Topic 2

Regenerative Braking System in Electric Vehicles

Learning Objectives

Energy regeneration plays a key role in sustainable development. In this topic, we will explore how to make use of scientific knowledge and innovative technology to regenerate energy in electric vehicles (EVs) through the following activities:

Activity I

Charging a supercapacitor

Activity II

More power! Connecting electric motors in series

Activity III

Killing two birds with one stone - Regenerative Braking System (RBS)

Activity IV

Design and make model car with the RBS and investigate its properties

The 17 Sustainable Development Goals (SDGs)

The 17 SDGs proposed in the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provide a shared blueprint for peace and prosperity for people and the planet, now and into the future.

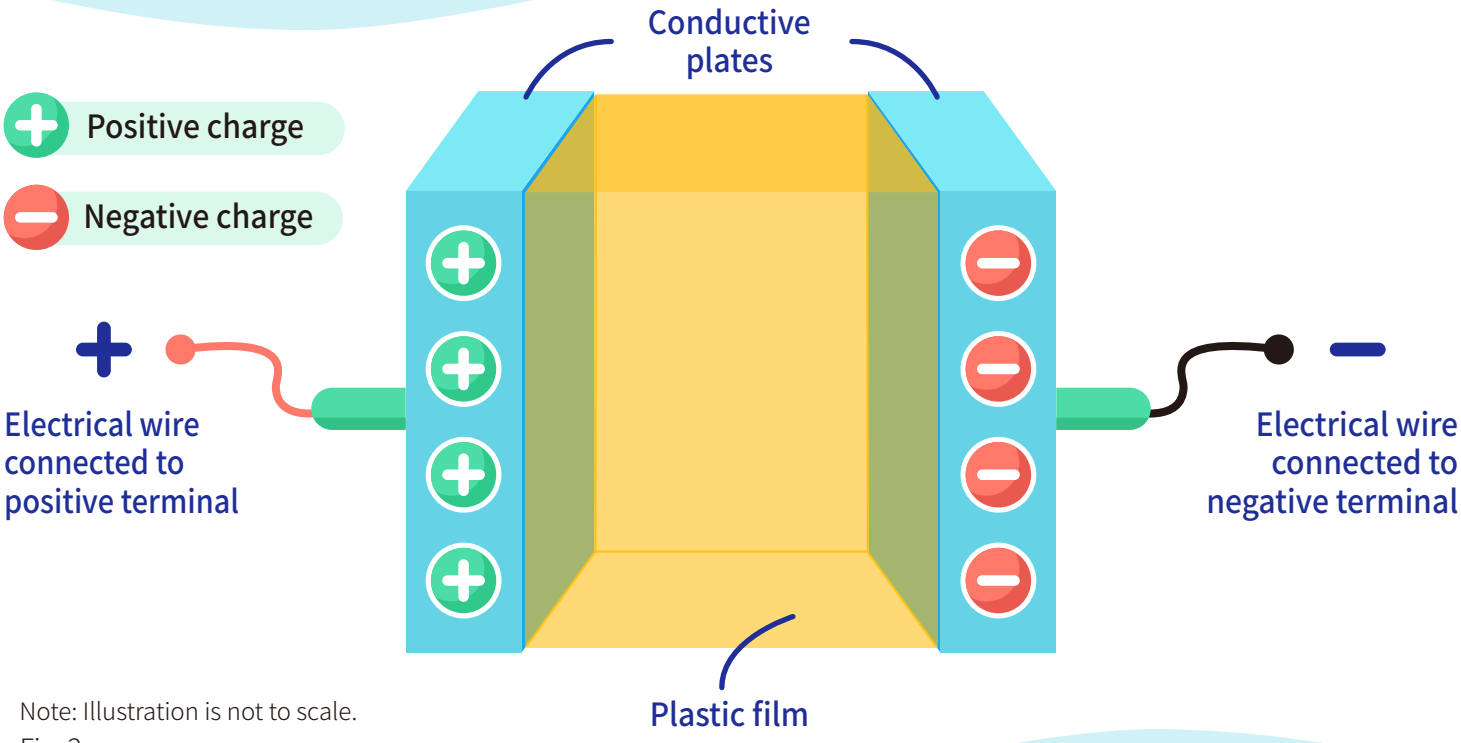
Reference:
https://sdgs.un.org/goals

Fig. 1

The regenerative braking technique used in electric vehicles (EVs) is aligned with SDG 7 (Affordable and Clean Energy). Regenerative braking allows electric vehicles to store the energy that would otherwise be lost during braking by converting it into usable electricity to recharge the vehicle's battery. This helps reduce reliance on fossil fuels and promotes the use of clean energy sources, contributing towards a sustainable future.

Background knowledge: How capacitor works

A **capacitor** is an electronic component for storing charges and electrical energy. Its simplest structure consists of two conducting plates placed close to each other, **without electrical conduction** between them, e.g. separated by a plastic film. **Capacitance** refers to the capability of storing charges and energy inside a capacitor (SI unit: Farad *F*).



Note: Illustration is not to scale.
Fig. 2

When a capacitor is connected to a power supply, charges accumulate on the conducting plates, electrical energy is stored in the capacitor, as shown in Fig. 2.

Activity I (Demonstration)
Charging a supercapacitor

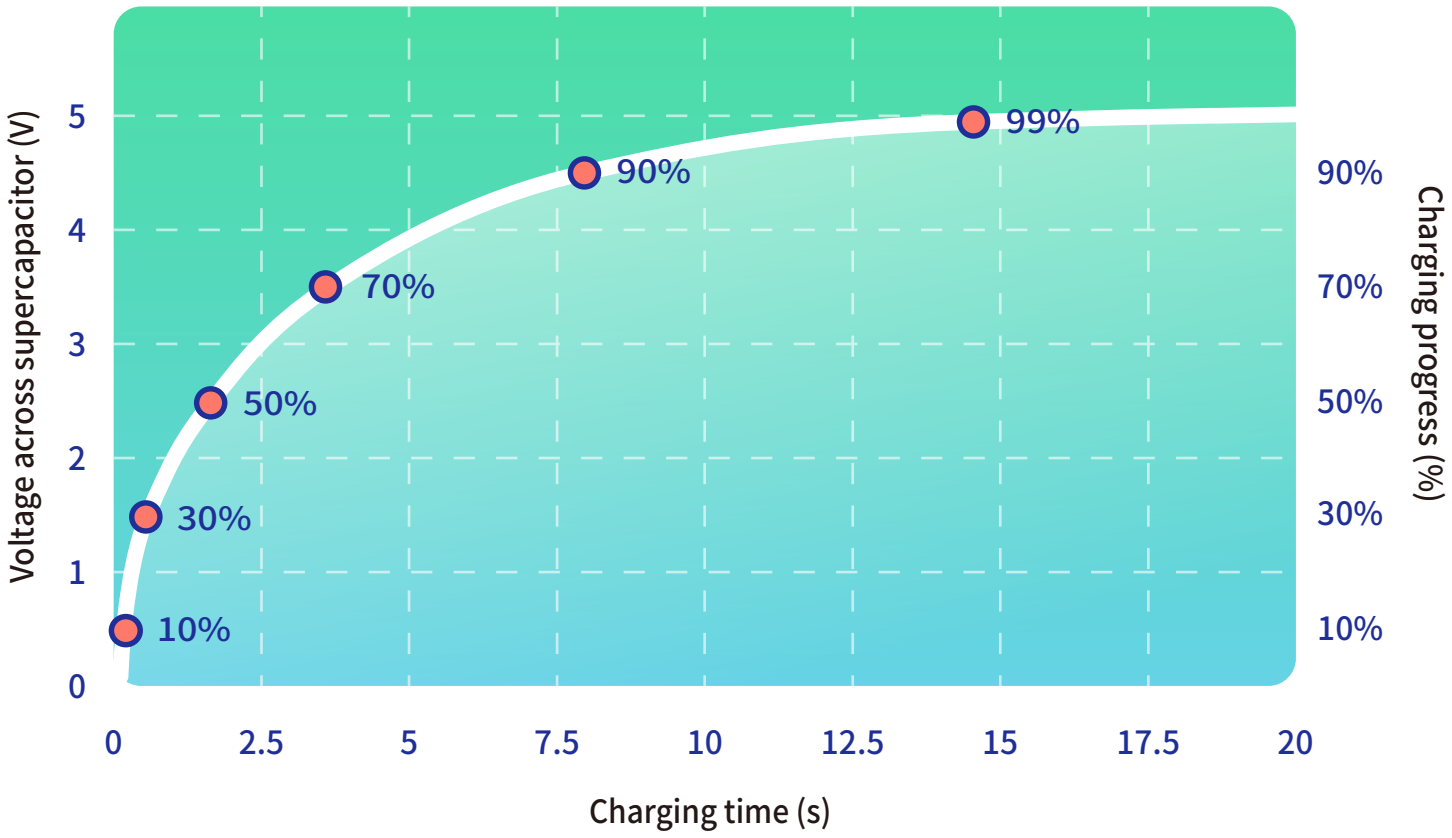
Introduction

In this activity, we will investigate the charging rate of a supercapacitor.

Instructions

Watch the video. Study the graph and the table showing the voltage across the supercapacitor during charging. Then answer the following questions.

Video 4



Stage	Charging progress (%) and Voltage	Charging time (s)
A	10% (0.5 V)	0.01
	30% (1.5 V)	0.35
B	50% (2.5 V)	1.48
	70% (3.5 V)	3.46
C	90% (4.5 V)	7.95
	99% (4.95V)	14.64

Questions

1 In which stage is the charging rate highest?

2 It is known that **"like charges repel each other"**. Explain why the charging rate in stage A is higher than that in stage C.

3 What is the advantage of this property of supercapacitors when they are used as fast-charging batteries for electric vehicles (EVs)? Explain briefly.

Conclusion

Due to the property that "**like charges repel each other**", it is _____ efficient to charge up a supercapacitor at the initial stage than that at the final stage.

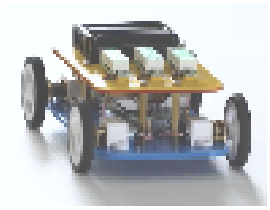
Activity II (Demonstration)
More Power! Connecting the Electric Motors in Series

Introduction

In this activity, we will study the voltage generation from electric motors connected in series.

Watch the video below and compare the voltage generation from a single motor with that from motors connected in series.

Video 5



Question

4 When a lorry is moving at 50 km/h, a single generator installed in regenerative braking system can deliver 12V. If 10 wheels of the lorry are installed with the same generators connected in series, predict the generated voltage when the lorry is moving at the same speed.

Conclusion

In this activity, we learnt that the voltage generated from electric motors connected in series circuit is _____ than that from a single electric motor.

Activity III(Demonstration)
Killing Two Birds with One Stone - Regenerative Braking System (RBS)

Introduction

In this activity, we will learn how the Regenerative Braking System (RBS) works. Watch the video on the right and learn about the difference between traditional braking system and RBS.

Video 6

Traditional Braking System

When the brakes are applied, the brake pads press against rotors of the vehicle, which causes the vehicle to slow down rotors to reduce the speed of the vehicle. **All** kinetic energy associated with the decrease in speed of the vehicle is converted to thermal energy and sound energy. These energy are then lost into the environment and are not recoverable, resulting in a waste of energy.

Regenerative Braking System (RBS)

When the brakes are applied, **some** kinetic energy is converted to electrical energy which can be stored in a battery. This electrical energy can then be used to power the vehicle, reducing the fuel consumption.

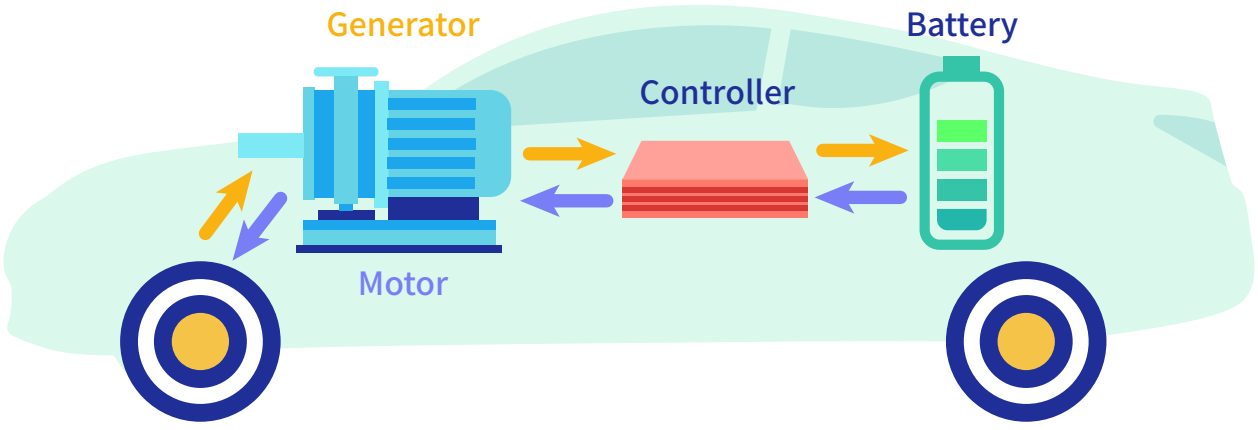


Fig. 3

Questions

5 Compare the traditional braking system and regenerative braking system (RBS) and fill in the blanks below.

	Traditional braking system	Regenerative braking system
Working principle	Brake pads press on the vehicle's rotors to reduce its speed	Converts some kinetic energy to electrical energy that could be used immediately or stored for later use
Energy conversion	**All** kinetic energy ▶ [ ] energy + [ ] energy	**Some** kinetic energy ▶ [ ] energy

Table 1

6 When comparing the traditional braking system and the RBS, why does the traditional braking system cause the wheels to become hotter when the brakes are applied?

7 How can the RBS help in reducing fossil fuel consumption?

Conclusion

Regenerative braking system can convert the kinetic energy that would otherwise be wasted in the traditional braking system to electrical energy.

This electrical energy could be used immediately or stored for later use to power the vehicle, resulting in a reduction in fossil fuel consumption and the amount of greenhouse gases emission.

Activity IV
Design and make a model car with RBS and investigate its properties

Introduction

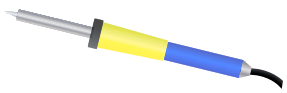
In this activity, we will construct two model cars, with and without RBS, and compare their performance when moving down on a slope.

Watch the video on the right and begin to construct the model cars.

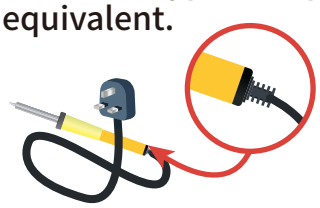
Video 7

Safety precautions for handling soldering iron and soldering gun

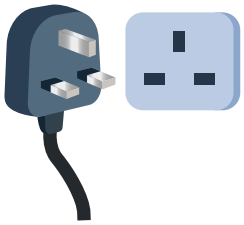
1. Soldering iron body should be made of steel, securely attached to a high strength plastic, or wood handle for good insulation.



2. The supply cable should enter the handle through a rubber grommet, secured inside with a screw-down type clamp or equivalent.

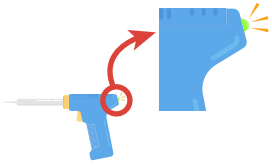


3. The soldering iron or soldering gun should be fitted with a 3-pin plug and properly fused.

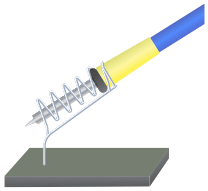


4. The ON/OFF switch of soldering gun should be biased to the 'OFF' position to minimise fatigue during long periods of use.

5. The pistol grip type soldering gun should preferably have an indicator light activated from the main ON/OFF switch.



6. The soldering gun or the soldering iron should be used with a proper stand.



7. Soft soldering should only be done where ventilation is sufficient to avoid the inhaling of harmful fumes.

Watch the video and answer the questions.

Video 8

Question

8 The car with the RBS turned on moves more slowly on a slope. Which of the following is the reason?

- A. The RBS converts some of the kinetic energy to useful electrical energy.
- B. The RBS makes the car heavier and hence slows down the motion.

9 What component of the RBS is responsible for converting the kinetic energy to electrical energy during the braking process?

Extended question

Imagine that you are an engineer of an automobile manufacturer. What components will you put into your EV to echo SDG 7 (Affordable and Clean Energy)?

Conclusion

The RBS in EVs can convert some of the kinetic energy during braking, which would otherwise be wasted, into useful electric energy, reducing fossil fuel consumption.