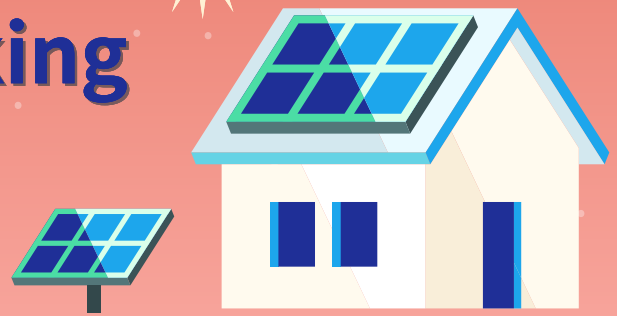


## Topic 4

# Sun Trajectory and Solar Tracking



## Learning Objectives

Green building design is an approach to architecture and construction that emphasises environmental sustainability and resource efficiency. In this topic, we will explore how to make use of scientific knowledge and innovative technology to track the sun path and reduce energy consumption through the following activities:

### Activity I

Exploring the sun path

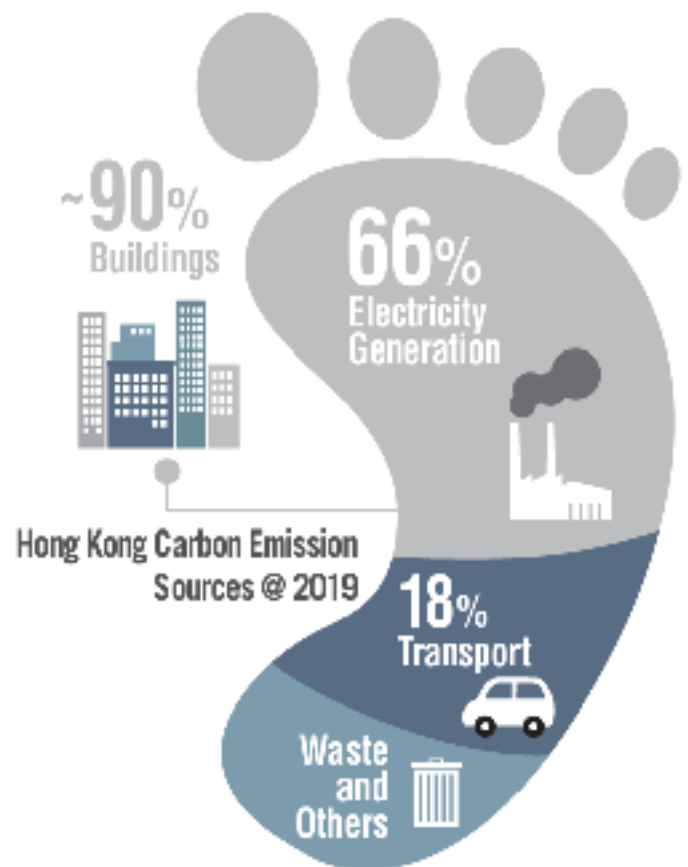
### Activity II

Solar tracking

## Zero carbon building design

In 2019, electricity generation was the largest source of carbon emission. Zero carbon building design aims to construct buildings with net-zero carbon emissions. This can be achieved by:

- Minimising the energy required to operate buildings  
**Reason:** *To minimise the use of fossil fuels and other energy sources that emit greenhouse gases*
- Harvesting renewable energy and using energy-efficient technologies  
**Reason:** *To offset any remaining carbon emissions*



Hong Kong Carbon Emission Source@2019

Fig. 1 Adopted from Hong Kong's climate action plan 2050

The story of Hong Kong's first zero carbon building: the CIC-Zero Carbon Park (零碳天地)

<https://zcp.cic.hk/eng/story-of-zcb>

(English version only)

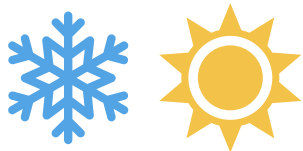


To achieve net zero carbon emissions, the following strategies could be adopted in building design.

1

Avoid strong direct sunlight incidence in the hot summer, but welcome sunlight in the cold winter.

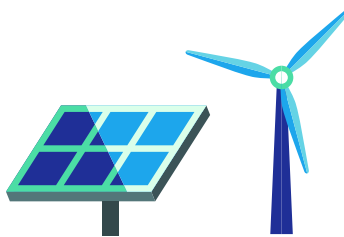
**Goal:** To reduce energy consumptions from air conditioners and heaters.



2

Adopt renewable energy sources (e.g. solar and wind energy).

**Goal:** To reduce of the use of fossil fuels and hence greenhouse gas emissions.



3

Maximise the use of natural visible light and high energy-efficient lighting systems for illumination.

**Goal:** To reduce energy consumption from lighting systems.



4

Use energy-efficient air conditioning and heating systems and optimise building orientation for natural ventilation.

**Goal:** To reduce energy consumption from air conditioning systems.



5

Use energy recovery systems.

**Goal:** To collect and reuse the energy which is otherwise wasted.



## Questions

- 1 Which of the following is a strategy for zero carbon building design?
- A Adding luxury lighting decorations on the building
  - B Harvesting renewable energy
  - C Using air-conditioning system with low energy efficiency
  - D Blocking all sunlight from entering buildings
- 2 Name one green building design strategy adopted in the CIC–Zero Carbon Park.

## Green building design and the four seasons

The Earth, with its tilted axis, orbits the Sun and its tilted axis, causing the four seasons (Fig. 2). Hong Kong is located in the Northern Hemisphere at a latitude of about  $22^\circ$ . This geographic location results in deviation of the sun's position in different seasons.

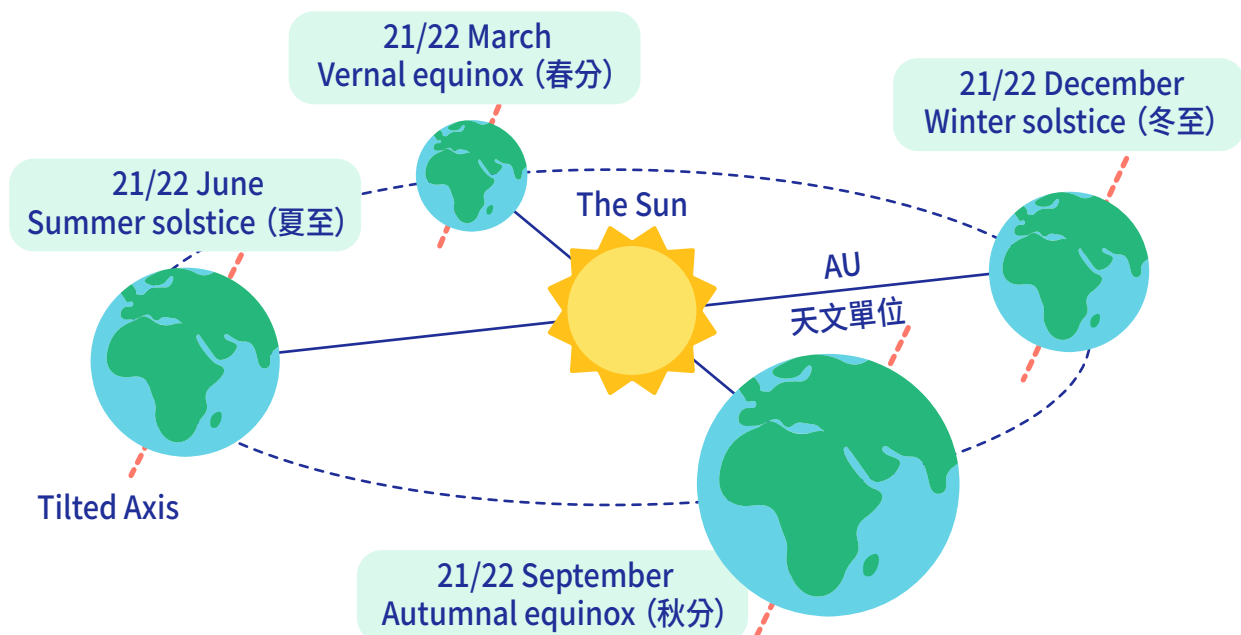


Fig. 2 Equinoxes and solstices

Compare the sun's trajectory (or sun path) on the two solstices. On the summer solstice 21 June 2022, the sun is almost directly overhead at noon (Fig. 3a). On the winter solstice 21 December 2022, the sun's elevation is approximately  $44^\circ$  at noon (Fig. 3b).



Fig. 3a The sun trajectory on summer solstice.

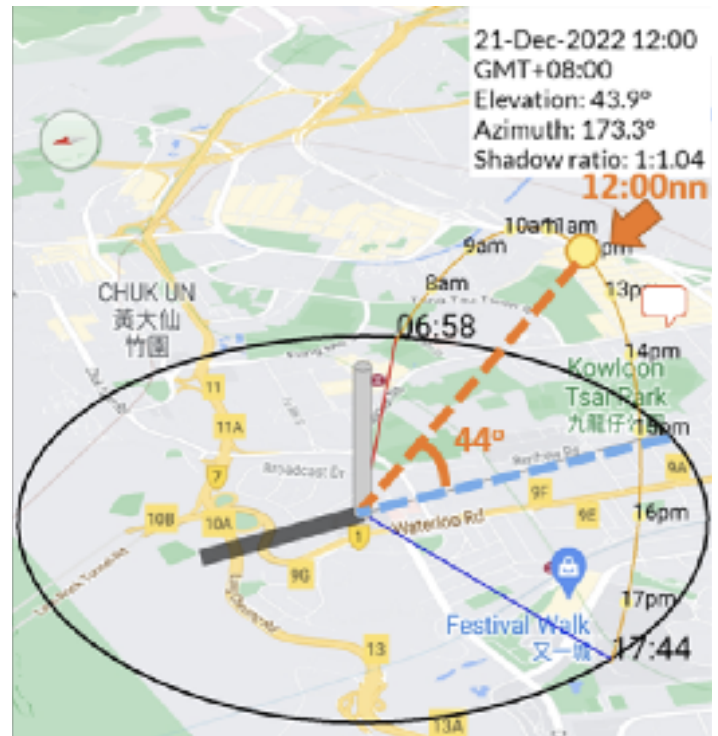


Fig. 3b The sun trajectory on winter solstice.

A passive approach for green building design is to avoid excessive direct sunlight from entering buildings in summer, but allow more sunlight to enter in winter. The sun's trajectory (or sun path) in the four seasons give us clues about green building design.

## Activity I

### Exploring the sun path

### Introduction

In this activity, we will predict the sun path as seen through a window in a building and determine when sunlight can enter the indoor through the window using the mobile app “Sun Path Explorer”.

### Instructions

Download and install the Android app “Sun Path Explorer” from the Google Play Store (Fig. 4).  
(This app is only available on Android devices.)

<https://bit.ly/3qiwBaE>

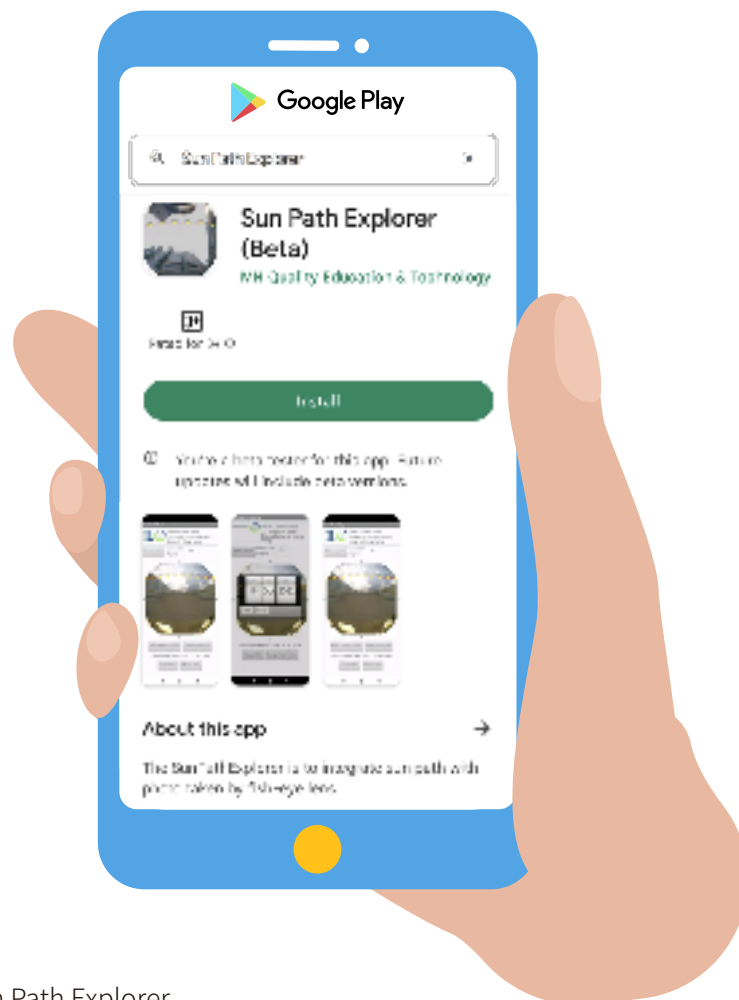


Fig. 4 Android mobile App: Sun Path Explorer.

- 1 Place the phone horizontally near the room window facing south. Take a zenith photo that is flipped using a fisheye lens (wide-angle lens). Students are advised to take the zenith photos near room window (Fig. 5a-b).



Fig. 5a Take zenith photo with fish eye lens (wide angle lens).



Fig. 5b Example of zenith photo taken.

- 2 Launching the app and select the zenith photo (Fig. 5c).
- 3 Enter the field of view (FOV)\* of the fisheye lens (Fig. 5c).

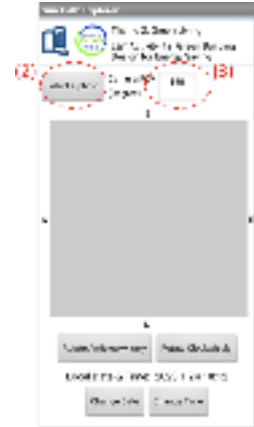


Fig. 5c Select the zenith photo and enter the estimated FOV.

- 4 Map your zenith photo to the right direction. You may want to rotate your photo clockwise or anticlockwise (Fig. 6a).

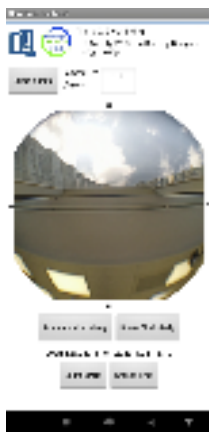


Fig. 6a

- 5 Tap on the centre of the photo and drag to draw a circle that represents the FOV (Fig. 6b).
- 6 Wait until the sun's trajectory, calculated by the defined FOV, appears on the zenith photo (Fig. 6c).
- 7 Study the sun's trajectory and determine the time interval of sunshine.

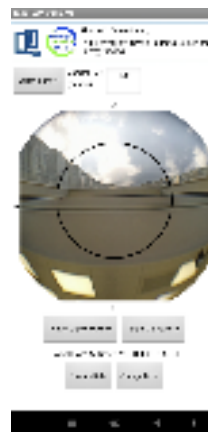


Fig. 6b

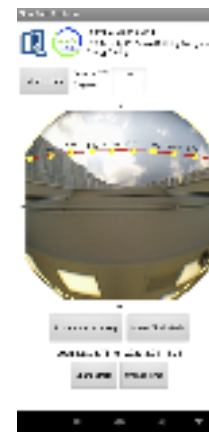


Fig. 6c

\* The Field of view (FOV) refers to the observable area, measured in angles, that a person can see or an optical device can detect.

When may the sunlight enter the room? Fig. 7 shows an example of sun path from the app. When the sun “overlaps” with the building, sunlight is blocked; otherwise, sunlight could enter the room through the window. In this example, sunlight is blocked by the building before 09:00 and after 14:00, so the time interval of sunshine is between 09:00 and 14:00.

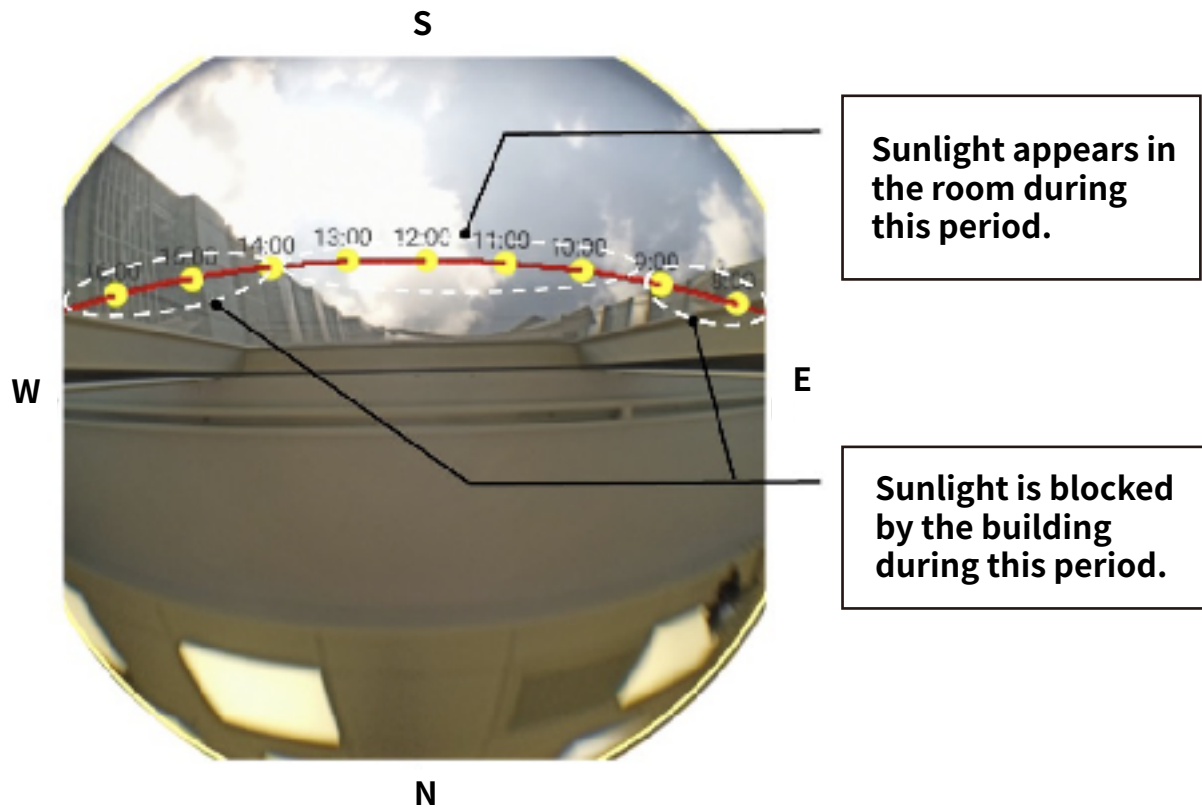
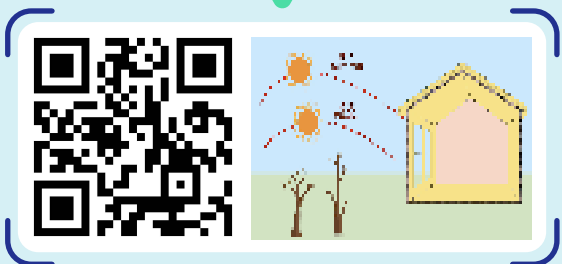


Fig. 7 A demonstration of sun path analysis using the “Sun Path Explorer” Android app

### Video on FOV estimation and exploration of sun path

Watch the demonstration video to learn how to predict the sun path using the “Sun Path Explorer”.

Video 11



## Part A: Time interval of sunshine - Today

Use the “Sun Path Explorer” Android app to explore today’s sun path.

- Date (*today*):
- Season (circle the most appropriate): Spring / Summer / Autumn / Winter
- Estimate the time during which the sunlight can enter the room. Attach a screen capture of the analysed sun path.

Sunlight can enter the room from

to  .

Please attach your screen capture here.

## Part B: Time interval of sunshine - 6 months from today

Explore the sun path 6 months later.

- Date (*6 months from today*):
- Season (circle the most appropriate): Spring / Summer / Autumn / Winter
- Change the date in the app to the date stated in (a).*** Estimate the time during which the sunlight can enter the room. Attach a screen capture of the analysed sun path.

Sunlight can enter the room from

to  .

Please attach your screen capture here.

## Questions

3 Based on the findings in Part A (today) and Part B (6 months from today):

Compare the duration that sunlight can enter the room on the two dates.

The duration that sunlight can enter the room on

(6 months from today) is longer / shorter than that on

(today).

4 a What is the total number of hours for which the sunlight would enter your room on the two days stated in Part A and Part B?

b Ask one of your classmates about the total number of hours for which the sunlight would enter his/her room on the same two days.

c Account for the difference in a and b .  
(Hints: You may consider factors such as the height and orientation of the buildings, the distance between the buildings, etc.)

## Activity II

### Solar tracking

### Introduction

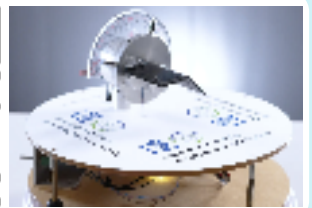
In this activity, we will learn the working principle of solar tracking by observing a typical solar tracker.

### Instructions

There is seasonal variation in sun path. In view of this, “Solar tracking” helps adjust the orientation of solar panels to harvest maximum amount of solar energy.

Watch the video to understand the working principle of solar tracking.

#### Video 12



### The Solar Trackers (Fig. 8a-c)

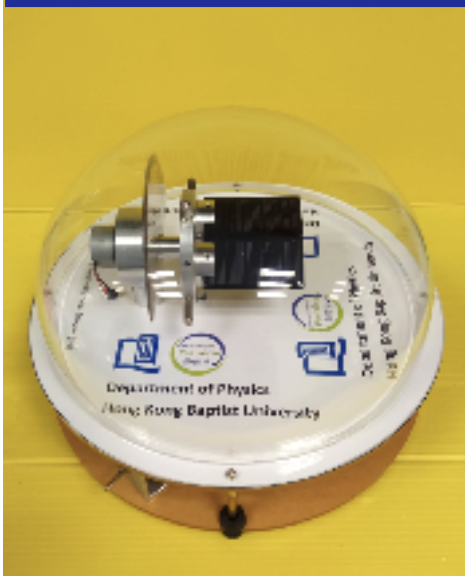


Fig. 8a

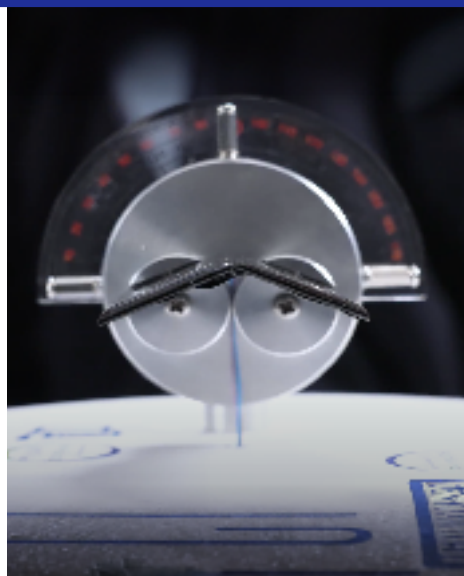


Fig. 8b

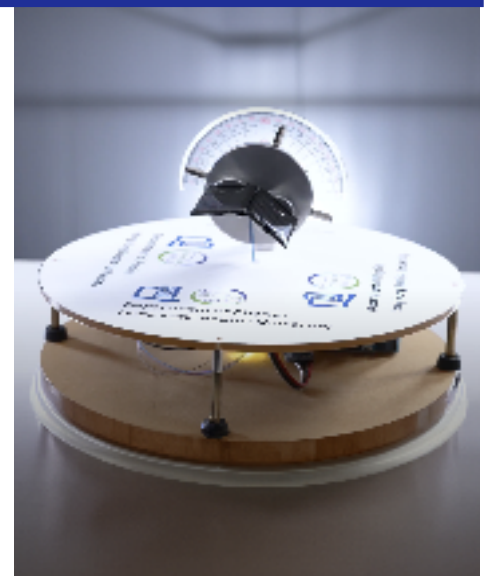


Fig. 8c

### Questions

5

How are the two solar panels arranged in the solar trackers (Fig. 8a-c)?  
(Circle your answer.)

On a plane

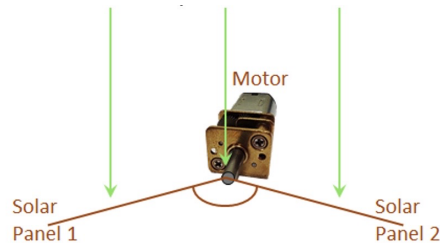
At an angle

## Working principle of solar tracking

A common technique of constructing solar tracking devices is to compare the light intensities on the two solar panels arranged at an angle and adjust the orientation of the solar panels accordingly.

When the light intensities received by each solar panel are similar, the panels remain in the original orientation (Fig. 9a). However, when one panel receives a higher light intensity than the other, the motor rotates the panels in a way that reduces the light intensity difference (Fig. 9b-c).

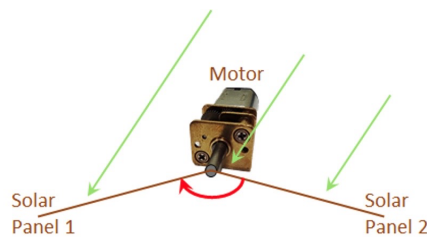
Case I: The light intensities on the two solar panels are similar.



Action: The panels remain in the original orientation.

Fig. 9a

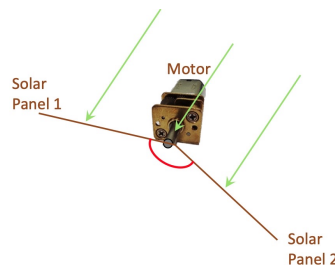
Case II: The light intensities on the two solar panels are different.  
(e.g.  $I_2 > I_1$ )



Action: The motor rotates the panels in a way that reduces the light intensity difference. (The direction of rotation is indicated by the red arrow.)

Fig. 9b

Case III: The panels rotate to an orientation such that the light intensities on the panels become similar and the electric motor stops.



The most solar energy can be harvested.

Fig. 9c

## Questions

- 6 What is/are the advantage(s) of installing “rotating solar panels with light sensors” over “fixed solar panels”?

- 7 Where in the building would you suggest to install the solar panels? Explain briefly.

### Conclusion

- Through strategic planning and design of buildings, net-zero carbon emissions can be achieved by minimising the amount of energy required to operate the building, harvesting renewable energy and using energy-efficient technologies.
- As the sun path varies across seasons, the building orientation is one of the factors that green building engineers would consider before constructing a building. We can make use of technology to predict when sunlight can enter a room through a window.
- To harvest the most solar energy, solar trackers could be adopted to adjust the direction of the solar panels to align with the position of the sun.