Future Clean Transport Technology

MECH70003

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Contents

Part 1

Thermal Propulsion Systems

1.1   IC Engine Fundamentals

Engine Components, Thermodynamic Considerations, Gas Cycles, Overall Performance, Design Considerations, Mechanical Efficiency.

1.2   Combustion System

Combustion & Turbulence; Abnormal Combustion; Heat Transfer.

1.3   Air System

Volumetric Efficiency, Flow Past the Valve, Downsizing, Boosting Systems.

Part 2

Hybrid-Electric Propulsion System

2.1 Hybrid & Electric Vehicle Technology

Advantages disadvantages, different architectures (series/parallel), electrical machines & power electronics.

2.2 Intoduction to Electrochemistry

(Batteries, supercapacitors, fuel cells), heat generation, effect temperature, heat removal.

2.3 Battery Technology

Battery pack design, thermal management, battery management systems.

2.4 Fuell Cells

Fuel cell systems design, water management, thermal management.

2.5 Transport Systems

Transport systems, lifecycle emissions & energy chain, recycling, automation.

Random Examples

Definition 2.5.1: Limit of Sequence in $\mathbb{R}$

Let $\{s_n\}$ be a sequence in $\mathbb{R}$. We say

$$\lim_{n \to \infty} s_n = s$$

where $s \in \mathbb{R}$ if $\forall$ real numbers $\epsilon > 0$ $\exists$ natural number N such that for $n > N$

$$s - \epsilon < s_n < s + \epsilon \text{ i.e. } |s - s_n| < \epsilon$$

Question 1

Is the set $x-$axis$\backslash\{$Origin$\}$ a closed set

Solution: We have to take its complement and check whether that set is a open set i.e. if it is a union of open balls

Note:-

We will do topology in Normed Linear Space (Mainly $\mathbb{R}^n$ and occasionally $\mathbb{C}^n$)using the language of Metric Space

Claim 2.5.1 Topology

Topology is cool

Example 2.5.1 (Open Set and Close Set)

Open Set:
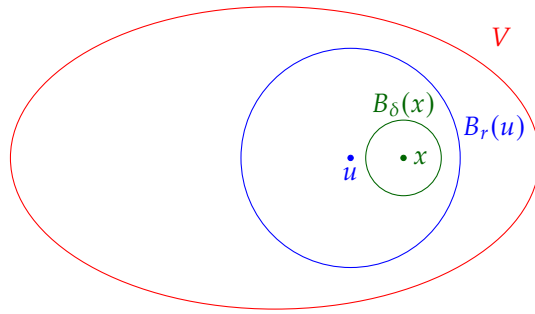- ϕ
- $\bigcup_{x \in X} B_r(x)$ (Any $r > 0$ will do)
- $B_r(x)$ is open

Closed Set:
- $\underline{X, \phi}$
- $\overline{B_r(x)}$

$x-$axis $\cup$ $y-$axis

Theorem 2.5.1

If $x \in$ open set V then $\exists$ $\delta > 0$ such that $B_\delta(x) \subset V$

Proof: By openness of V, $x \in B_r(u) \subset V$

Given $x \in B_r(u) \subset V$, we want $\delta > 0$ such that $x \in B_\delta(x) \subset B_r(u) \subset V$. Let $d = d(u, x)$. Choose δ such that $d + \delta < r$ (e.g. $\delta < \frac{r-d}{2}$)

If $y \in B_\delta(x)$ we will be done by showing that $d(u, y) < r$ but

$$d(u, y) \leqslant d(u, x) + d(x, y) < d + \delta < r$$

☺

Corollary 2.5.1

By the result of the proof, we can then show...

Lenma 2.5.1

Suppose $\vec{v}_1, \ldots, \vec{v}_n \in \mathbb{R}^n$ is subspace of $\mathbb{R}^n$.

Proposition 2.5.1

$1 + 1 = 2$.

Random

Definition 2.5.2: Normed Linear Space and Norm $\| \cdot \|$

Let V be a vector space over $\mathbb{R}$ (or $\mathbb{C}$). A norm on V is function $\| \cdot \| \; V \to \mathbb{R}_{\geqslant 0}$ satisfying

① $\|x\| = 0 \iff x = 0 \; \forall \, x \in V$

② $\|\lambda x\| = |\lambda| \|x\| \; \forall \, \lambda \in \mathbb{R}(\text{or } \mathbb{C}), \; x \in V$

③ $\|x + y\| \leqslant \|x\| + \|y\| \; \forall \, x, y \in V$ (Triangle Inequality/Subadditivity)

And V is called a normed linear space.
● Same definition works with V a vector space over $\mathbb{C}$ (again $\| \cdot \| \to \mathbb{R}_{\geqslant 0}$) where ② becomes $\|\lambda x\| = |\lambda| \|x\|$ $\forall \, \lambda \in \mathbb{C}, \; x \in V$, where for $\lambda = a + ib$, $|\lambda| = \sqrt{a^2 + b^2}$

Example 2.5.2 ($p-$Norm)
$V = \mathbb{R}^m$, $p \in \mathbb{R}_{\geqslant 0}$. Define for $x = (x_1, x_2, \cdots, x_m) \in \mathbb{R}^m$

$$\|x\|_p = \left(|x_1|^p + |x_2|^p + \cdots + |x_m|^p \right)^{\frac{1}{p}}$$

(In school $p = 2$)

Special Case $p = 1$: $\|x\|_1 = |x_1| + |x_2| + \cdots + |x_m|$ is clearly a norm by usual triangle inequality.
Special Case $p \to \infty$ ($\mathbb{R}^m$ with $\| \cdot \|_\infty$): $\|x\|_\infty = \max\{|x_1|, |x_2|, \cdots, |x_m|\}$
For $m = 1$ these $p-$norms are nothing but $|x|$. Now exercise

Prove that triangle inequality is true if $p \geqslant 1$ for $p-$norms. (What goes wrong for $p < 1$?)

Solution: **For Property ③ for norm-2**

When field is $\mathbb{R}$:

We have to show

$$\sum_i (x_i + y_i)^2 \leqslant \left(\sqrt{\sum_i x_i^2} + \sqrt{\sum_i y_i^2} \right)^2$$

$$\implies \sum_i (x_i^2 + 2x_i y_i + y_i^2) \leqslant \sum_i x_i^2 + 2\sqrt{\left[\sum_i x_i^2\right]\left[\sum_i y_i^2\right]} + \sum_i y_i^2$$

$$\implies \left[\sum_i x_i y_i\right]^2 \leqslant \left[\sum_i x_i^2\right]\left[\sum_i y_i^2\right]$$

So in other words prove $\langle x, y\rangle^2 \leqslant \langle x, x\rangle\langle y, y\rangle$ where

$$\langle x, y\rangle = \sum_i x_i y_i$$

Note:-

- $\|x\|^2 = \langle x, x\rangle$

- $\langle x, y\rangle = \langle y, x\rangle$

- $\langle \cdot, \cdot\rangle$ is $\mathbb{R}-$linear in each slot i.e.

$$\langle rx + x', y\rangle = r\langle x, y\rangle + \langle x', y\rangle \text{ and similarly for second slot}$$

Here in $\langle x, y\rangle$ x is in first slot and y is in second slot.

Now the statement is just the Cauchy-Schwartz Inequality. For proof

$$\langle x, y\rangle^2 \leqslant \langle x, x\rangle\langle y, y\rangle$$

expand everything of $\langle x - \lambda y, x - \lambda y\rangle$ which is going to give a quadratic equation in variable λ

$$\langle x - \lambda y, x - \lambda y\rangle = \langle x, x - \lambda y\rangle - \lambda\langle y, x - \lambda y\rangle$$
$$= \langle x, x\rangle - \lambda\langle x, y\rangle - \lambda\langle y, x\rangle + \lambda^2\langle y, y\rangle$$
$$= \langle x, x\rangle - 2\lambda\langle x, y\rangle + \lambda^2\langle y, y\rangle$$

Now unless $x = \lambda y$ we have $\langle x - \lambda y, x - \lambda y\rangle > 0$ Hence the quadratic equation has no root therefore the discriminant is greater than zero.

When field is $\mathbb{C}$:

Modify the definition by

$$\langle x, y\rangle = \sum_i \overline{x_i} y_i$$

Then we still have $\langle x, x\rangle \geqslant 0$

Algorithms

Algorithm 1: what

Input: This is some input
Output: This is some output
/* This is a comment */

```
1  some code here;
2  x ← 0;
3  y ← 0;
4  if x > 5 then
5  |   x is greater than 5 ;                              // This is also a comment
6  else
7  |   x is less than or equal to 5;
8  end
9  foreach y in 0..5 do
10 |   y ← y + 1;
11 end
12 for y in 0..5 do
13 |   y ← y − 1;
14 end
15 while x > 5 do
16 |   x ← x − 1;
17 end
18 return Return something here;
```