

Mathematics IB Assignment — Written 1

Semester 1, 2024

Algebra

(a) Prove that

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

is a subspace of $\mathbb{R}^3$.

(b) Find a basis for V and compute its dimension.

Solution:

(a) We just need to verify the following three properties.

- $0 \in V$: Putting $x = y = z = 0$ in the defining equation for V we have

$$4(0) - 0 + 0 = 0,$$

therefore $0 \in V$.

- $u, v \in V \Rightarrow u + v \in V$: Let $u = (u_1, u_2, u_3), v = (v_1, v_2, v_3) \in V$, we have

$$u + v = (u_1 + v_1, u_2 + v_2, u_3 + v_3).$$

Plugging into the equation for V :

$$4(u_1 + v_1) - (u_2 + v_2) + (u_3 + v_3) = (4u_1 - u_2 + u_3) + (4v_1 - v_2 + v_3) = 0,$$

since $u, v \in V$, therefore $u + v \in V$.

- $v \in V, c \in \mathbb{R} \Rightarrow cv \in V$: If $v = (v_1, v_2, v_3)$ and $c \in \mathbb{R}$ then

$$cv = (cv_1, cv_2, cv_3).$$

Plugging into the defining equation for V :

$$4(cv_1) - (cv_2) + (cv_3) = c(4v_1 - v_2 + v_3) = c(0) = 0 \Rightarrow cv \in V.$$

(b) Note that if $v = (x, y, z) \in V$ then $y = 4x + z$. That implies that every vector in V is of the form

$$(x, 4x + z, z) = x(1, 4, 0) + z(0, 1, 1).$$

It follows that V is the span of the vectors $(1, 4, 0)$ and $(0, 1, 1)$. To show that these vectors form a basis we need to verify that they are linearly independent. Given $a, b \in \mathbb{R}$, suppose that

$$a(1, 4, 0) + b(0, 1, 1) = (a, 4a + b, b) = (0, 0, 0).$$

Looking at the first and third coordinates we get $a = b = 0$, therefore $(1, 4, 0)$ and $(0, 1, 1)$ form a basis of V .

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