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VECTOR SPACE

Field :A non-empty commutative set (F, +, .) is a field if every non-zero element of F has multiplicative inverse.

Note :If (F, +, .) is field then (F, +) and (F^*, .) are abelian group.

Note :

(1) Z_p is a field iff p is prime.

(2) Cardinality of field never divisible by two distinct prime number.

i.e. if F is field then $|F| = p^n$; p is prime.

Internal composition :If A be any set s.t. $a * b \in A$, where $a \in A$, $b \in A$ then * is said to be internal composition in the set A.

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N | Z | Q | R | C

{1, 2, ...}

{ -1, 0, 1 }

p/q p, q ∈ Z, q ≠ 0

R = Q ∪ Q^c

C = R ∪ iR

a × b ∈ Z

a × (b × c) = (a × b) × c

e × a = a

e = 1

a × 1/a = e

(Q*, ×)

(R*, ×)

(C*, ×)

(Z, +)

(Q, +)

(R, +)

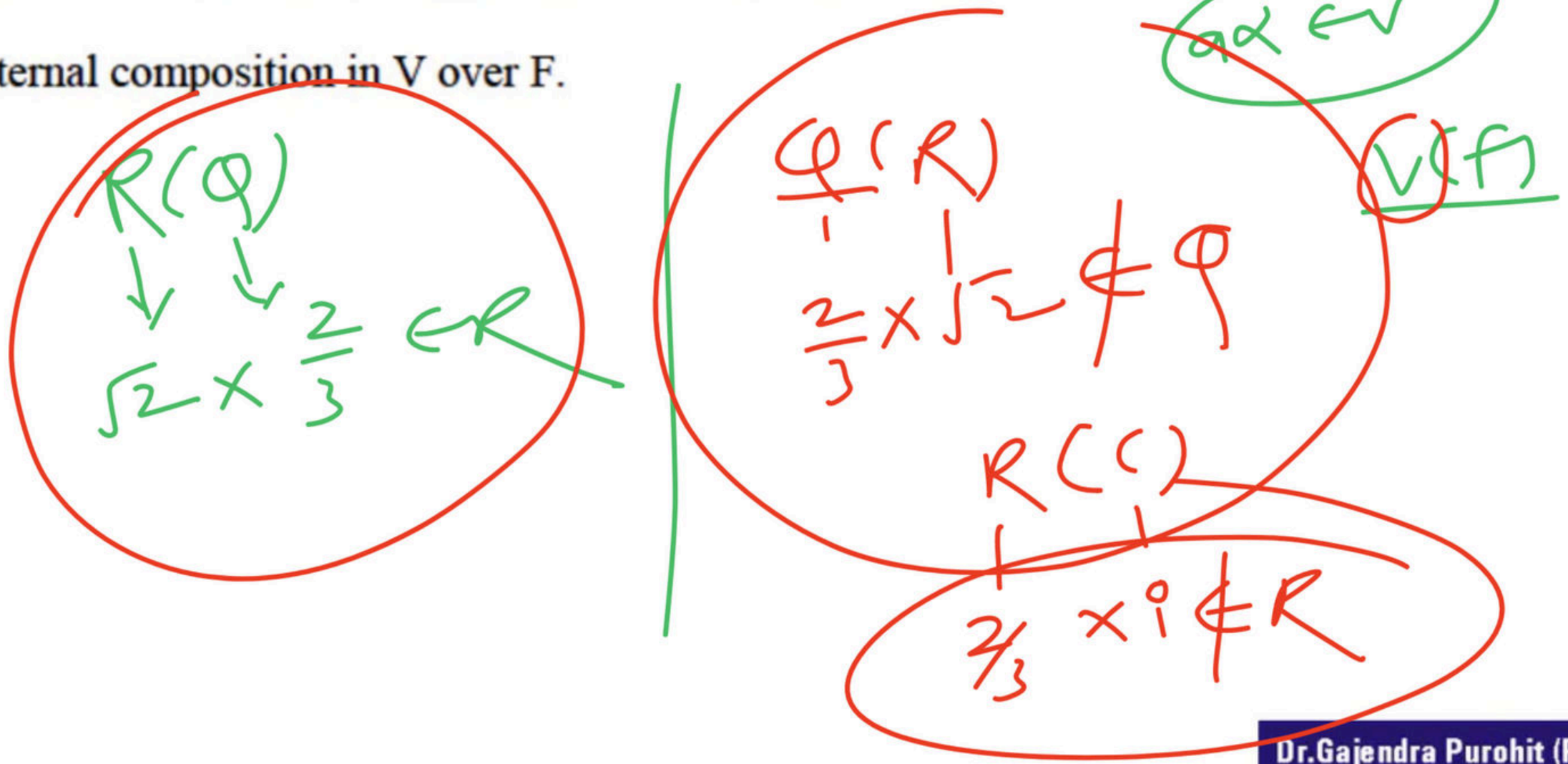
(C, +)

(Q, +, ×) ✓

(R, +, ×)

External composition : Let V & F be any two set.

If a * $\alpha \in$ V ,where a $\in$ V , $\alpha \in$ F then '*' is said to be external composition in V over F.



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Vector Space :Let $(F, +, .)$ be a field & V be non-empty set. The elements of F are called scalars & the elements of V are called vectors. Then V is a vector space over the field if –

(i) $(V, +)$ is abelian group.

(ii) V is closed with respect to scalar multiplication $\alpha u \in V$, for all $\alpha \in F$, $u \in V$

(iii) Scalar multiplication and vectors addition

(a) $\alpha(u + v) = \alpha u + \alpha v$, for all $\alpha \in F$, for all $u, v \in V$

(b) $(\alpha + \beta)u = \alpha u + \beta u$, for all $\alpha, \beta \in F$, for all $u \in V$

(c) $(\alpha\beta)u = \alpha(\beta u)$; for all $\alpha, \beta \in F$, for all $u \in V$

(iv) $1.u = u$; for all $u \in V$, where 1 is the unit element of the field F.

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Matrix Vector space :

Let $V = \{[a_{ij}]_{m\times n}; a_{ij} \in P\}$ and F = Q

then V is vector space over F if Q is subset of P

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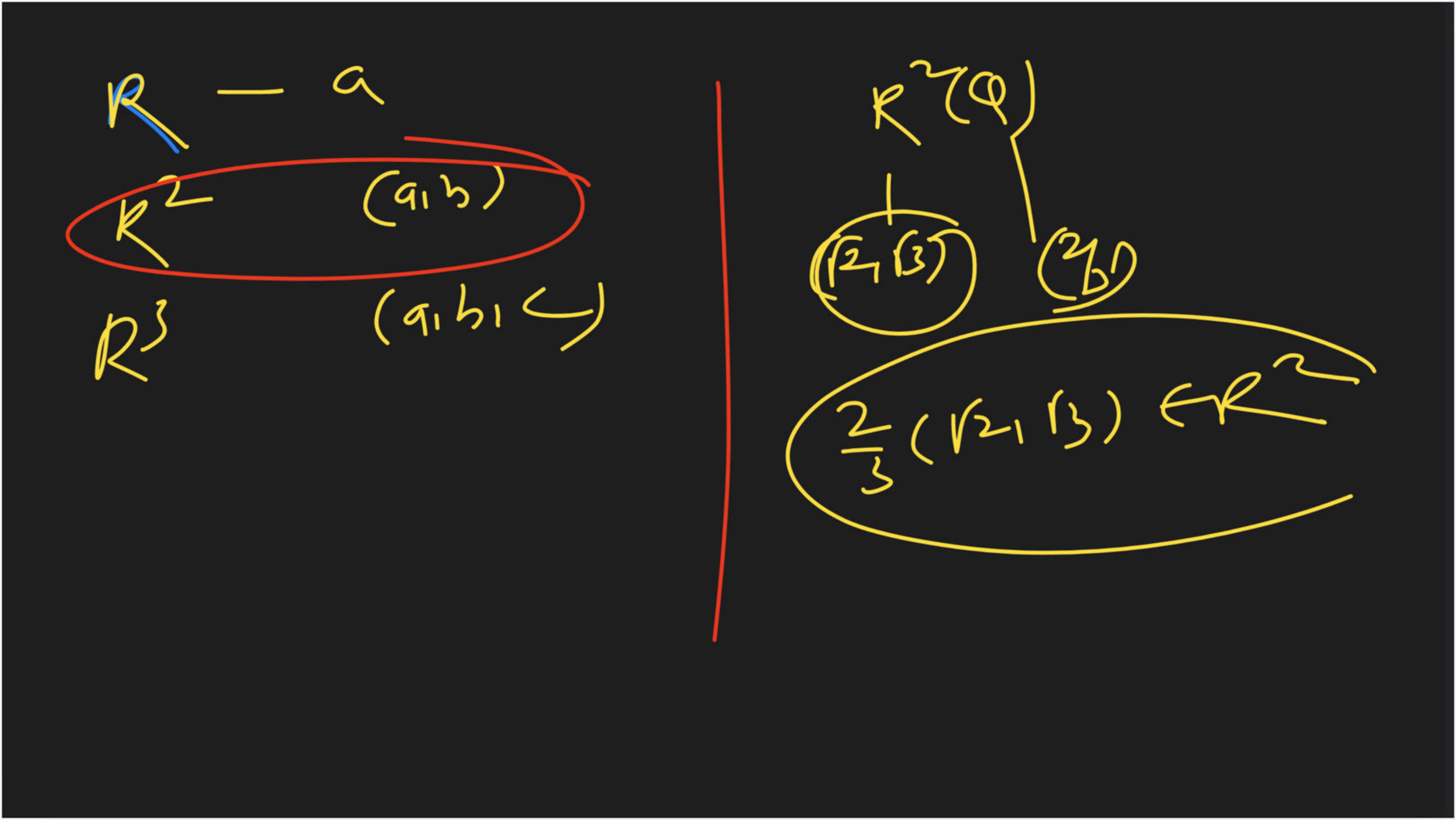
$$\mathbb{Q}(\sqrt{2}) = \{a + \sqrt{2}b \mid a, b \in \mathbb{Q}\}$$

$b = 0$

$\mathbb{Q} \subset \mathbb{Q}(\sqrt{2})$

$\{a + \sqrt{2}0 \mid a \in \mathbb{Q}\} = \mathbb{Q}$

$\mathbb{Q}\sqrt{2}(\mathbb{Q})$


R — a
R²
(a, b)
R³
(a, b, c)
R²(q)
(2, 3)
(2, b)
2/3 (2, 3) ∈ R²

Polynomial Vector space :

$R[x] = \{p(x) : p(x) = a_0 + a_1 x + \cdots \mid a_i \in R\}$ $(V, +)$

$p(x) = 1 - 2x$

$q(x) = 1 + 2x$

$p(\phi) + q(x) = 1$

$1 - 2x + 2x$ $\quad +2x - 2x$

1

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Sequence Vector Space :

Let $V = \{\langle x_n \rangle \mid x_n \in R\}$ and $F = R$

s.t. $\langle x_n \rangle + \langle y_n \rangle = \langle x_n + y_n \rangle$ and $\alpha \langle x_n \rangle = \langle \alpha x_n \rangle$

(Ex) $V = \{\langle x_n \rangle \mid \langle x_n \rangle$ is convergent$\}$ ✓

$V = \{\langle x_n \rangle \mid \langle x_n \rangle$ is oscillating$\}$ ✗

$V = \{\langle x_n \rangle \mid \lim_{n \to \infty} x_n = 0\}$ ✓

$V = \{\langle x_n \rangle \mid \lim_{n \to \infty} x_n = 1\}$ ✗

$V = \{\langle x_n \rangle \mid \lim_{n \to \infty} x_n =$ DNE$\}$ ✗

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Function Space :

Let $V = \{f \mid f : X \to R\}$ & $F = (R, +, .)$

$V = \{f \mid f : x \to R$ is continuous$\}$

$V = \{f \mid f : x \to R$ bounded$\}$

$V = \{f \mid f : R \to R$ and f vanished at finitely many points in $R\}$

$f(x) = 0$

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$V = \{f : \mathbb{R} \to \mathbb{R} \text{ and } f \text{ is monotone}\}$

$f(x) = x^3$

$g(x) = -x$

$f(x) + g(x) = x^3 - x$

$V = \{f \mid f : \mathbb{R} \to \mathbb{R}, \ f(x) = f(-x)\}$

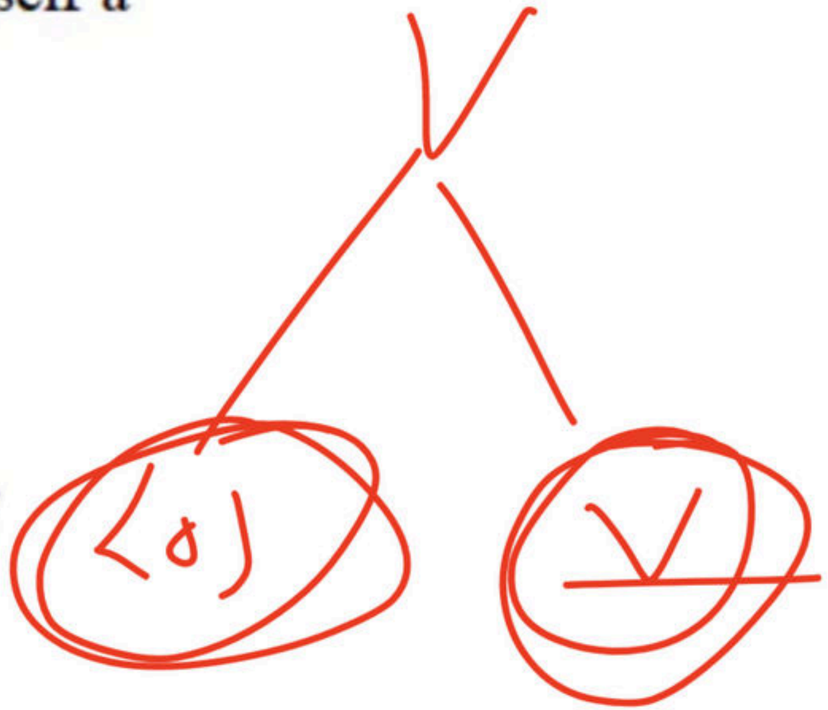
$V = \{f \mid f : \mathbb{R} \to \mathbb{R}, \ f(x) = -f(x)\}$

Subspace : Let V(F) be a vector space. Let W be any non-empty subset of V, then W is called subspace of V over F if W itself a vector space with the same field and same composition.

Note :

(1) {0} and V itself are always subspace of V.

(2) Any subspace other than {0} and V known as proper subspace of V.



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Test for subspace :A necessary and sufficient condition for subspace.

(1) Two step test :

(a) $x + y \in W$ for all $x \in W$, for all $y \in W$

(b) $\alpha x \in W$ for all $\alpha \in F$, $x \in W$

(2) One step test :

$\alpha x + \beta y \in W$; for all $\alpha, \beta \in F$ & for all $x, y \in W$

Subspace in R : The only subspace in R are {0} & (R)

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Subspace in R^2 : There are three subspace in R^2.

(i) $W_1 = \{(0, 0)\}$

(ii) $W_2 = R^2$

(iii) Any line passing through an origin is also a subspace of R^2.

Subspace in R^3

There are four subspace in R^3

(i) $W = \{(0, 0, 0)\}$

(ii) $W = R^3$

(iii) Any plane passing through an origin

(iv) Any line passing through an origin

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Vector Matrix Space :

Matrix space : Let $V = \{A = [a_{ij}]_{n\times n};\ a_{ij} \in R\}$ & $F = R$

(I) $\omega_1 = \{A \in V : AA^T = A^TA = I\}$

(II) $\omega_2 = \{A \in V : A^2 = A\}$

(III) $\omega_3 = \{A \in V : A^2 = I\}$

(IV) $\omega_4 = \{A \in V : A = A^T\}$

(V) $\omega_5 = \{A \in V : A = -A^T\}$

(VI) $\omega_6 = \{A \in V : Tr(A) = 0\}$ is Subspace

(VII) $\omega_7 = \{A \in V : |A| = 0\}$

$A = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$

A

3A

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$W_8 = \{ A = [a_{ij}] \quad A$ upper triangular $\}$

lower Tm

diagonal

Scalar

Polynomial space :

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Q.1. Which one of the following sets of vectors $\alpha = (a_1, a_2, ..., a_n)$ in R^n is a subspace of $R^{n(n\geq 3)}$?

(a) all α such that $a_1 \geq 0$

(b) all α such that $a_1 + 3a_2 = a_3$

(c) all α such that $a_2 = a_1^2$

(d) all α such that $a_1 a_2 = 0$

$(1,0,0\cdots)$

$(0,1,0,0\cdots)$

$(1,1,0\cdots)$

$(1,0,0\cdots)$

$-2(1,0,1,0\cdots)$ ←

$a_1 + 3a_2 - a_3 = 0$

$P_1 = (1,1,0,0\cdots)$

$P_2 = (2,1,0,0\cdots)$

$P_1 + P_2 = (3,2,0,0\cdots)$

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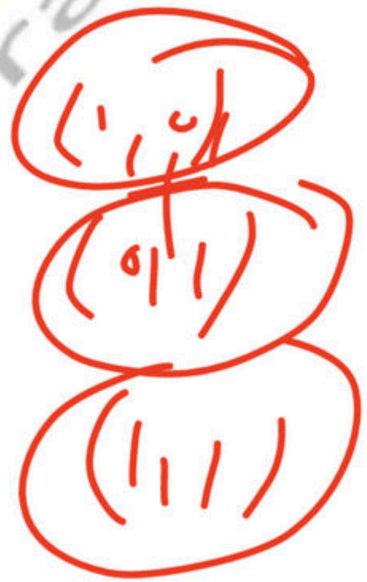
Q.2. Which of the following subsets are subspace?

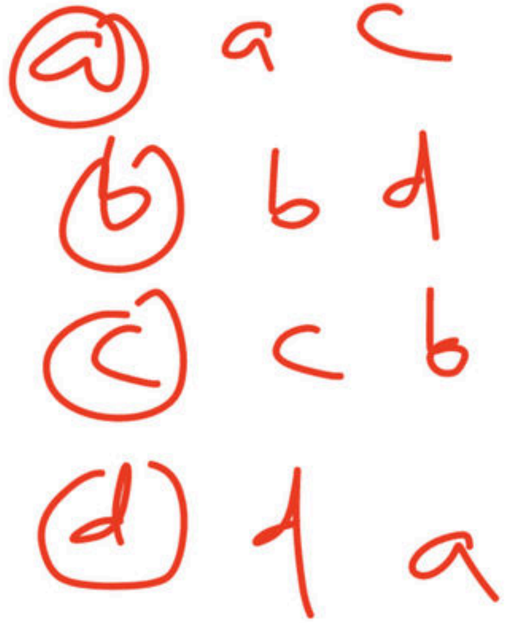
(a) $W = \{(x, y) \in R^2; xy = 0\}$

(b) $X = \{(x, y) \in R^2; y = 3x\}$

(c) $Y = \{(x, y) \in R^2; x^2 - y^2 = 0\}$

(d) $Z = \{(x, y) \in R^2; x^2 + y^2 = 0\}$





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Q.3 Which one of the following is a subspace of R^3?

(a) $(x, y, z) \in R^3 \mid x + 2y = 0, 2x + 3z = 0\}$

(b) $\{(x, y, z) \in R^3 \mid 2x + 3y + 4z - 3 = 0, z = 0\}$

(c) $\{(x, y, z) \in R^3 \mid x \geq 0, y \geq 0\}$

(d) $\{(x, y, z) \in R^3 \mid x - 1 = 0, y = 0\}$

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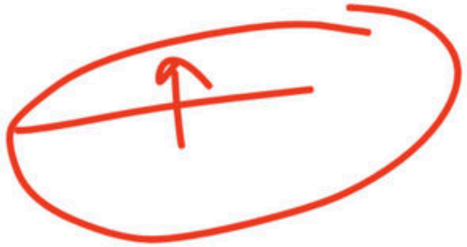
Q.4 Which of the following sets of functions from R to R is a vector space over R?

$$S_1 = \{f \mid \lim_{x \to 3} f(x) = 0\}$$

$$S_2 = \{g \mid \lim_{x \to 3} g(x) = 1\}$$

$$S_3 = \{h \mid \lim_{x \to 3} h(x) \text{ exists}\}$$



(a) Only S_1 (b) Only S_2

(c) S_1 and S_3 but not S_2

(d) All the three vector spaces

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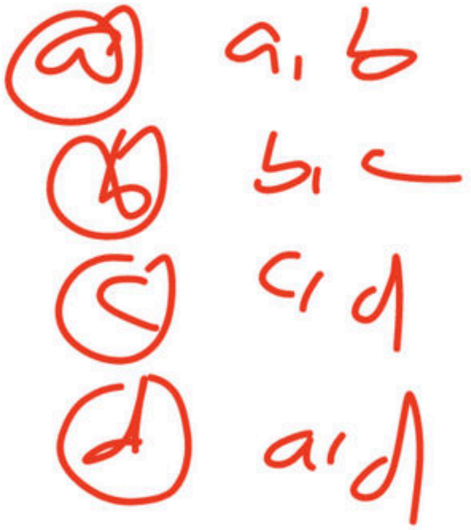
Q.5 Let M_n denote the vector space of all n ×n real matrices. Among the following subsets of M_n, decide which are linear subspaces.

(a) $V_1 = \{A \in M_n : A \text{ is non-singular}\}$

(b) $V_2 = \{A \in M_n : \det(A) = 0\}$

(c) $V_3 = \{A \in M_n : \text{trace}(A) = 0\}$

(d) $V_3 = \{BA : A \in M_n\}$, where B is some fixed matrix in M_n.



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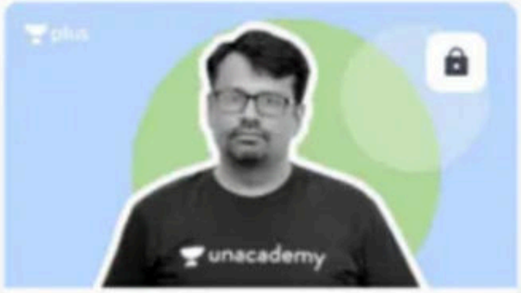

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- Studied at **M.Sc., NET, PhD(Algebra), MBA(Finance), BEd**
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