PRACTICAL TEST: THE SUN, A UNIQUE ENERGY SOURCE FOR THE SOLAR SYSTEM
PRACTICAL TEST: 太陽、太陽系內的唯一能源

In the event of a manned mission to Mars, the sun appears to be the most immediately accessible source of energy. The planet is further away from the sun than Earth and, therefore, receives less energy. **We will therefore determine the surface area of solar panels that need to be deployed on the surface of Mars as part of a permanent colonization mission.**
在前往火星的載人任務中，最容易取得到的能源是來自太陽。距離太陽比地球還遠的行星，接收較少的能源。**我們將決定需要部署在火星上太陽能面板的表面積，以作為火星永久殖民任務的一環。**

PART I : Measuring the solar constant. 測量太陽常數

The solar constant expresses the amount of solar energy received on a $1m^2$ surface located at a distance of 1 astronomical unit (average Earth-Sun distance), and exposed perpendicular to the Sun's rays in the absence of atmosphere. For the Earth it is therefore the energy flux at the top of the atmosphere. It is expressed as watts per square meter ($W \times m^{-2}$).
太陽常數為距離太陽 1 天文單位（地球-太陽之平均距離）處暴露在無大氣、垂直太陽光線的 1 m2 面積 所接收的太陽能。對地球來說，是大氣層頂部的能量通量，可以用每平方公尺瓦特數($W \times m^{-2}$)來呈現。

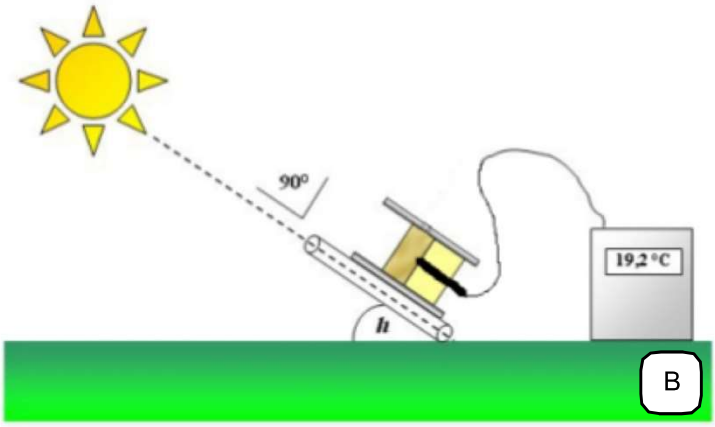
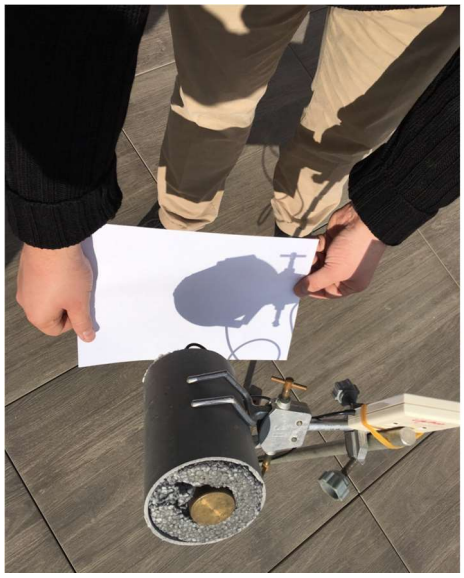


FIGURE 1: Measuring of the solar constant.
***(A)** The measuring device. It consists of a set of supports (1) with a bracket, clamps and nuts; a calorimeter (2) - an assemblage of a PVC tube, insulating foam and a brass or steel mass (3) that can be heated by the sun; a digital thermometer (4) to measure the temperature during the experiment. Note : You will use your own IESO exam board as an inclinometer, a timer and a calculator (provided).*
***(B)** Principle behind the measurement of solar constant. In order to orient the surface of an object perpendicularly to the sun's rays, it is sufficient to place a sheet behind the object and orient the object to minimize its shadow.*

圖 1: 測量太陽常數
***(A)** 測量儀器。包含一組配件 (1)托架、夾鉗、nut 旋鈕；一個熱量計 (2) - 一支 PVC 管、絕熱泡沫與黃銅或不銹鋼塊 (3) 這些能被太陽曬熱； 一隻數位溫度計 (4) 在實驗中測量溫度用。 注意： 你將用自己的 IESO 評量板作為傾斜儀，一隻計時器與一個計算器 (大會提供)。*
***(B)** 太陽常數量測的原理。 用物體的表面垂直陽光作為指向計，可以將一張紙放在儀器下方，將陰影極小化來獲得很好的指向。*

Question 1:How should the device be oriented? Select the correct answer. (Only one answer possible)
如何操作器具之指向？選擇正確的答案。（只有一個可能答案）

1-



2-

3-

4-

PART II : Measuring the terrestrial solar constant.量測地球上的太陽常數

TECHNICAL EVALUATION 1 BY REFEREE

Instructions :

- Take note of the material provided to you (that of Part I).
  請注意並小心使用提供給你的儀器或材料
- Orient the device such that the surface of the mass is perpendicular to the sun's rays.
  調整器材的排列方向，使器材表面垂直於陽光
- Acquaint yourself with all the parameters necessary to determine the solar constant. They are presented in the table 1 below.
  自行了解並熟悉決定太陽常數必需要的所有參數，並在下列表一呈現它們
- Measure the angle of the axis the device makes with the horizontal. This is the height of the sun above the horizon.
  量測器材軸與水平的角度，這可以進一步計算出太陽在水平之上的高度。
- Start the experiment. Note the initial temperature. After 10 minutes, record the final temperature.
  開始實驗。先記錄最初的溫度。並在 10 分鐘後，紀錄終溫。
- Bring the device to a shaded area.
  帶著器材到陰涼處

After completing the experiment, enter the measured values in table 1 :
完成實驗後，在表 1 填入測量值：

Parameters	**Symbol and unit**	**Value**
Mass	M (kg)	
Diameter of the mass	D (m)	
Thermal capacity of the mass	C_p (J x K^{-1} x kg^{-1})	
Height of the Sun above the horizon	h (°)	
Initial temperature	T_i (°C)	
Final temperature	T_f (°C)	
Duration of the experiment	Δt (s)	

TABLE 1 : Experimental parameters required to determine the solar constant.
決定太陽常數所需要的實驗參數

We have taken our measurements on the surface of the Earth, but the solar constant is a calculated value that excludes the influence of the atmosphere. It is therefore necessary to apply a correction factor.

我們已在地球表面測量太陽的參數，但是在地表計算太陽常數需要排除大氣的影響。因此需要運用一個修正因子來完成計算。

In other words, any power value, denoted $\mathbf{P_d}$, depends on the value of the solar constant **F** corrected by a factor ***cor***, which depends on the thickness and transparency properties of the atmosphere traversed. The relationship is then written as :

換句話說，任何地表量到的功率值標記為 $\mathbf{P_d}$， 太陽常數值 F 需要用一修正因子 ***cor*** 來修正，而這修正因子與太陽光行經大氣的厚度、透明性質有關，其關係被寫成：

$$F = P_d \times cor \qquad \text{(a)}$$

Height of the Sun h (°)	**20**	**30**	**40**	**50**	**60**	**65**
Clear blue sky 晴朗藍天	2.5	2.0	1.7	1.5	1.4	1.3
Intermediate sky 中度晴朗天空	4.2	3.5	2.6	2.1	1.8	1.5
Cloudy sky 有雲天空	5.3	4.3	3.2	2.5	2.2	2.0

*TABLE 2 : Data for the determination of the factor **cor** as a function of the thickness and transparency of the layer of atmosphere traversed.*

*表 2：*修正因子 cor 的資料表，cor 為陽光行經大氣層之厚度(以太陽仰角表示)與透明度的函數

Question 2: The solar constant F is… (only one possible answer) 太陽常數 F 是…(只有一可能答案)

1- smaller than that which is measured on the ground and dependent on weather conditions.
小於在地面的測量值、且會隨天氣條件而變化

2- smaller than that which is measured on the ground and not dependent on weather conditions.
小於在地面測量、但不會隨天氣條件而變化

3- identical to that which is measured on the ground and dependent on weather conditions.
與在地面的量測值相同、且會隨天氣條件而變化

4- greater than that which is measured on the ground and not dependent on weather conditions.
大於在地面的測量值、但不會隨天氣條件而變化

5- greater than that which is measured on the ground and dependent on weather conditions.
大於在地面的測量值、且會隨天氣條件而變化

We assume that our assembly is flawless, though that is not the case. For example, thermal insulation problems limit the accuracy of our data. The values obtained will actually be lower than the data values from a more precise device

雖然不是真的，但我們假設我們的設備是無瑕疵的。例如，熱絕緣問題限制了我們數據的精確度，我們得到的數值其實要比用更精確設備得到的數值低。

Consider our system to perform as : 考慮我們的系統可以表示為：

$$E_{solar} = M \times C_p \times \Delta Temperature \quad \text{(b)}$$

Recall the relationship between power and energy : 記得在功率與能量間的關係：

$$E_{solar} = P_{solar} \times \Delta t \quad \text{(c)}$$

The power received per unit surface area S at ground level P_d is related to the power received P_{solar} by the relationship : 在地面每單位面積接收到的功率 P_d 與接收到的功率 P_{solar} 之關係為:

$$P_{solar} = P_d \times S \quad \text{(d)}$$

Question 3: The solar constant F can be calculated by the relationship deduced from formulae (a), (b), (c) and (d). Choose the correct relationship below: (Only one answer possible)

太陽常數 **F** 可以用關係**(a), (b), (c)**與 **(d)**來簡約計算。選擇一個正確的關係式：（只有一個可能答案）

1- $F = \dfrac{S \times \Delta t \times cor}{M \times C_p \times \Delta Temperature}$ because F increases when S increases.

2- $F = \dfrac{S \times \Delta t}{M \times C_p \times \Delta Temperature \times cor}$ because when S increases, more energy is captured.

3- $F = \dfrac{M \times C_p \times \Delta Temperature \times cor}{S \times \Delta t}$ because F is proportional to the variation in temperature.

4- $F = \dfrac{M \times C_p \times \Delta Temperature}{S \times \Delta t \times cor}$ because F is inversely proportional to the correction factor.

The surface area of a disc can be calculated using $S = \pi \times r^2$ where S is the surface area in m^2 and R the radius of the mass M. Recall that the order of magnitude of a value is the power of 10 closest to the value. For example, 32 is closer to 10 than to 100, and thus has an order of magnitude of 10^1, whereas 74, which is closer to 100 than to 10, has an order of magnitude of 10^2.

盤的表面積可以使用 $S = \pi \times r^2$ 來計算，其中 S 為表面積以 m2 為單位，r 是質塊 M 的半徑。記住數值的級數即數量級（order）是近似值量化成 10 的級數。例如，32 近似值為 10，比 100 更近似，因此數量級為 10^1。74 要比 10 更接近 100，數量級為 10^2。

Question 4: According to your measurements, the value of the terrestrial solar constant has an order of magnitude of :

依據你的測量，地球上的太陽常數值的數量級為：

1-10^{1} W x m^{-2}.
2- 10^{2} W x m^{-2}.
3-10^{3} W x m^{-2}.
4-10^{4} W x m^{-2}.

PART III : Measuring the solar constant across the solar system.
PART III :橫越太陽系測量太陽常數

TECHNICAL EVALUATION 2 BY REFEREE

Measuring the solar constant in the solar system amounts to an understanding of how this parameter changes as a function of distance from the Sun.
在太陽系中測量太陽常數，能了解這參數的變化與離太陽距離之關係。

Instructions :
- Familiarize yourself with the equipment provided. 自行熟悉提供之設備
- The light meter can move inside the tube ; you can read the distance between the light meter and the light source directly at the indicator level.
光照計可以在管內移動；你可以在顯示幕上讀取光照計與光源間的距離。
- Measure the light intensity for different distances to answer question 5.
對不同距離測量光強度，以回答問題 5。

Question 5: The solar constant is… (only one answer possible) 太陽常數是…（只有一可能的答案）
1- proportional to the distance to the Sun. 與太陽的距離成正比
2- proportional to the square of the distance to the Sun. 與太陽距離平方成正比
3- inversely proportional to the square root of the distance to the Sun.
與太陽距離平方根成反比
4- inversely proportional to the distance to the Sun. 與太陽的距離成反比
5- inversely proportional to the square of the distance to the Sun. 與太陽的距離平方成反比

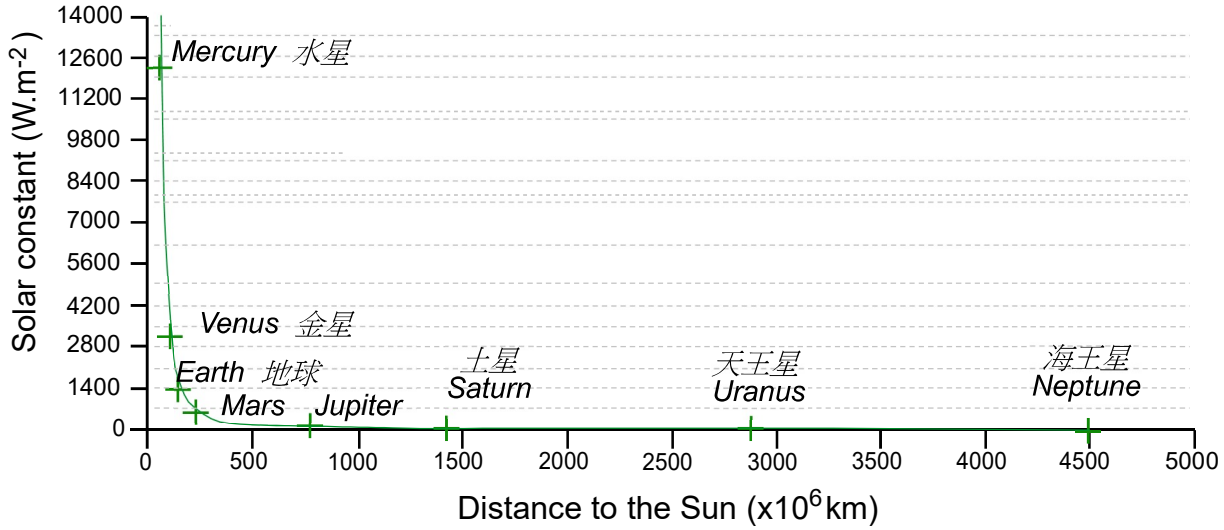


FIGURE 2 : Solar constant versus the distance to the Sun for eight planets of the solar system.
圖 2：太陽系中八顆行星之太陽常數對其與太陽距離關係圖 其中 Mars 火星 Jupiter 木星

Question 6: The solar constant… (only one answer possible) 太陽常數…（只有一個可能的答案）

1- is about 700 W x m^{-2} on Mars, or between 22% and 28% of the solar constant on Venus.
對火星來說約為 700 W x m^{-2} ，或是此數值約是金星太陽常數的 22% 與 28%之間’

2- is twice as large on Mars, compared to Earth.
在火星上是地球的兩倍

3- is very weak for the last four most distant planets.
對最遠的四顆行星是非常微弱’的

4- is proportional to the distance from the Sun.
與太陽的距離成正比

5- is greater on Saturn than on Uranus because the former has a larger radius.
對於土星要比天王星大，因為前者有較大的半徑

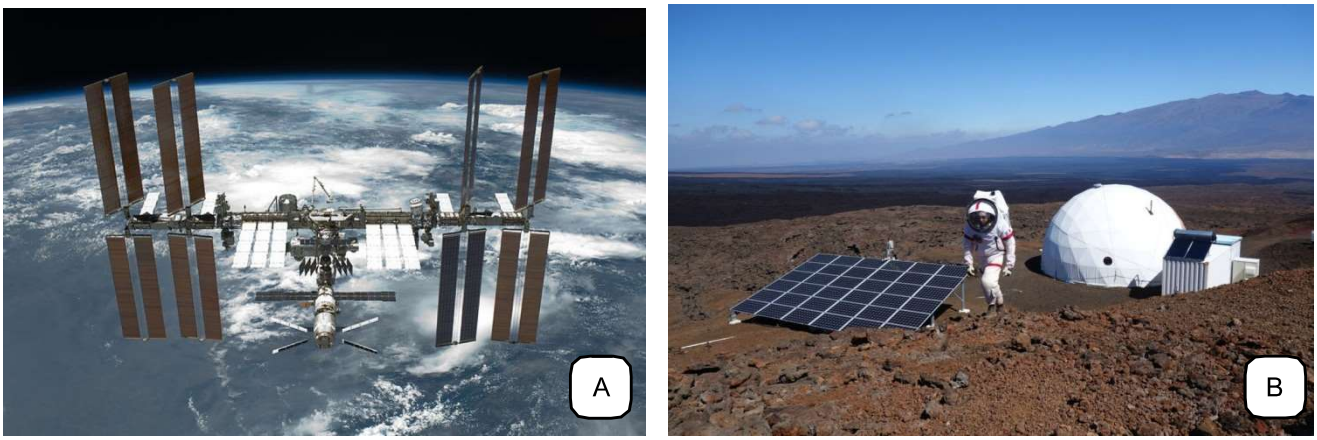


FIGURE 3 : (A) Photograph of the International Space Station (ISS) in Earth orbit. It has dimensions of 110x74x30 (LxWxH in meters) and a total mass of 400 tonnes, its autonomous operation is provided by eight solar generators. Each consists of a mast surrounded by two 32m x 11m surfaces that support the photovoltaic cells. (B) Dome simulating life on Mars during the HI- SEAS program that took place on the slopes of the Kilauea volcano in Hawaii. The living conditions and thus the energy requirements for the autonomy (essentially pressurization and heating) of this Mars colonization module are similar to those of ISS.

圖 3：(A)在地球軌道上之國際太空站(ISS)照片，ISS 大小為 110x74x30 (LxWxH in meters)，總質量為 400 公噸。它的自動操作系統是由八個太陽能發電機所提供，每個包含兩具 32m x 11m 光電池面板。(B)在 HISEAS 計畫中，模擬在火星生活的圓頂安裝在夏威夷 Kilauea 火山坡上，其火星殖民模組的生活條件與自動化的能源需求（必要的壓力與加熱）與在 ISS 的類似。

Question 7: Based on the information in Figures 2 and 3, how many generators would be needed for an autonomous manned mission to Mars?

依據圖 2 與圖 3 的訊息，對於一個自動化載人到火星的任務，需要多少發電機？

1- about 4　大約 4
2- about 8　大約 8
3- about 10　大約 10
4- about 12　大約 12
5- about 14　大約 14
6- about 16　大約 16
7- about 18　大約 18