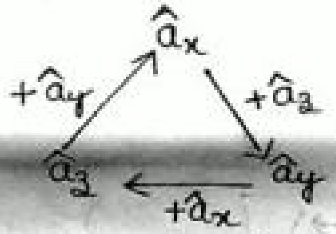
4) Distributive law.
$$\vec{A}\cdot(\vec{B}+\vec{C}) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C}$$

5) $\vec{A}\cdot\vec{A} = |A|^2 = A^2$

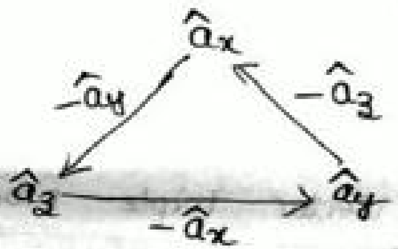
4) It is not associative
$$\vec{A}\times(\vec{B}\times\vec{C}) \neq (\vec{A}\times\vec{B})\times\vec{C}$$

5) It is Distributive.
$$\vec{A}\times(\vec{B}+\vec{C}) = (\vec{A}\times\vec{B}) + (\vec{A}\times\vec{C})$$

6) $\vec{A}\times\vec{A} = 0$



Clockwise direction
(+ve result)



Anticlockwise dir'n
(−ve result)

$\hat{a}_x \times \hat{a}_y = +\hat{a}_z$ $\qquad$ $\hat{a}_y \times \hat{a}_x = -\hat{a}_z$

$\hat{a}_y \times \hat{a}_z = +\hat{a}_x$ $\qquad$ $\hat{a}_z \times \hat{a}_y = -\hat{a}_x$

Scalar Triple product

Given three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$, we define the Scalar triple product as

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

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

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

$\vec{C} = (C_x, C_y, C_z)$ then $\vec{A}\cdot(\vec{B}\times\vec{C})$

$\vec{A}\cdot(\vec{B}\times\vec{C}) = \begin{vmatrix} A_x & A_y & A_z \end{vmatrix}$

(12) Soln

$\vec{P} = (0, 2, 4)$ $\quad Q = (-3, 1, 5)$

(a) $\vec{R}_P = 0\hat{a}_x + 2\hat{a}_y + 4\hat{a}_z$

(b) $\vec{R}_{PQ} = \vec{R}_Q - \vec{R}_P$

$= (-3, 1, 5) - (0, 2, 4)$

$\vec{R}_{PQ} = (-3, -1, 1) = -3\hat{a}_x - 1\hat{a}_y + 1\hat{a}_z$

(c) $d = |\vec{R}_{PQ}| = \sqrt{(-3)^2 + (-1)^2 + 1^2} = 3.317$

(d) $\hat{a}_A = \dfrac{\vec{A}}{|\vec{A}|} = \dfrac{\vec{R}_{PQ}}{\ldots} = (-3, -1, +1)$

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

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

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

$\vec{C} = (C_x, C_y, C_z)$ then $\vec{A}\cdot(\vec{B}\times\vec{C})$

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

Since the result of this vector multiplication is scalar.

Vector Triple product.

For vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$, we define the vector triple product as

(b) $\vec{R}_{PQ} = \vec{R}_Q - \vec{R}_P$

$= (-3,1,5) - (0,2,4)$

$\vec{R}_{PQ} = (-3,-1,1) = -3\hat{a}_x - 1\hat{a}_y + 1\hat{a}_z$

(c) $d = |\vec{R}_{PQ}| = \sqrt{(-3)^2 + (-1)^2 + 1^2} = 3.317$

(d) $\hat{a}_A = \dfrac{\vec{A}}{|A|} = \dfrac{\vec{R}_{PQ}}{|R_{PQ}|} = \dfrac{(-3,-1,+1)}{3.317}$

$\hat{a}_A = -0.904\hat{a}_x - 0.3014\hat{a}_y + 0.3014\hat{a}_z$

multiply by 10 then

$\vec{A} = -9.04\hat{a}_x - 3.014\hat{a}_y + 3.014\hat{a}_z$

$\vec{A} = |A|\hat{a}_A$

$$\boxed{\vec{A} = -9.045\hat{a}_x - 3.015\hat{a}_y + 3.014\hat{a}_z}$$

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Vector Triple product.

... vectors $\vec{A}, \vec{B}$ and $\vec{C}$, we define the ...tor triple product as.

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

The above eqn may be remembered as "bac-cab" rule and it should be noted that

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

but $(\vec{A}\cdot\vec{B})\vec{C} = \vec{C}(\vec{A}\cdot\vec{B})$

Problem

Points P and Q are located at (0,2,4) and (-3,1,5) and calculate

i) The position of Vector $\vec{R}_P$

... vector from $\vec{P}$ to $\vec{Q}$

$$\boxed{A = -9.045\,a_x - 3.015\,a_y + 3.014\,a_z}$$

Assignment Question

* Given points P(1,-3,5), Q(2,4,6), R(0,3,8) find

(a) the position vectors of P and R

(b) The distance vector R_{QR}

(c) The distance b/w Q and R.

Soln:- (a) $\hat{a}_x - 3\hat{a}_y + 5\hat{a}_z$,

$3\hat{a}_x + 8\hat{a}_y$

(b) $-2\hat{a}_x - \hat{a}_y + 2\hat{a}_z$

20.988 x 29.700 厘米

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The above eqn may be remembered as "bac-cab" rule and it should be noted that

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

but $(\vec{A}\cdot\vec{B})\vec{C} = \vec{C}(\vec{A}\cdot\vec{B})$

Problem

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

i) the position of vector $\vec{R}_P$

ii) the distance vector from $\vec{P}$ to $\vec{Q}$

iii) the distance b/w $\vec{P}$ and $\vec{Q}$

iv) A vector parallel to PQ with magnitude of 10.

find

(a) the position vectors of P and R

(b) The distance vector R_{QR}

(c) The distance b/w Q and R.

Soln:- (a) $\hat{a}_x - 3\hat{a}_y + 5\hat{a}_z$,

$3\hat{a}_x + 8\hat{a}_y$

(b) $-2\hat{a}_x - \hat{a}_y + 2\hat{a}_z$

(11)

Scalar Triple product

Given three vectors $\vec{A}, \vec{B}$ and $\vec{C}$, we define the Scalar triple product as

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

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

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

$\vec{C} = (C_x, C_y, C_z)$ then $\vec{A}\cdot(\vec{B}\times\vec{C})$

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

(12) Soln

$\vec{P} = (0, 2, 4) \qquad Q = (-3, 1, 5)$

(a) $\vec{R}_P = 0\hat{a}_x + 2\hat{a}_y + 4\hat{a}_z$

(b) $\vec{R}_{PQ} = \vec{R}_Q - \vec{R}_P$

$= (-3, 1, 5) - (0, 2, 4)$

$\vec{R}_{PQ} = (-3, -1, 1) = -3\hat{a}_x - 1\hat{a}_y + 1\hat{a}_z$

(c) $d = |\vec{R}_{PQ}| = \sqrt{(-3)^2 + (-1)^2 + 1^2} = 3.317$

(d) $\hat{a}_A = \dfrac{\vec{A}}{|A|} = \dfrac{\vec{R}_{PQ}}{|R_{PQ}|} = \dfrac{(-3, -1, +1)}{3.317}$

$\hat{a}_A = -0.904\hat{a}_x - 0.3014\hat{a}_y + 0.3014\hat{a}_z$

(11)

Scalar Triple product

Given three vectors $\vec{A}, \vec{B}$ and $\vec{C}$, we define the Scalar triple product as

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

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

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

$\vec{C} = (C_x, C_y, C_z)$ then $\vec{A}\cdot(\vec{B}\times\vec{C})$

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

Since the result of this vector multiplication

(12) Soln

$\vec{P} = (0, 2, 4)$ $\quad Q = (-3, 1, 5)$

(a) $\vec{R}_P = 0\hat{a}_x + 2\hat{a}_y + 4\hat{a}_z$

(b) $\vec{R}_{PQ} = \vec{R}_Q - \vec{R}_P$

$= (-3, 1, 5) - (0, 2, 4)$

$\vec{R}_{PQ} = (-3, -1, 1) = -3\hat{a}_x - 1\hat{a}_y + 1\hat{a}_z$

(c) $d = |\vec{R}_{PQ}| = \sqrt{(-3)^2 + (-1)^2 + 1^2} = 3.317$

(d) $\hat{a}_A = \dfrac{\vec{A}}{|A|} = \dfrac{\vec{R}_{PQ}}{|R_{PQ}|} = \dfrac{(-3, -1, +1)}{3.317}$

$\hat{a}_A = -0.904\hat{a}_x - 0.3014\hat{a}_y + 0.3014\hat{a}_z$

multiply by 10 then

Co-ordinate System and Transformation

The physical Quantities we shall be dealing with in EM are functions of Space and Time.

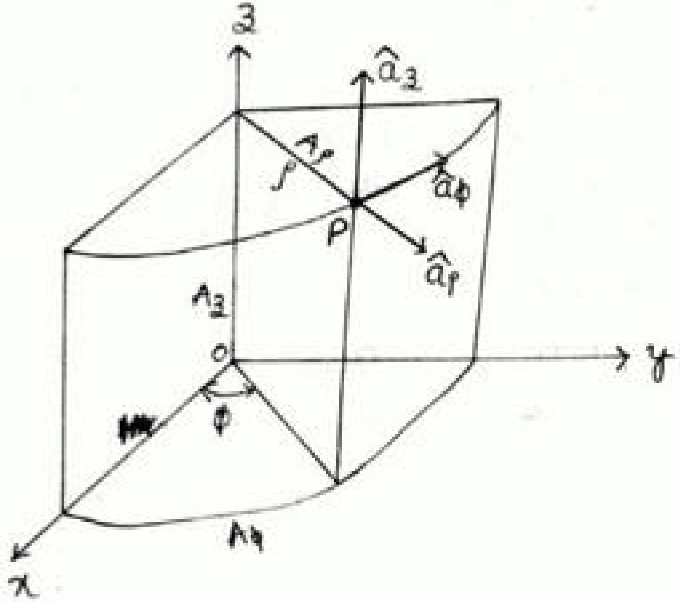
In order to describe the spatial Variations of the Quantities, we must be able to define all points uniquely in space in a Suitable manner. This requires using an appropriate coordinate System.

A point or Vector can be represented in any Curvilinear coordinate system, which may be orthogonal or Nonorthogonal.

In this Section we will study the three best-known coordinate System:

i) Cartesian

~~A point P in cylindrical coordinates is represented as (ρ, ϕ, z) and is as shown in figure below.~~

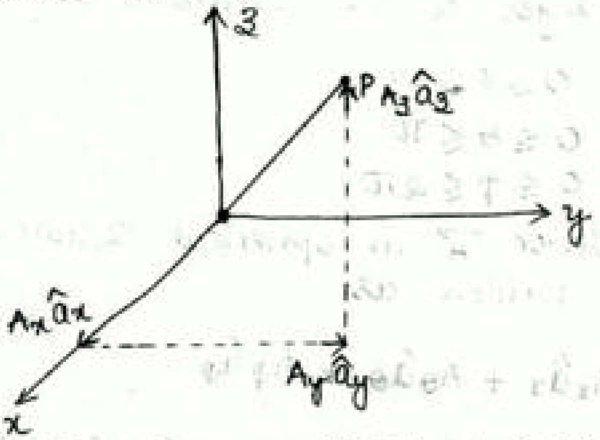


A point 'P' in cylindrical coordinate System is represented as (ρ, ϕ, z) and is

iii) the spherical.

Cartesian coordinates (x, y, z)

A point 'p' can be represented as (x, y, z) as shown in figure below.



The ranges of the coordinate variables x, y, z are.

$$-\infty < x < \infty$$
$$-\infty < y < \infty$$
$$-\infty < z < \infty$$

A vector $\vec{A}$ in cartesian (otherwise known as

Here each space variable is defined as follows.

ρ = Radial distance from the z-axis.
or
The Radius of the cylinder passing through P.

ϕ = Angle is measured from x-axis

z = Axis is same as cartesian form.

The range of variables are.

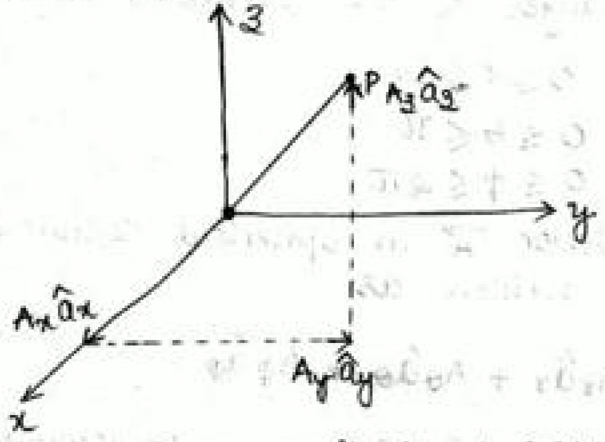
$$0 \le \rho \le \infty$$
$$0 \le \phi \le 2\pi$$
$$-\infty \le z \le \infty$$

A vector $\vec{A}$ in cylindrical coordinates can be written as

$$\boxed{\vec{A} = A_\rho \hat{a}_\rho + A_\phi \hat{a}_\phi + A_z \hat{a}_z}$$

where $\hat{a}_\rho, \hat{a}_\phi, \hat{a}_z$ are unit vectors in the ρ, ϕ, z directions.

as shown in figure below.



The ranges of the coordinate variables x, y, z are

$$-\infty < x < \infty$$
$$-\infty < y < \infty$$
$$-\infty < z < \infty$$

A vector $\vec{A}$ in cartesian (otherwise known as rectangular) coordinates can be written as
(A_x, A_y, A_z) or $A_x \hat{a}_x + A_y \hat{a}_y + A_z \hat{a}_z$

ϕ = Angle is measured from x-axis
z = Axis is same as Cartesian form.

the range of variables are.

$$0 \le \rho \le \infty$$
$$0 \le \phi \le 2\pi$$
$$-\infty \le z \le \infty$$

A vector $\vec{A}$ in cylindrical coordinates can be written as

$$\boxed{\vec{A} = A_\rho \hat{a}_\rho + A_\phi \hat{a}_\phi + A_z \hat{a}_z}$$

Where $\hat{a}_\rho, \hat{a}_\phi, \hat{a}_z$ are unit vectors in the ρ, ϕ, z directions.

Magnitude of $\vec{A}$ is $|A| = \sqrt{A_\rho^2 + A_\phi^2 + A_z^2}$

(A_x, A_y, A_z) or $A_x \hat{a}_x + A_y \hat{a}_y + A_z \hat{a}_z$

(15)

Notice that the unit vectors $\hat{a}_\rho, \hat{a}_\phi, \hat{a}_z$ are mutually perpendicular to each other because our coordinate system is orthogonal

$\hat{a}_\rho$ points in the direction of increasing ρ

$\hat{a}_\phi$ in the direction of increasing ϕ

$\hat{a}_z$ in the positive z-direction.

The relationship b/w the variables (x, y, z)

(16)

Spherical coordinates (r, θ, ϕ)

The spherical coordinate system is most appropriate when one is dealing with problems having a degree of spherical symmetry. A point 'P' can be represented as (r, θ, ϕ) and is illustrated in fig below

those of the cylindrical ...

Rect → cylindrical

$$\rho = \sqrt{x^2+y^2}$$

$$\phi = \tan^{-1}\frac{y}{x}$$

$$z = z$$

or

cylindrical → rectangular

$$x = \rho\cos\phi$$

$$y = \rho\sin\phi$$

$$z = z$$

Note

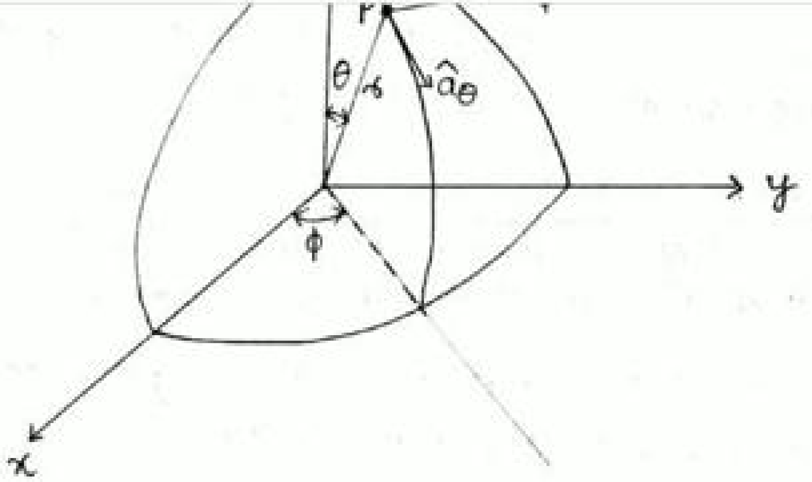
$$\hat{a}_\rho\cdot\hat{a}_\rho = \hat{a}_\phi\cdot\hat{a}_\phi = \hat{a}_z\cdot\hat{a}_z = 1$$

$$\hat{a}_\rho\cdot\hat{a}_\phi = \hat{a}_\phi\cdot\hat{a}_z = \hat{a}_z\cdot\hat{a}_\rho = 0$$

$$\hat{a}_\rho \times \hat{a}_\phi = \hat{a}_z$$

$$\hat{a}_\phi \times \hat{a}_z = \hat{a}_\rho$$

$$\hat{a}_z \times \hat{a}_\rho = \hat{a}_\phi$$



Here each space variables are defined as follows.

r = The distance from origin to point P.

θ = colatitude (The angle b/w z axis and positive vector P)

ϕ = Angle is measured from x-axis in x-y plane.

The ranges of the variables are.

$$0 \le r \le \infty$$

$\hat{a}_\rho \times \hat{a}_\phi = \hat{a}_z$

$\hat{a}_\rho \times \hat{a}_\phi = \hat{a}_z$

$\hat{a}_\phi \times \hat{a}_z = \hat{a}_\rho$

$\hat{a}_z \times \hat{a}_\rho = \hat{a}_\phi$

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ϕ = Angle is measured from x-axis in x-y plane.

The ranges of the variables are.

$$0 \le r \le \infty$$
$$0 \le \theta \le \pi$$
$$0 \le \phi \le 2\pi$$

The vector $\vec{A}$ in spherical coordinate system written as

$$\vec{A} = A_r \hat{a}_r + A_\theta \hat{a}_\theta + A_\phi \hat{a}_\phi$$

where $\hat{a}_r$, $\hat{a}_\theta$, $\hat{a}_\phi$ are unit vectors along r, θ, ϕ directions.

VECTOR CALCULUS.p...

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(17)

The relationship b/w variables (x, y, z) of the Cartesian coordinate system and those of the spherical coordinates system $[r, \theta, \phi]$ is written as below.

$$\boxed{\begin{aligned} r &= \sqrt{x^2 + y^2 + z^2} \\ \theta &= \tan^{-1}\left[\frac{\sqrt{x^2+y^2}}{z}\right] \\ \phi &= \tan^{-1}\left(\frac{y}{x}\right) \end{aligned}}$$

→ Transformation from Cartesian form to spherical coordinate system.

$x = r\sin\theta\cos\phi$

Transformation from spherical co-ordinate

(b) $Q(3, 0, 5)$ (c) $R(-2, 6, 0)$ (18)

2) Express the following in cartesian form

(a) point $P(\overset{\rho}{1}, \overset{\phi}{60^\circ}, \overset{z}{2})$

$x = \rho\cos\phi = 1\cos 60^\circ = 1/2 = 0.5$

$y = \rho\sin\phi = 1\sin 60^\circ = \frac{\sqrt{3}}{2} = 0.8660$

$z = z = 2$

(b) $T(\overset{r}{4}, \overset{\theta}{\pi/2}, \overset{\phi}{\pi/6})$

$x = r\sin\theta\cos\phi = 4\sin\pi/2\cos\pi/6 = 3.46$ rad

$y = r\sin\theta\sin\phi = 4\sin\pi/2\sin\pi/6 = 2$ rad

$z = r\cos\theta = 4\cos\pi/2 = 0$ rad

9 11

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of the Cartesian Co-ordinate System and those of the Cylindrical System (ρ, ϕ, z) are

Rect → cylindrical

$$\rho = \sqrt{x^2 + y^2}$$

$$\phi = \tan^{-1} \frac{y}{x}$$

$$z = z$$

or

cylindrical → rectangular

$$x = \rho \cos\phi$$

$$y = \rho \sin\phi$$

$$z = z$$

Note

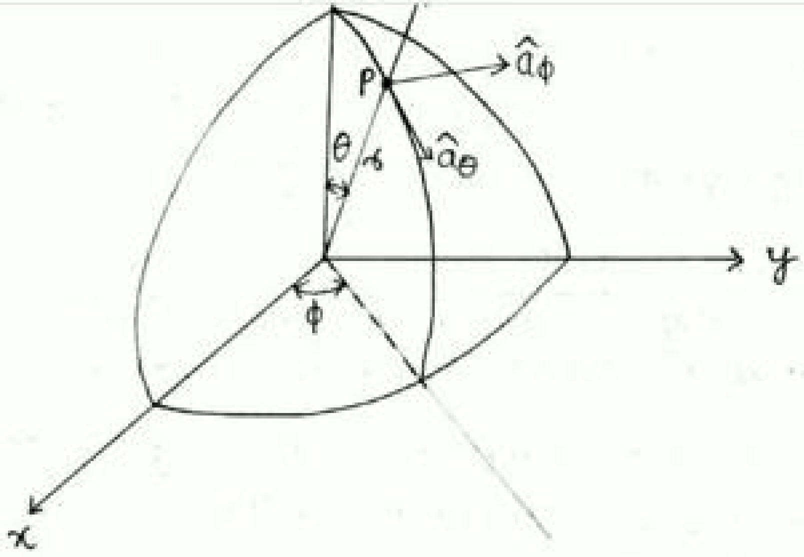
$$\hat{a}_\rho \cdot \hat{a}_\rho = \hat{a}_\phi \cdot \hat{a}_\phi = \hat{a}_z \cdot \hat{a}_z = 1$$

$$\hat{a}_\rho \cdot \hat{a}_\phi = \hat{a}_\phi \cdot \hat{a}_z = \hat{a}_z \cdot \hat{a}_\rho = 0$$

$$\hat{a}_\rho \times \hat{a}_\phi = \hat{a}_z$$

$$\hat{a}_\phi \times \hat{a}_z = \hat{a}_\rho$$

$$\hat{a}_z \times \hat{a}_\rho = \hat{a}_\phi$$



Here each space variables are defined as follows.

r = The distance from origin to point P.

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ϕ = Angle is measured from x-axis in x-y plane.

The ranges of the variables are.

Notice that the unit vectors $\hat{a}_\rho, \hat{a}_\phi, \hat{a}_z$ are mutually perpendicular to each other because our coordinate system is orthogonal. $\hat{a}_\rho$ points in the direction of increasing ρ, $\hat{a}_\phi$ in the direction of increasing ϕ, $\hat{a}_z$ in the positive z-direction.

The relationship b/w the variables (x, y, z) of the Cartesian Co-ordinate System and those of the Cylindrical System (ρ, ϕ, z) are

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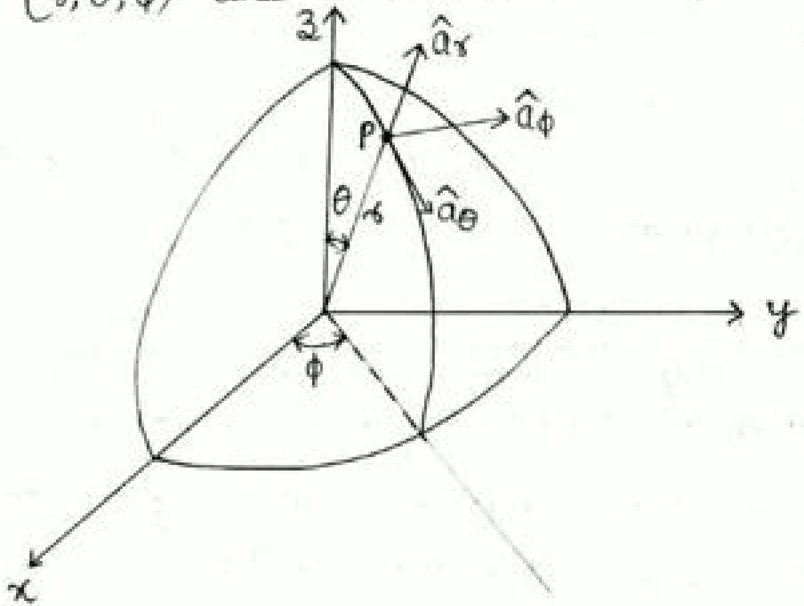

of the Cartesian Co-ordinate System and those of the Cylindrical System (ρ, ϕ, z) are

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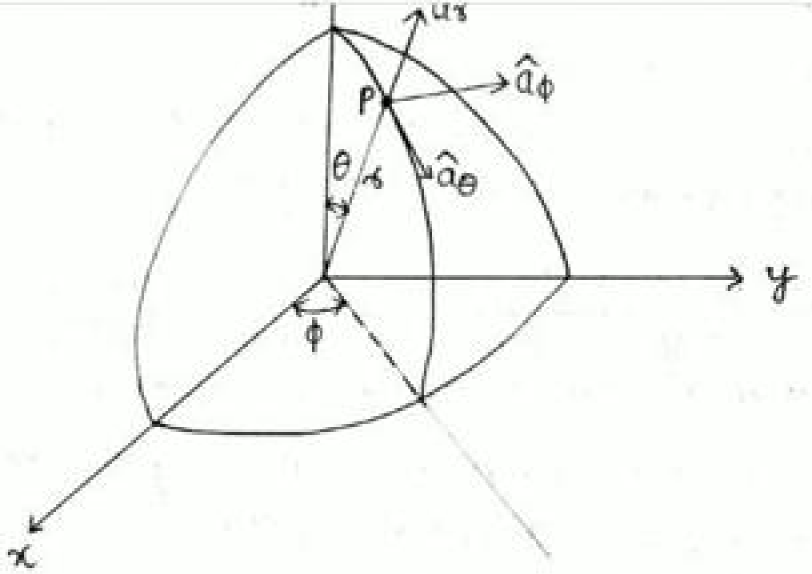
$$\hat{a}_z \times \hat{a}_\rho = \hat{a}_\phi$$



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The ranges of the variables are

$z = z$

Note

$$\hat{a}_\rho \cdot \hat{a}_\rho = \hat{a}_\phi \cdot \hat{a}_\phi = \hat{a}_z \cdot \hat{a}_z = 1$$

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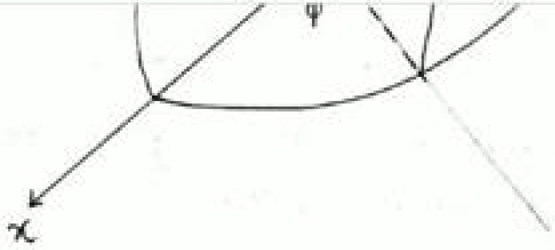

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The vector $\vec{A}$ in spherical coordinate system written as

The relationship b/w variables (x, y, z) of the Cartesian coordinate system and those of the spherical coordinates system $[r, \theta, \phi]$ is written as below.

$$\boxed{\begin{aligned} r &= \sqrt{x^2+y^2+z^2} \\ \theta &= \tan^{-1}\left[\frac{\sqrt{x^2+y^2}}{z}\right] \\ \phi &= \tan^{-1}\left(\frac{y}{x}\right) \end{aligned}}$$

→ Transformation from Cartesian form to spherical coordinate system.

$x = r\sin\theta\cos\phi$

Transformation from ...

(b) $Q(3, 0, 5)$ (c) $R(-2, 6, 0)$

2) Express the following in cartesian form

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(b) $T(\overset{r}{4}, \overset{\theta}{\pi/2}, \overset{\phi}{\pi/6})$

$x = r\sin\theta\cos\phi = 4\sin\pi/2\cos\pi/6 = 3.46$ rad

$y = r\sin\theta\sin\phi = 4\sin\pi/2\sin\pi/6 = 2$ rad

$$\boxed{\begin{aligned} x &= r\sin\theta\cos\phi \\ y &= r\sin\theta\sin\phi \\ z &= r\cos\theta \end{aligned}} \rightarrow$$

Transformation from spherical co-ordinate system to cartesian form.

Problems

1) Express the following point in cylindrical and spherical coordinates

(a) $P(1,-4,-3)$ cylindrical.

$\rho = \sqrt{x^2+y^2} = \sqrt{1+16} = \sqrt{17} = 4.123$

$\phi = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{-4}{1}\right) = -75.96$

$z = z = -3$

$x = r\sin\theta\cos\phi = 4\sin\pi/2\cos\pi/6 = 3.46$

$y = r\sin\theta\sin\phi = 4\sin\pi/2\sin\pi/6 = 2$ rad

$z = r\cos\theta = 4\cos\pi/2 = 0$ rad

3)(a) Give the cartesian coordinates of the point $C(\rho = 4.4, \phi = -115°, z = 2)$

(b) Give the cylindrical coordinates of the point $D(x = -3.1, y = 2.6, z = -3)$

(c) Specify the distance from C to D.

~~(c) Sp~~

Soln: (a) $x = \rho\cos\phi = 4.4\cos\phi$

$= 4.4\cos(-115) = -1.86$

$y = \rho\sin\phi = 4.4\sin\phi$

$= 4.4\sin(-115) = -3.99$

$$\boxed{\begin{aligned} r &= \sqrt{x^2+y^2+z^2} \\ \theta &= \tan^{-1}\left[\frac{\sqrt{x^2+y^2}}{z}\right] \\ \phi &= \tan^{-1}\left(\frac{y}{x}\right) \end{aligned}}$$

→ from Cartesian form to Spherical Coordinate System.

$$\boxed{\begin{aligned} x &= r\sin\theta\cos\phi \\ y &= r\sin\theta\sin\phi \\ z &= r\cos\theta \end{aligned}}$$

→ Transformation from spherical co-ordinate system to cartesian form.

Problems

1) Express the following points in cylindrical and spherical coordinates

(a) $P(1,-4,-3)$ cylindrical.

$y = \rho\sin\phi = 1\sin 60 = \frac{\sqrt{3}}{2} = 0.8660$

$z = z = 2$

(b) $T(\overset{r}{4}, \overset{\theta}{\pi/2}, \overset{\phi}{\pi/6})$

$x = r\sin\theta\cos\phi = 4\sin\pi/2\cos\pi/6 = 3.46$ rad

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3) (a) Give the cartesian coordinates of the point $C(\rho = 4.4, \phi = -115°, z = 2)$

(b) Give the cylindrical coordinates of the point $D(x=-3.1, y=2.6, z=-3)$

(c) Specify the distance from C to D.

~~(c) Sp~~

$$R_{CD} = R_D - R_C = (-3.1+1.86)\hat{a}_x + (2.6+3.99)\hat{a}_y + (-3-2)\hat{a}_z$$

$$R_{CD} = -1.24\,\hat{a}_x + 6.59\,\hat{a}_y - 5\,\hat{a}_z$$

$$|R_{CD}| = \sqrt{(-1.24)^2 + (6.59^2) + (-5)^2} = 8.36$$

4) Transform to cylindrical form

$\vec{F} = 10\hat{a}_x - 8\hat{a}_y + 6\hat{a}_z$ at point $(10, -8, 6)$

$$\rho = \sqrt{x^2+y^2} = \sqrt{10^2+(-8)^2} = 12.8062$$

$$\phi = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{-8}{10}\right) = -38.65^\circ$$

$$z = z = 6$$

$$\hat{a}_A = \frac{\text{Vector}}{\text{Magnitude}} = \frac{\vec{A}}{|A|} = \frac{\vec{A}}{A}$$

here the magnitude of vector $\vec{A}$ is a Scalar written as A or $|A|$ hence the vector $\vec{A}$ we can written as

$$\boxed{\vec{A} = A\,\hat{a}_A}$$

From above eqn we can say that the Vector $\vec{A}$ is in the terms of magnitude A and its direction $\hat{a}_A$

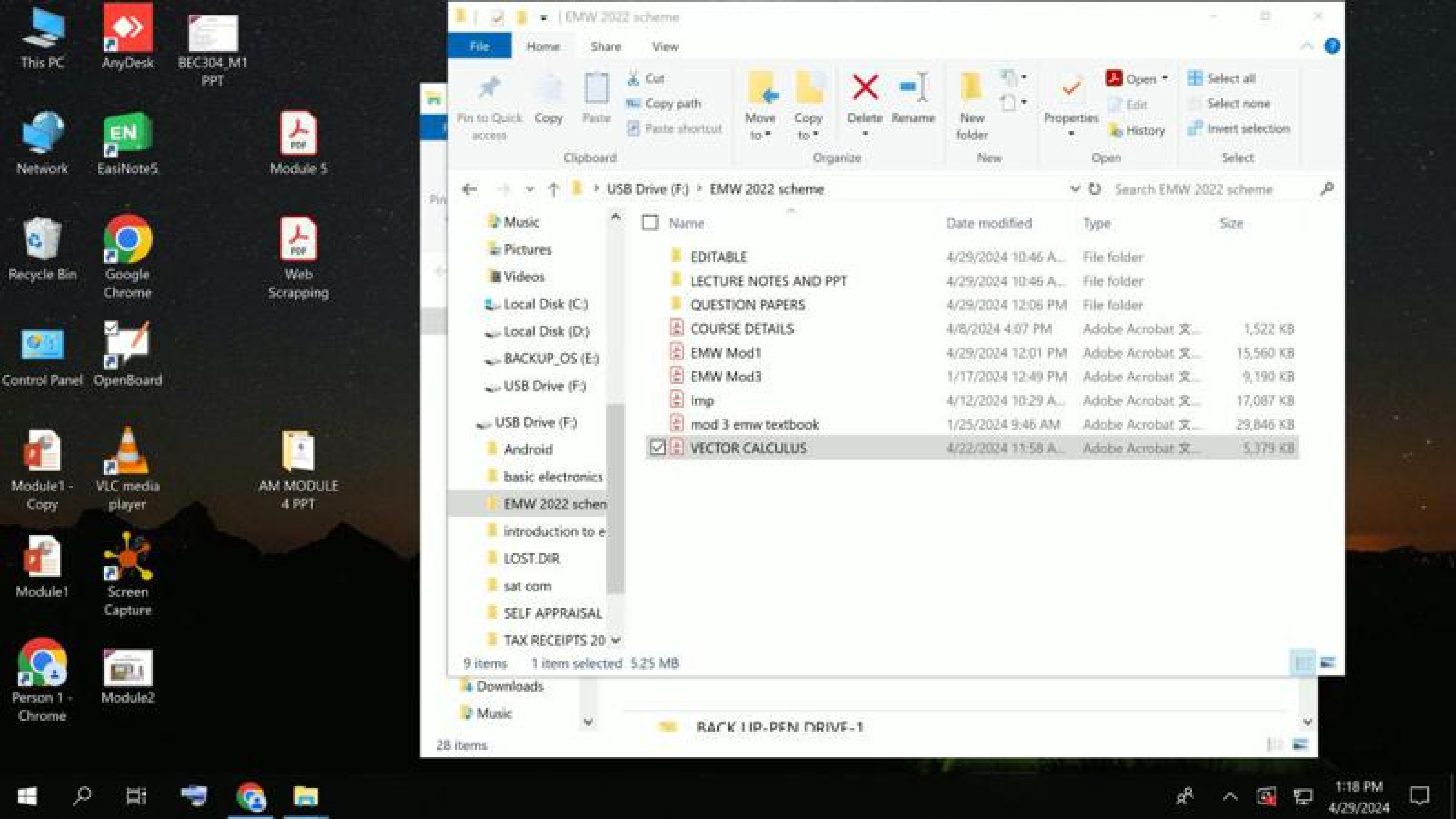
A vector $\vec{A}$ in Cartesian or Rectangular co-ordinates may be represented as

$$\boxed{A_x\hat{a}_x + A_y\hat{a}_y + A_z\hat{a}_z}$$

where

A_x, A_y, A_z = Components of $\vec{A}$ in x, y, z directions.

$\hat{a}_x, \hat{a}_y, \hat{a}_z$ = unit vectors in x, y, z directions.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