



香港大學電子學習發展實驗室
e-Learning Development Laboratory
The University of Hong Kong

資訊科技教育與學科有關係列：
運用3D打印機和資訊科技工具促進物理科的學與教

IT in Education Subject-related Series: Using 3D Printers and IT Tools to Enhance Learning and Teaching of Physics (SESSION 2)

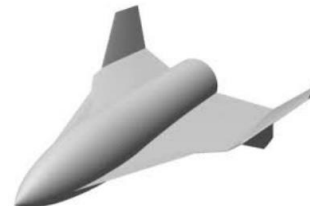
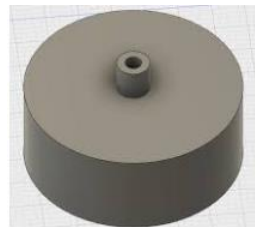
Instructors:

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回顧

1.1 介紹基本的3D打印技術

1.2 介紹能應用於物理科學與教活動中的3D打印物件或零件的製作方法

1.3 介紹有關3D打印物件或零件等綜合活動的例子

1.4 實踐工作坊：利用TinkerCAD軟件設計和製作與物理科相關的3D物件

1.5 課業簡介

第二節 課程流程 (3 小時)

2.1 課業討論及回饋

2.2 介紹3D打印製作的準備（包括: 設備、材料、技巧等）
和對打印模型的管理

2.3運用流動3D掃描應用程式（如Qlone、Scann3D等）
製作3D物件

2.4應用3D打印技術於教授物理學概念和進行實驗的例子

2.5 討論、問與答環節及總結

2.1 作業討論及意見回饋

建議思考點:

1. 有效促進物理科的學與教?
2. 如果沒有加入3D 打印所製作的實驗工具和實驗活動，成效有多少不同?
3. 在技術上遇到什麼困難?

2.2 介紹3D打印製作的準備（包括: 設備、材料、技巧等）和對打印模型的管理

- Different types of 3D printing materials:
Characteristic and the application
 - ABS material
 - PLA material
 - Conductive materials – electroplating and circuit printing (for teaching electric circuit)

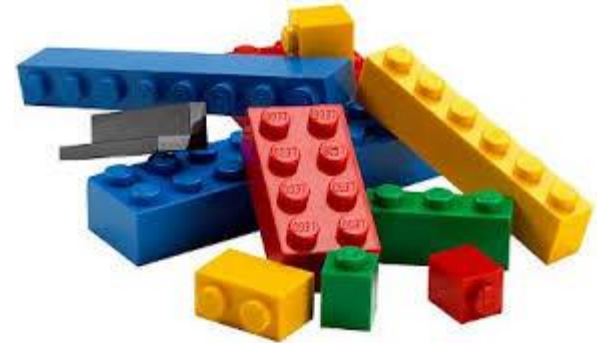
PLA (Poly Lactic Acid)

- **PLA** is a bio-degradable type of plastic that is manufactured out of plant-based resources such as corn starch or sugar cane.
- This is why it is called 'the green plastic'. Be sure to throw it in a filament recycler and you're as green as can be.
- It's widely used for packaging, such as food products
- It is flexible and bendable



ABS (Acrylonitrile Butadiene Styrene)

- **ABS plastic** is made out of oil-based resources
- it has a much higher melting point than PLA plastic.
- stronger and harder.
- ABS is widely used for purposes ranging from car bumpers and motorcycle helmets to musical instruments, golfclubs and Lego.
- Different conditions under different setting of infill %



PLA的優點和缺點

Pros and cons of PLA

- Pros

- Can be printed on a cold surface
- More environmental-friendly
- Shinier and smoother appearance
- Smells sweet when being print =)
- No harmful fumes during printing
- Higher 3d printer speed

- Cons

- Can deform because of heat (like a cassette in a car)
- Less sturdy (than ABS)

ABS的優點和缺點

Pros and cons of ABS

- Pros

- Very sturdy and hard
- Suitable for machine or car parts
- Higher melting point
- Longer lifespan

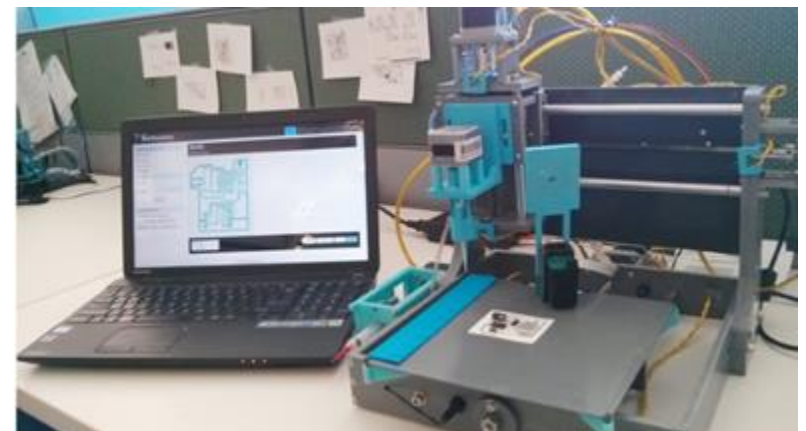
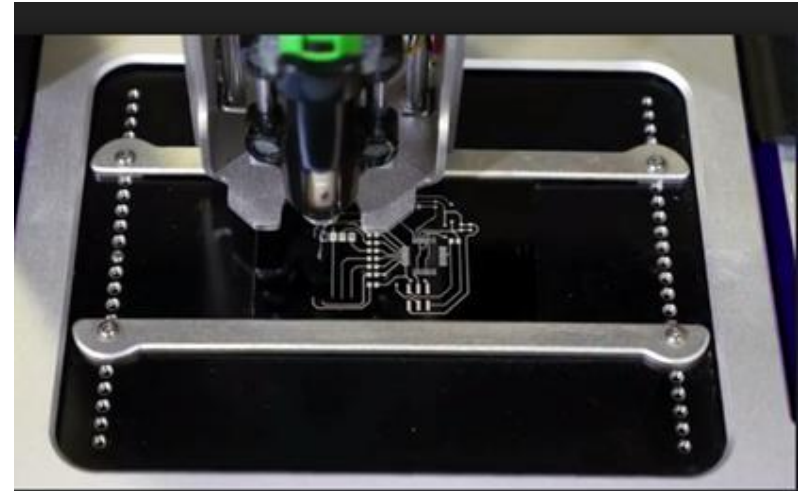
- Cons

- Made out of oil, so more damaging to the environment
- Deforms when not being print on a heated surface
- Hot plastic fumes when printing
- Therefore, you need ventilation
- More difficult to print
- Not suitable for using with food

運用3D打印應用於STEM教育

Other application of 3D printing for STEM education

- Printing PCB for teaching electronics
- Print conductive materials on a Printed Circuit Board to draw a electronic circuit



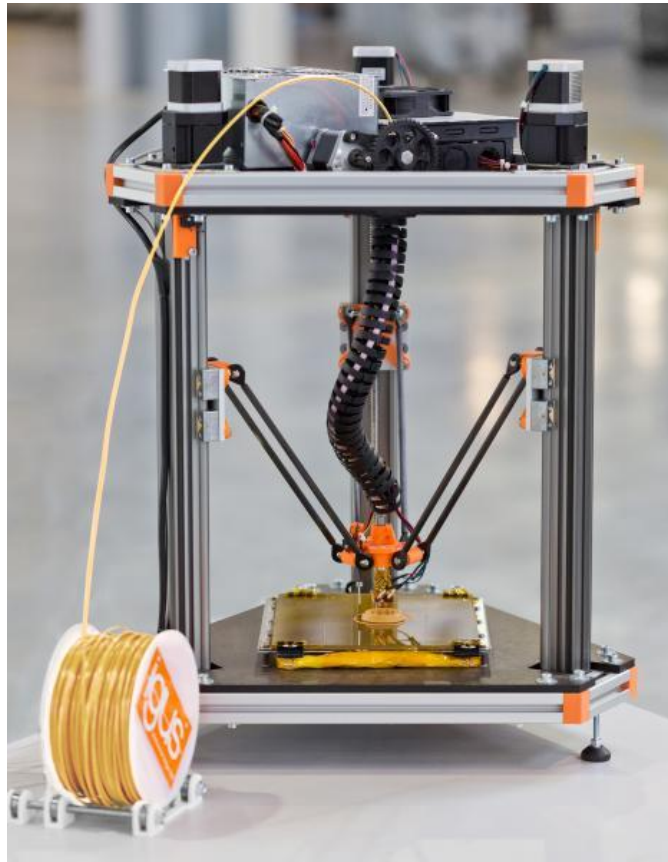
其他類型的3D打印 - 單纖維 (一般為工業用)

Other types of 3D printing - Filament-based

- A long plastic filament is fed by a spool to a nozzle where the material is liquefied and 'drawn' on the platform, where it immediately hardens again.
- The nozzle moves to place the material in the correct location to build your model up layer by layer.
- When a layer is drawn, the platform lowers by one layer thickness so the printer can start with the next layer.

其他類型的3D打印 - 單纖維 (一般為工業用)

Other types of 3D printing - Filament-based



其他類型的3D打印技術- 運用粉末

Other types of 3D printing - Powder-based

SLS = Selective Laser Sintering (選擇性激光燒結)

- It is used to create 3D prints in Polyamide, Alumide, Titanium, Rubber-like, and Wood.
- The interior of the printer is heated up to just below the melting point of the powder of your choice.
- The printer then spreads out an incredibly fine layer of this powder.
- A laser beam heats up the areas that need to be sintered together just above the melting point.
- And voila: the parts that were touched by the laser are now fused together while the rest continues to remain loose powder.

Source: <https://i.materialise.com/blog/3d-printing-technologies-and-materials/>

3D Printing with Nylon SLS (Selective Laser Sintering)

<https://www.youtube.com/watch?v=165QI-T09SE>

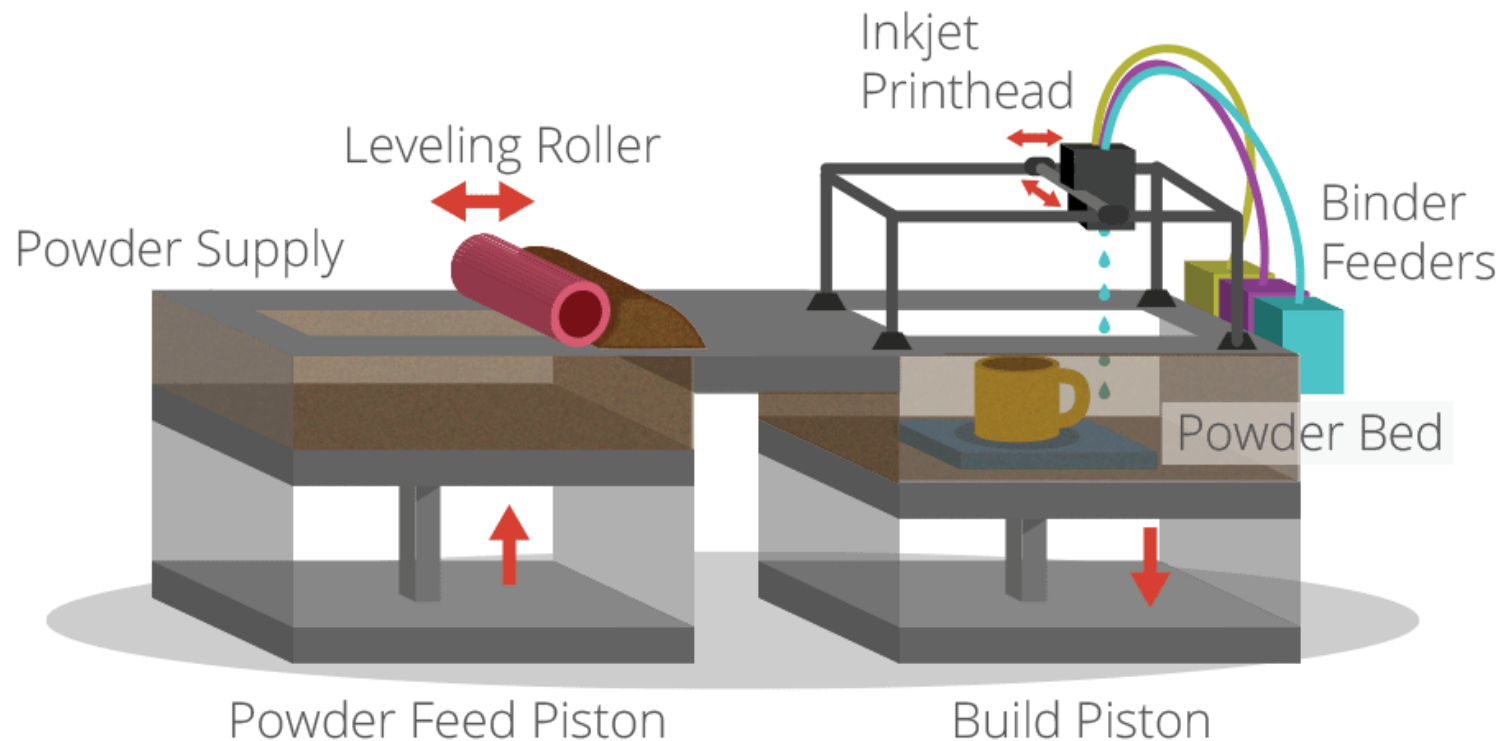


其他類型的3D打印技術- 運用粉末

Other types of 3D printing - Powder-based

SLS = Selective Laser Sintering (選擇性激光燒結)

Inkjet: Binder Jetting



其他類型的3D打印技術- 運用粉末

Other types of 3D printing - Powder-based

SLS = Selective Laser Sintering (選擇性激光燒結)



For prototyping
多用於模型製作

其他類型的3D打印技術– 樹脂溶液3D打印

Other types of 3D printing - Resin-based

- It takes place in a large tank and begins with a layer of liquid polymer spread over a platform.
- Since this piqued polymer is UV-sensitive, a UV laser hardens the area that will become one layer of your 3D print. The rest of the layer stays liquid.
- The platform is then lowered and the next layer is drawn directly on top of the previous one.
- When the object is complete, it is raised out of the tank via the supporting platform – much like a submarine rising to the surface of the water – with the excess liquid flowing away.

Source: <https://i.materialise.com/blog/3d-printing-technologies-and-materials/>

其他類型的3D打印技術- 樹脂溶液3D打印

Other types of 3D printing - Resin-based

Meet the second high-resolution, laser-drawn resin
3D printer from Formlabs

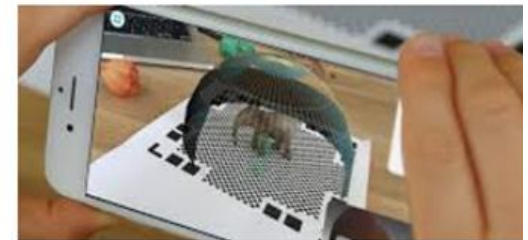
<https://www.youtube.com/watch?v=b-slcYo8isl>



2.3運用流動3D掃描應用程式製作3D物件

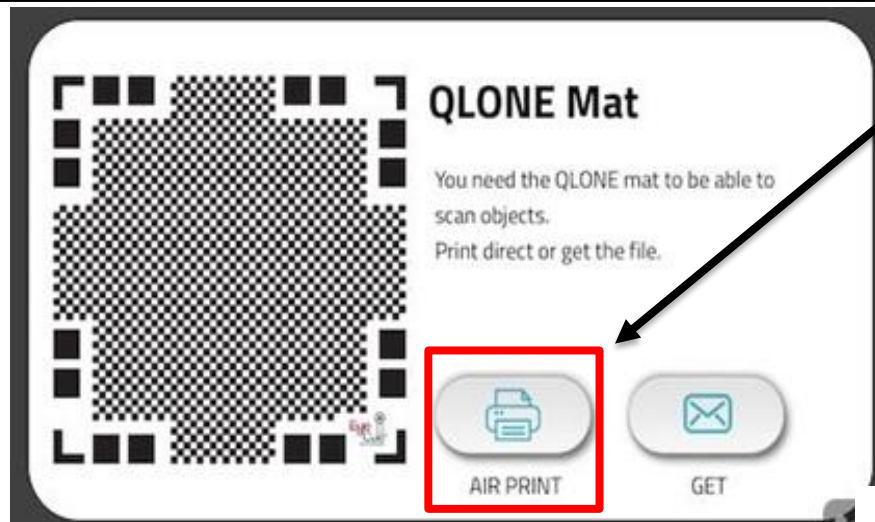
Hands-on workshop 3: Using mobile devices for 3D Scanning

- How to obtain a 3D object from scanning a real object by using smartphone software Qlone
- How to use a 3D scanner or smartphone to capture a 3D model
- Some samples of toy cars , boat and wind turbine will be provided for participants to try scanning these objects



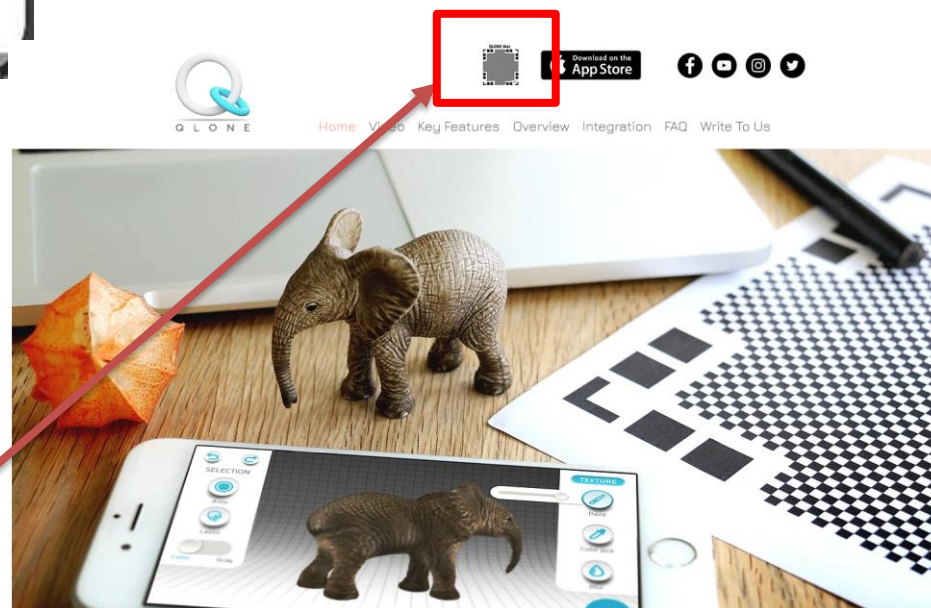
步驟一：列印QR碼工作紙

下載之後，該app會出現以下版面，要求使用者列印一張QR碼工作紙



- 如沒有連接雲瑞列印，可以到 Qlone官方網下載
- 網站：<https://www.qlone.pro/>

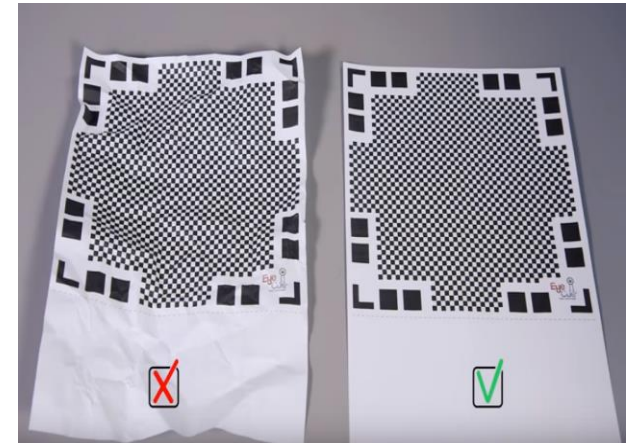
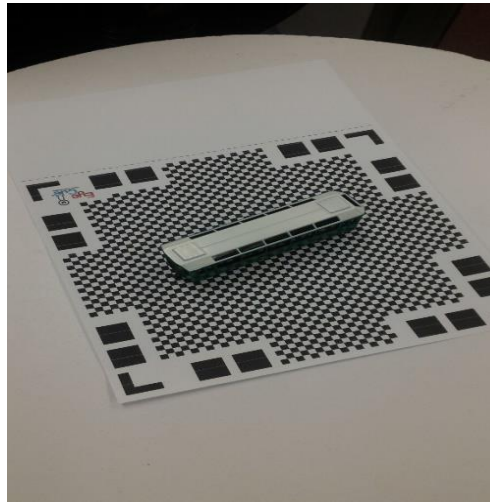
之後按此下載及列印一張QR碼工作紙



注意事項：



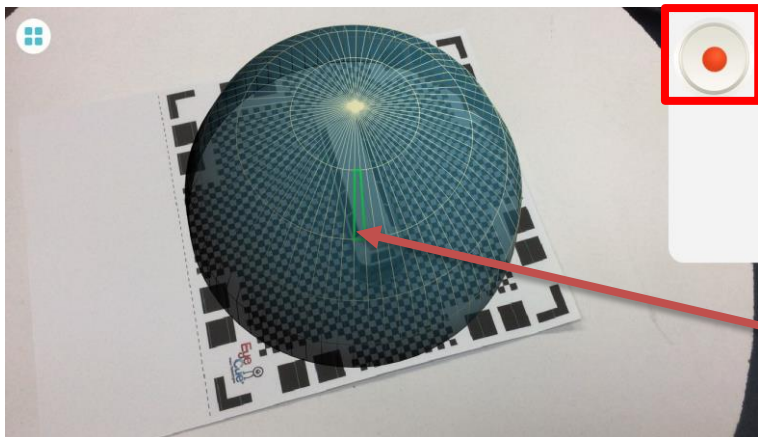
調整大小



- 使用Qlone之前必須列印一張QR碼工作紙及確保QR碼紙平坦及齊整。
- 將要掃描的實物放置在QR碼圖案上，物件尺寸最好大小適中。
- 不能大到超過QR碼的範圍，太小也是不行。
- 建議先調整QR碼圖案的大小再將它列印出來，以適應不同大小尺寸的物件。

步驟二：開始掃描

首先按下按鈕，
開始掃描

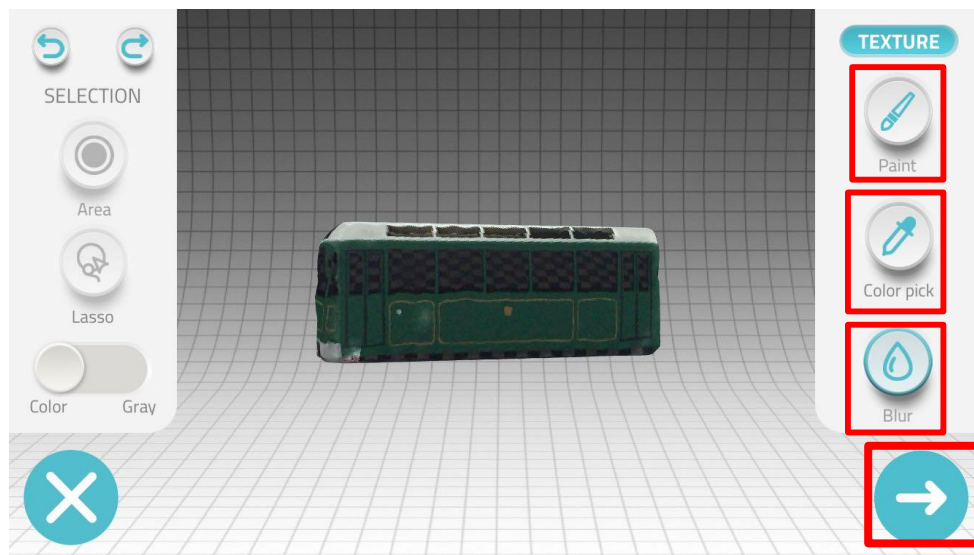
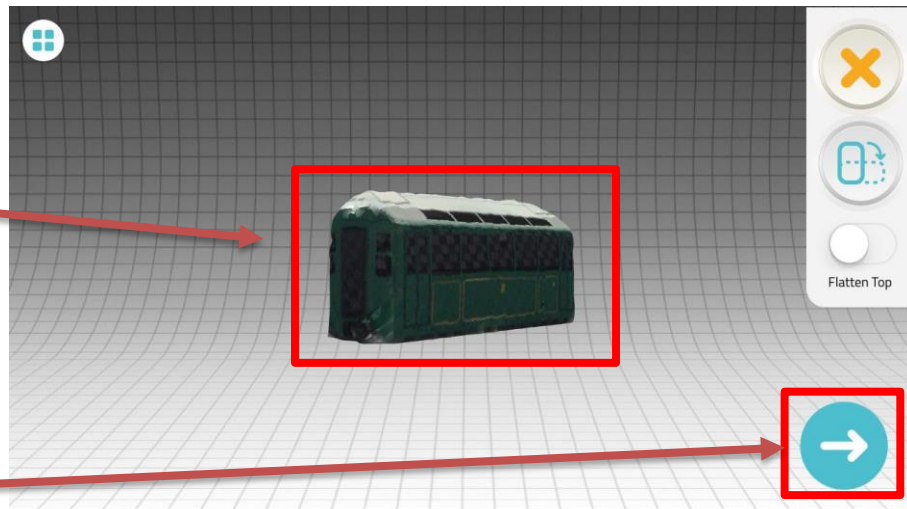


- 接著進入Qlone的掃描模式，將相機移動到其周圍，按下右上角處的紅色圓圈按鈕後開始掃描。
- Qlone的增強現實圓頂 “將圍繞物件並捕獲詳細的3D掃描資料，沿圓頂一直掃描。

步驟三：編輯

完成掃描後就會彈出製成品

按此進入下一步



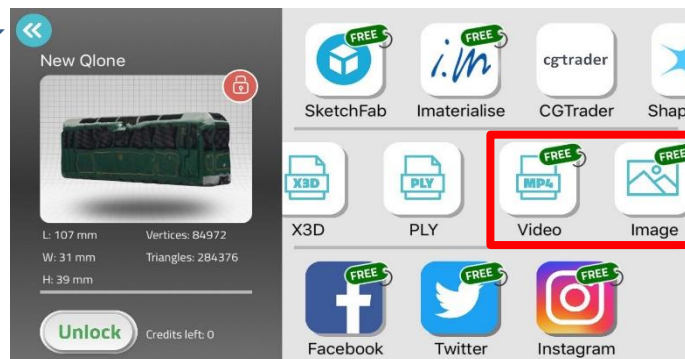
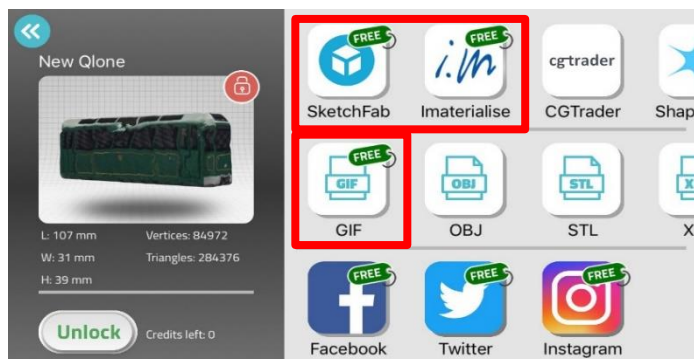
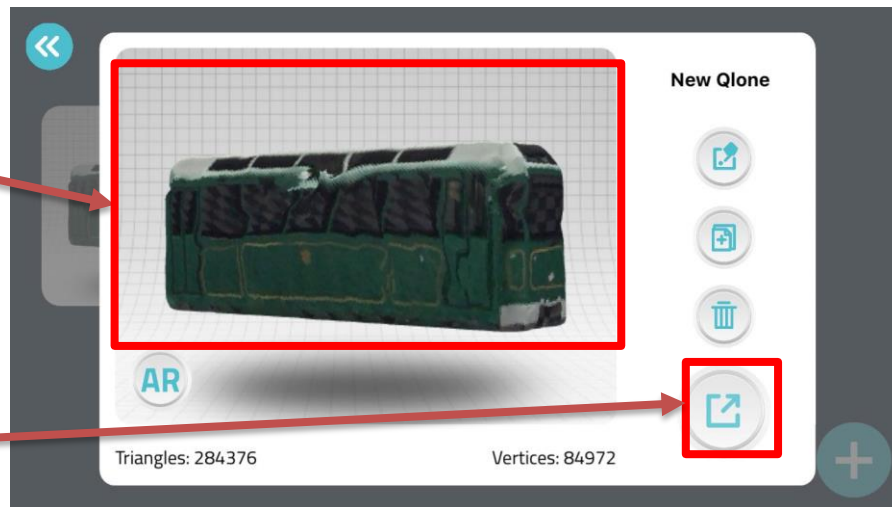
- 可以以不同角度觀察製成品。
- 一系列簡單的修改工具，就可以輕鬆修改和清理物件，例如Paint, Color pick及Blur。

按此進入下一步

步驟四：匯出

完成編輯後就會即時彈出製成品

按此進入下一步



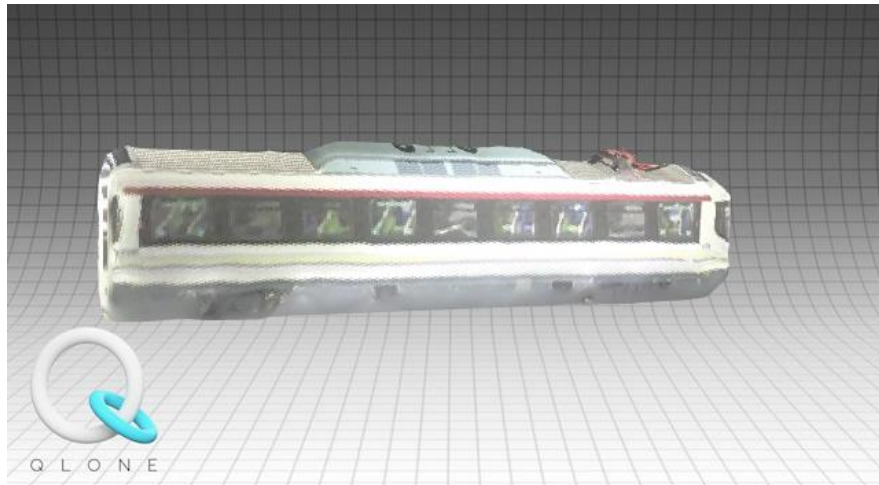
- 可以免費以.jpeg檔、.gif 檔及 .mp4檔 (video)形式匯出
- 不需要匯出/導入多個廣泛的軟體以進行網格清理*和優化
- 可免費直接上傳到Sketchfab 上 (3D打印共享平台)
- 可以透過Facebook、WhatsApp、Instagram等社交平台以及電子郵件匯出

*網格清理 (Mesh Cleanup): 移除或修改不匹配指定標準的多邊形。

以.gif檔及.mp4 video形式匯出：

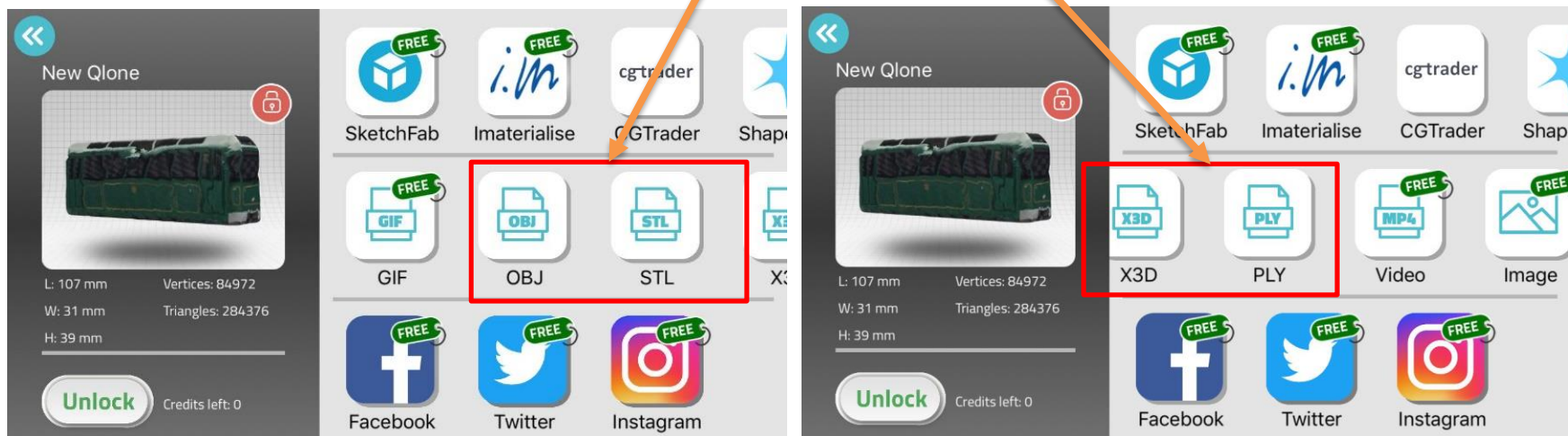
以video為例：

- 一般播放時間很短，物件的轉動速度頗快
- 操作時老師要留意如何向學生展示：
 - 例如定格、沿時間軸拖拉而改動物件顯示的角度等



進階版：

- Qlone掃描可以輕鬆匯出一系列檔案格式，像是STL、OBJ、PLY和X3D，但如要匯出以上格式的話，**需要付費**，而以上格式都是大部份3D Printer能支援的格式。
- 視乎老師實際需要而定。



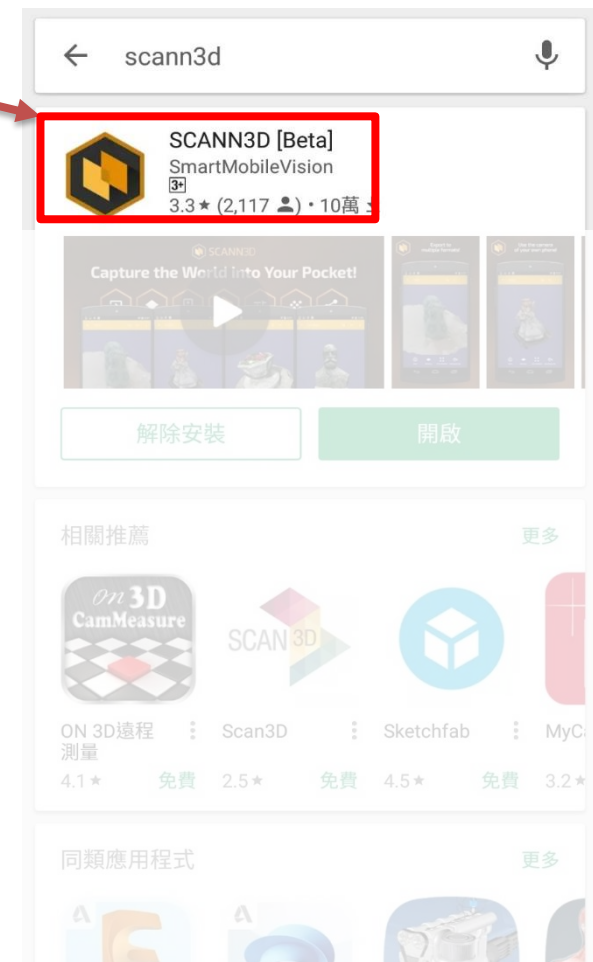
3D scanning應用程式- SCANN3D

(Android手機適用)



*可在Play Store中下載

- SCANN3D是一個掃描實體影像，以轉化為3D object的手機應用程式。
- 利用手機鏡頭掃描實體後，就會在手機上浮現3D影像。
- 完成製作之後，可以輸出到第三方的3D 圖像的編輯程式，並且3D printer打印。
- 形式是以連拍為主
- 可以將製成品分享到Sketchfab 的帳戶當中。
- 只支援Android手機。



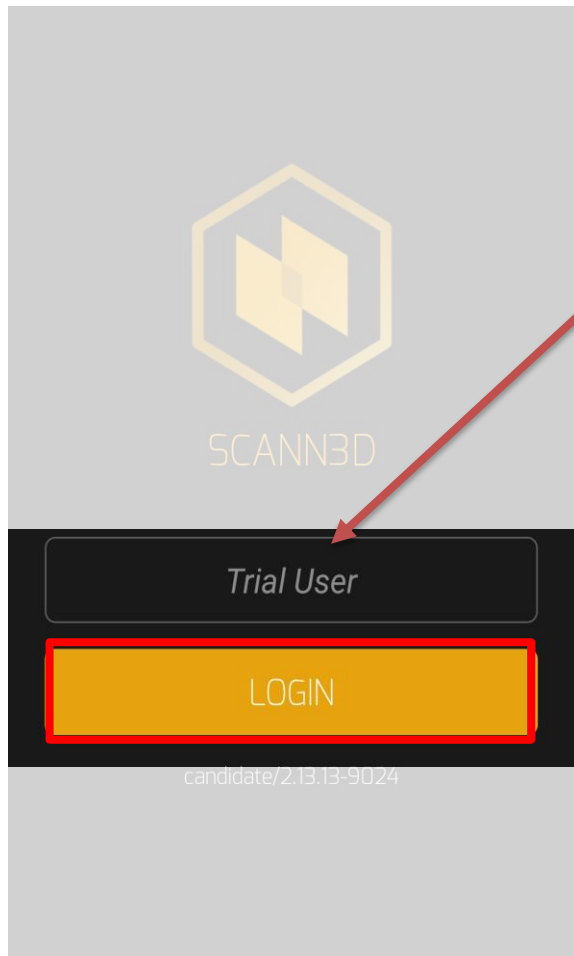
SCANN3D 教學影片



教學影片:

[https://www.youtube.com/watch?time_continue=1&v=TSIwD
TDvc68](https://www.youtube.com/watch?time_continue=1&v=TSIwD
TDvc68)

步驟一：登入



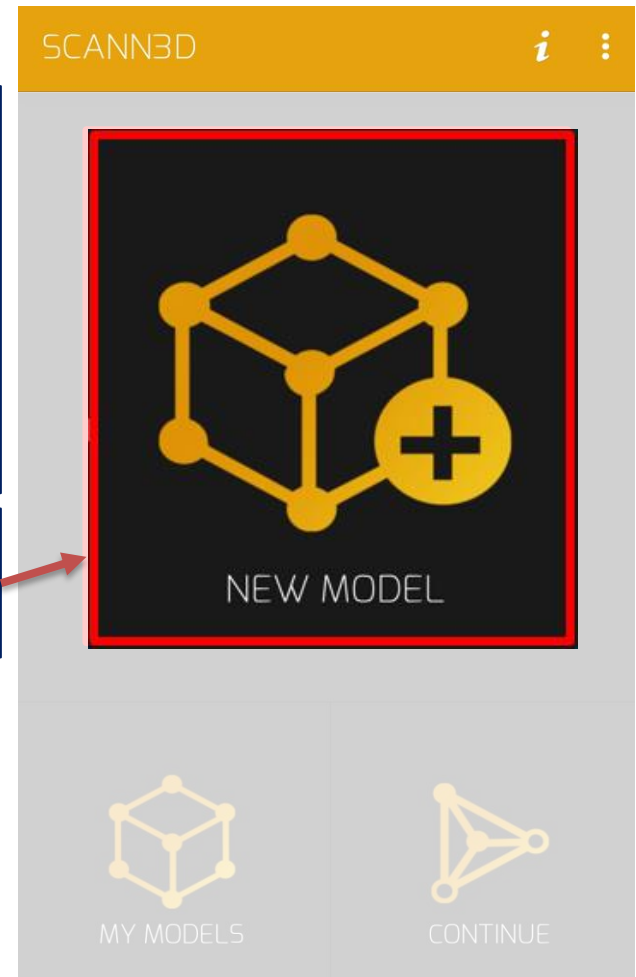
輸入你的 "Trail User"
用戶名稱*，
直接按login登入即可

*你需要輸入你的名稱
才可保留你掃描的檔案

登入後，直接按
New Model，隨即掃描。

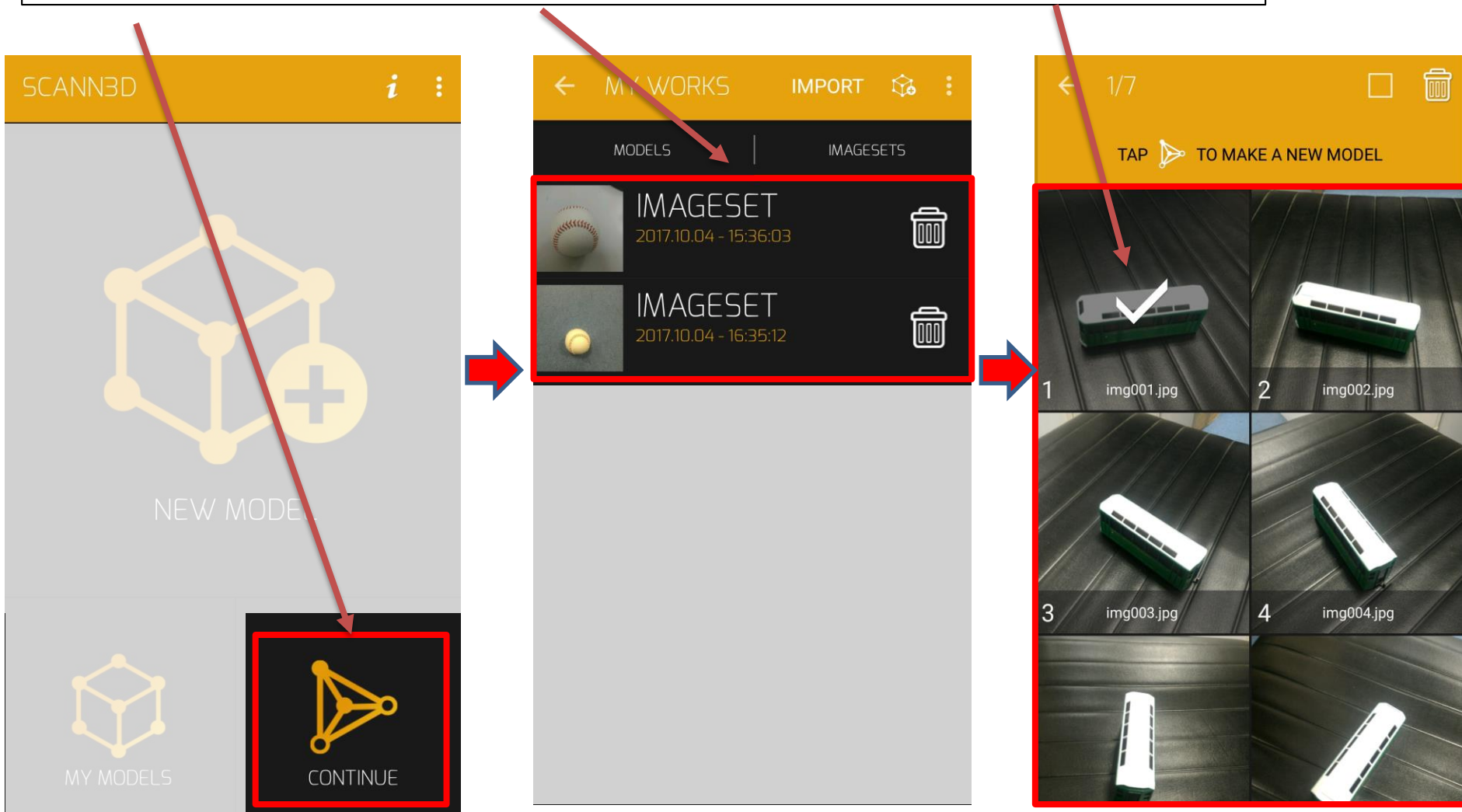


步驟二：掃描



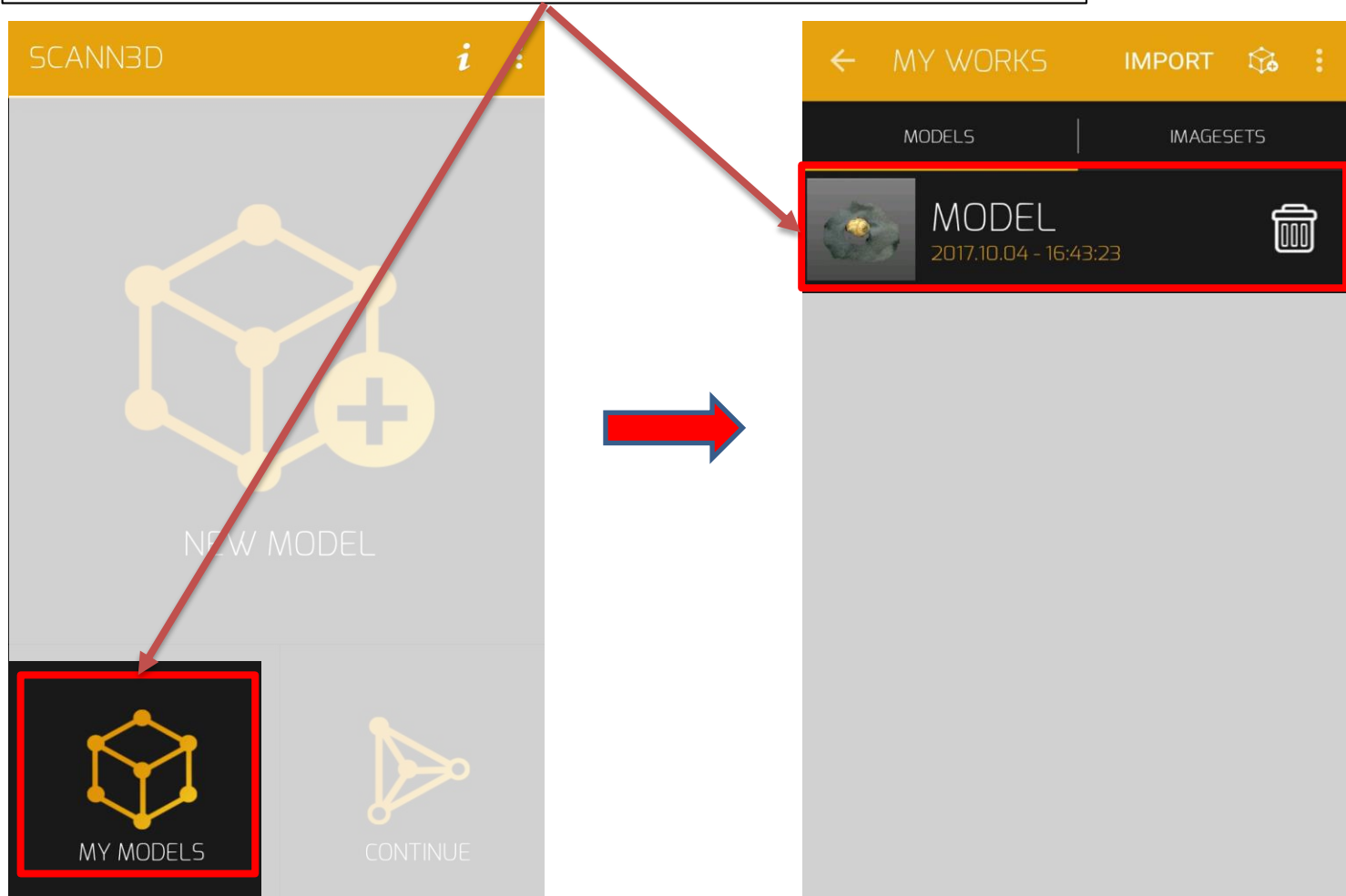
步驟三：檢視

按下Continue可以查看已拍照的圖片，亦可以刪除不合適的圖片



步驟三：檢視 已成功完成的 Model

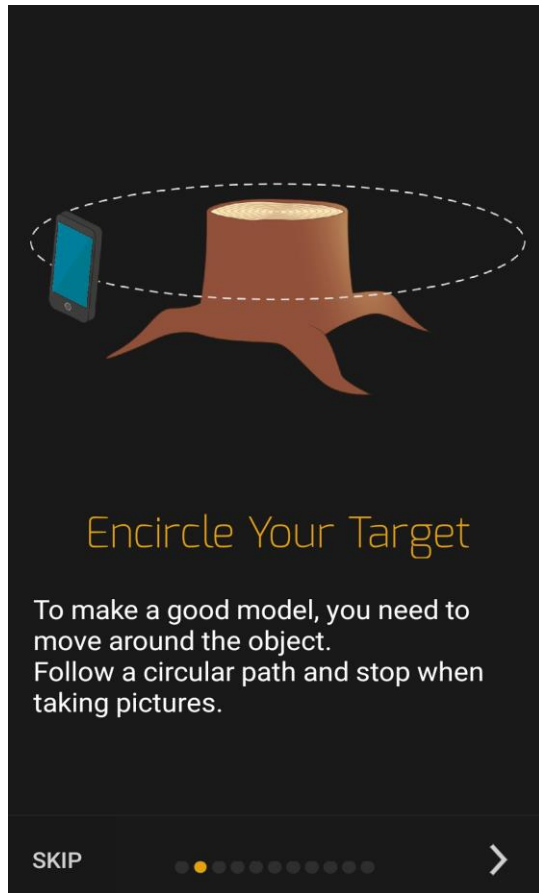
按下My Models 可以查看已完成的Model



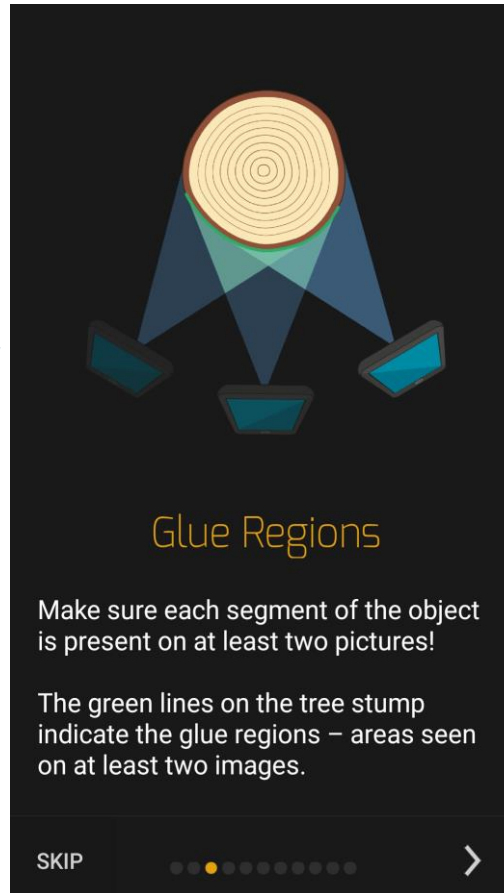
使用原則與局限

(適用於普遍的3D掃描應用程式)

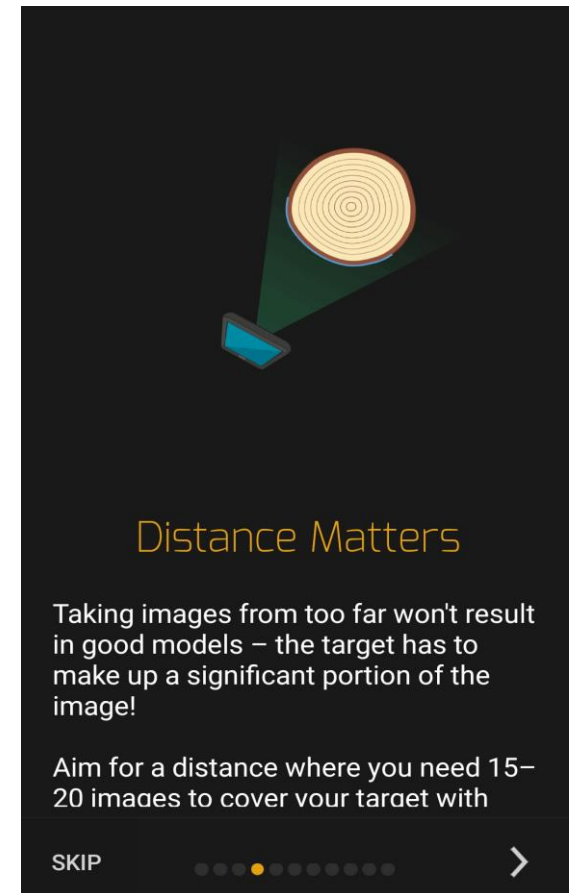
1. 必須在目標
360度圍繞拍照



2. 必須對目標的各面
最少影兩張相片




3. 距離方面要適中，
不能太遠及太近



使用原則與局限 (續)

(適用於普遍的3D掃描應用程式)

4. 聚光燈、陰影及不充足的光線下都會影響到效果




Lighting Matters

Spotlights, hard shadows, and uneven lighting generally results in incomplete models.

SKIP >

5. 必須**移動手機**，不要移動目標物




Be mobile

It is insufficient to move the target object: You need to move the device itself: you need to be mobile!

SKIP >

6. 不要選擇會移動的**目標物**，例如交通、動物



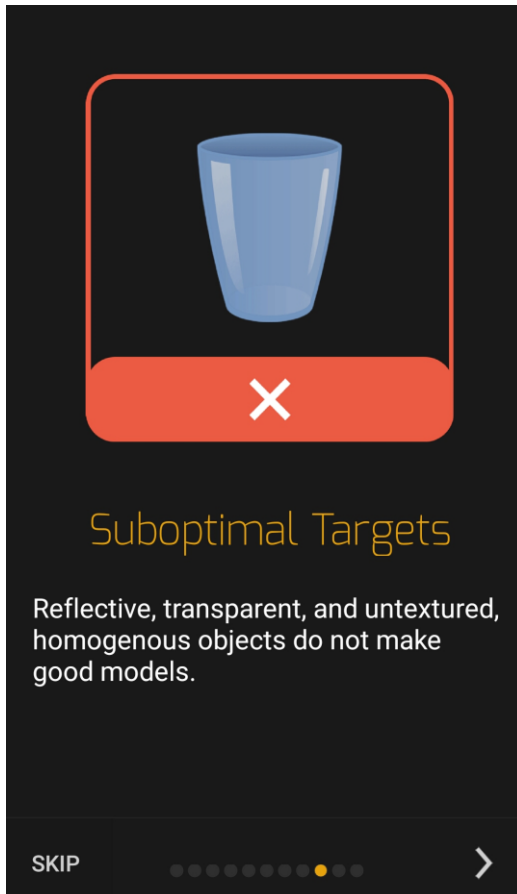
Moving Targets

Moving targets cannot be made into models. If you intend to model living beings, they need to remain still.

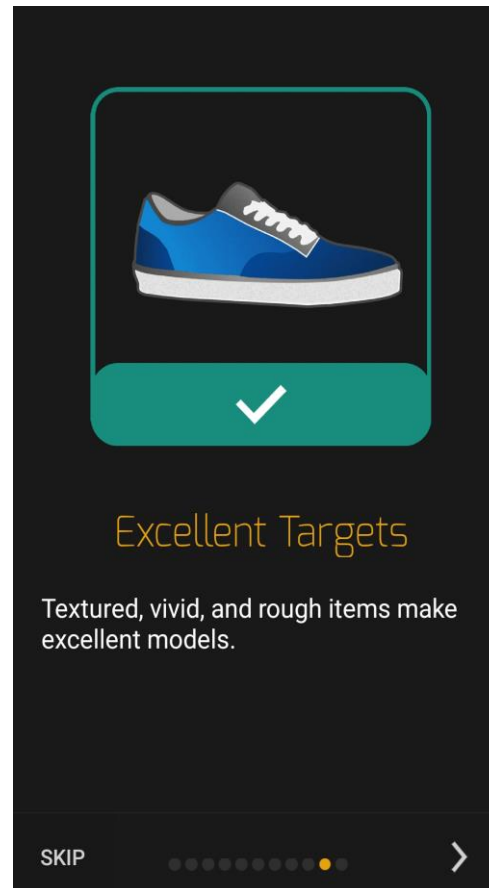
SKIP >

使用原則與局限 (續) (適用於普遍的3D掃描應用程式)

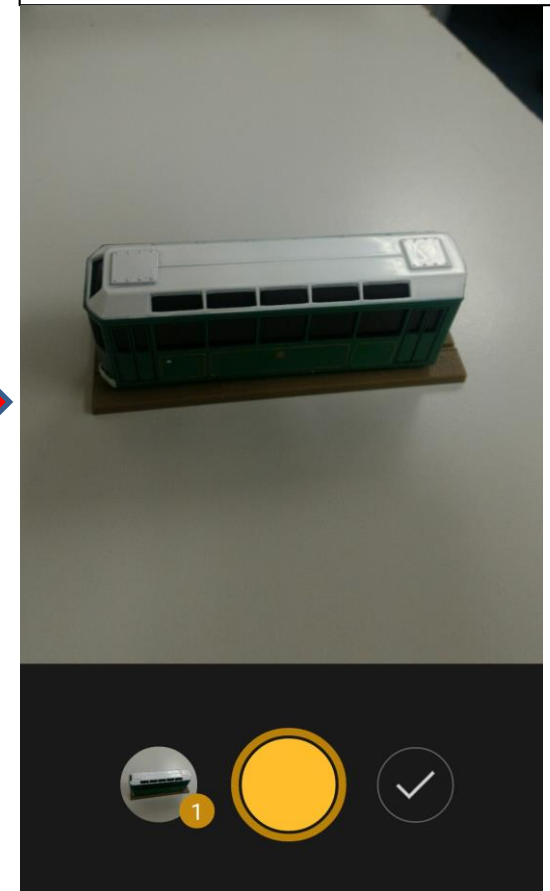
7.不要選擇會反光、透明、沒有結構的目標物



8.請選擇會堅固、結構完整及顏色鮮明的目標物



9. 完成教學頁後，便會出現鏡頭供使用者使用，可以根據目標物的體積而訂拍照圖片的數目，建議圖片數目為20-40張。



三維(3D)掃描技術操作的限制

	Qlone	SCANN3D
程式系統 (OS)	iOS	Android
一般操作困難	<ul style="list-style-type: none">• 清晰度: 受制於手機相機鏡頭本身可支援的解像度和可收光的能力• 光暗度: 視乎掃描時環境的光暗• 目標物: 不要選擇會反光 / 光面、透明、沒有結構、白色面的目標物	
個別操作困難	<ul style="list-style-type: none">• 可以利用轉盤方便掃描• 一般而言，掃描所示的Object的光度較暗• 匯出的影片速度較快	<ul style="list-style-type: none">• 必須移動手機，不要移動目標物• 運算和組成的時間需時，手機未能離開或使用其他應用程式。
匯出格式 (免費格式而言)	JPEG, GIF, MP4	3D Object, MTL, PNG file

配備其他儀器以提升掃描質素

- 效果較佳的Object 需要相應的儀器配合
 - 例如 Microsoft Kinect etc.
- 有關更多的硬件、軟件和應用程式得比較，你可參考：
<https://all3dp.com/1/best-3d-scanner-diy-handheld-app-software/>



分組做實驗時段

1. 自由分組，每組約5人一組
2. 每組將得到一份3D模型的實驗工具，分別有：
 1. 5隻模型船
 2. 一個 Open Bottle Cap
 3. 一個 Bottle Stand
 4. 一份DC Motor製作的材料

2.4 應用3D打印技術於教授物理學概念和進行實驗的例子

Examples of using 3D printer for teaching concepts and conducting experience in physics

1. Open bottle cap – Turning effect of a force
2. An 'anti-siege' machine - Turning effect of a force
3. Balance bottle holder – Free body diagram
4. Ship - Centre of gravity
5. Right hand grip rule – EM
6. Fleming's Left hand rule & Right hand rule (FBI) – EM
7. DC motor – EM
8. Mirror stand – Optics
9. Wind turbine – Energy
10. Stationary satellite (Geostationary satellite) – Gravitation

1. Open bottle cap – Turning effect of a force

- Design several models of open bottle cap to let students know how it helps to open the bottle cap such as longer handler, couple (two forces of equal magnitude and opposite directions act on the object)



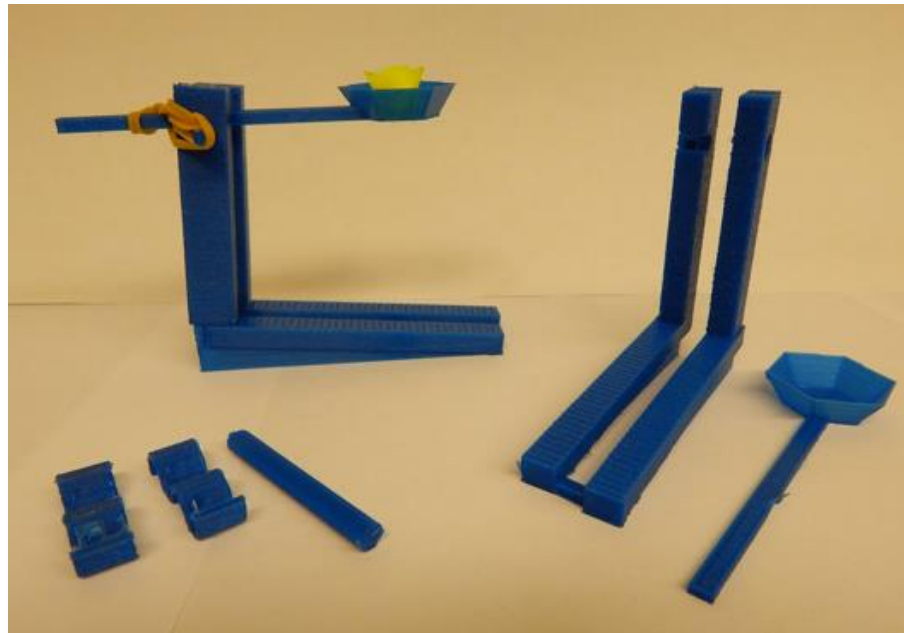
1. Open bottle cap – Turning effect of a force

- **Objective:** To find out how the distance from the pivot affect the turning effect
- **Time:** 10 mins
- **Apparatus:** A bottle with cap, spring balance, and different types open bottle cap 3D printing device (short length, middle length handler, longer length handler).
- **Procedure:** Students need connect the spring balance and the end of handler of the open bottle cap device. Apply a perpendicular force to the handler and record a spring balance reading.

	Short length	Middle length	Long length
Length of the handler (cm)			
Spring balance reading (N)			

2. An 'anti-siege' machine – Turning effect of a force

- Using 'anti-siege' machine to let students know how the turning effect of force making the 'anti-siege' machine working.

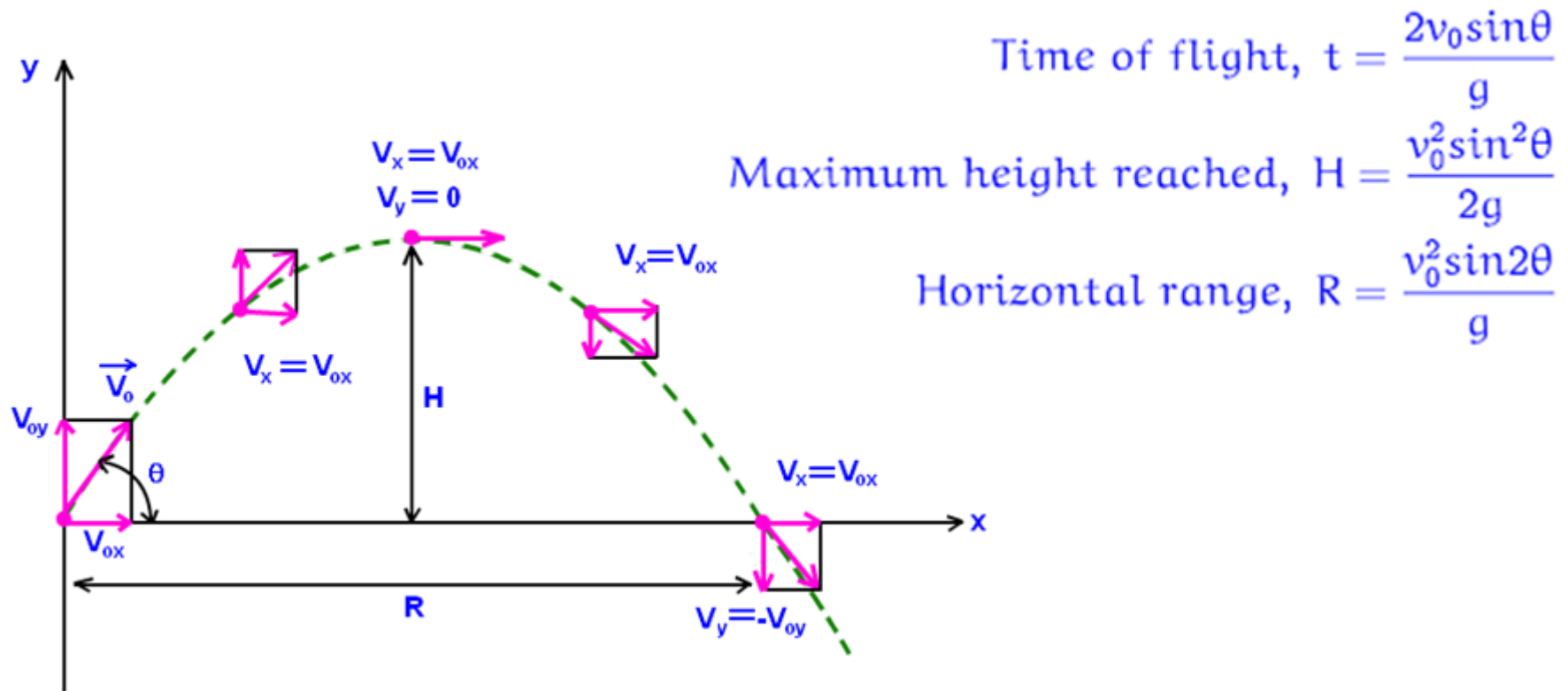


2. An ‘anti-siege’ machine – Turning effect of a force

- **Objective:** Students need to design an ‘anti-siege’ machine that can throw the object to longer distance
- **Time:** 40 mins
- **Apparatus:** Different 3D printing parts of an ‘anti-siege’ machine, and rubber acts as an object.
- **Procedure:** Students need to use the concept of ‘Principle of moment’ and Projectile to construct an ‘anti-siege’ machine that can throw the object to target.

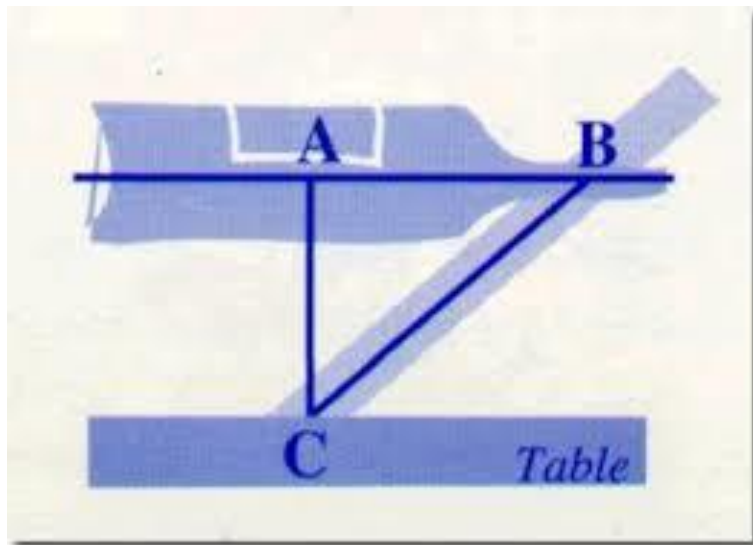
Projectile motion

- Equation of the horizontal range



3. Balance bottle holder – Free body diagram

- By using the Balance bottle holder, we can ask student how it works and how to find out the free body diagram (whole system, balance holder itself & bottle itself)

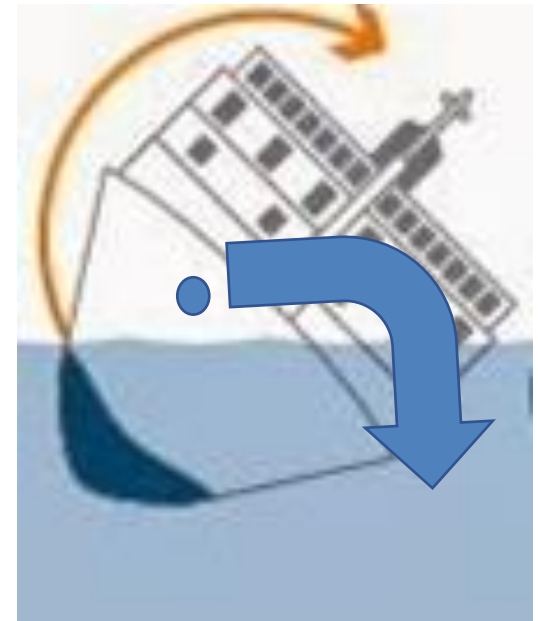


3. Balance bottle holder – Free body diagram

- **Objective:** Students need to know why the bottle holder can hold the bottle by using free-body diagram
- **Time:** 20 mins
- **Apparatus:** A 3D printing bottle holder and a wine bottle.
- **Procedure:** Before put the wine bottle into the bottle holder, student need to use free-body diagram to show why the bottle holder cannot stand firm by itself. After that they need to use free-body diagram to show why the bottle holder can hold the wine bottle and stand firm.

4. Ship - Centre of gravity

- Use the printed boat/ship to demonstrate the effect of base area and height affect
 - the centre of gravity
 - Moment
 - Pivot point



案例研究：Sewol的沉沒

Case study: Sinking of the Sewol

- Discuss the case of sinking of the Korean cruise liner 世越號 (Sewol) in Apr 2014.
- It was investigated that the cruise sunk because of its high centre of gravity.
- Bone fragments, personal belongings found from salvaged Sewol-ho ferry
- <https://www.youtube.com/watch?v=F0g-JCZNnsU>

延伸討論案例:

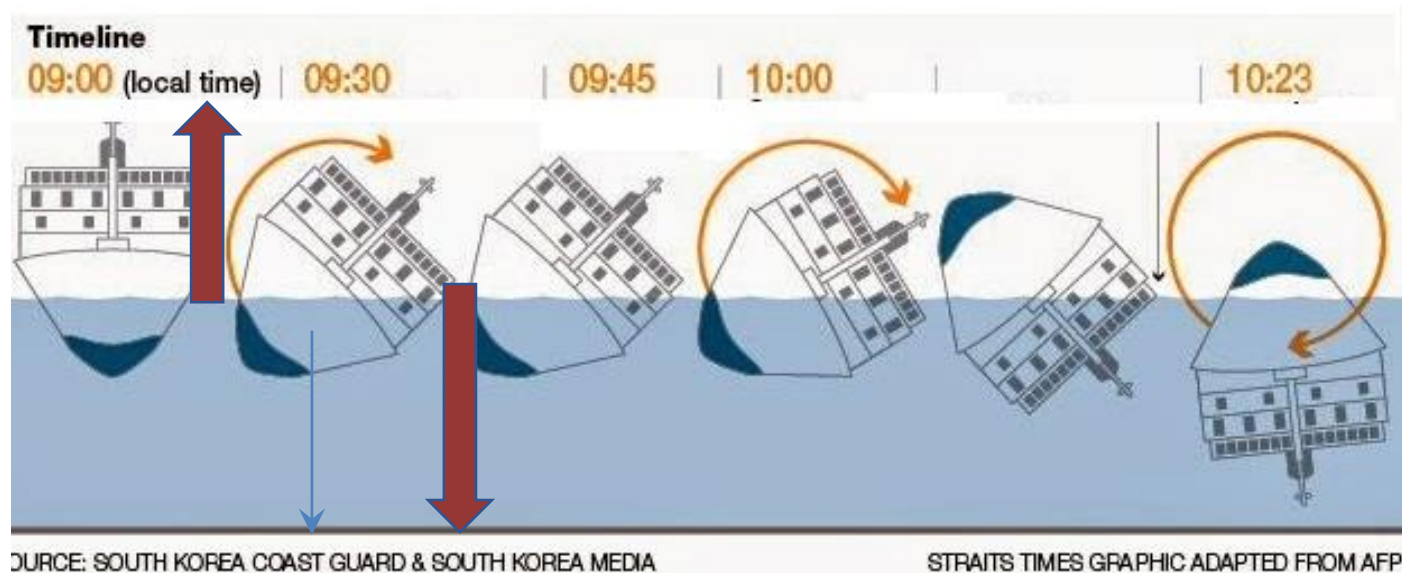
- 科技與生活和社會的關係
- 物理科在生活的應用
- 物理科學失效的嚴重性



案例研究：Sewol的沉沒

Case study: Sinking of the Sewol

- When the ship made a sharp turn, a large elevation angle was resulted
- The displacement of the centre of gravity to the pivot point created a large moment that turn the boat beyond the critical angle.

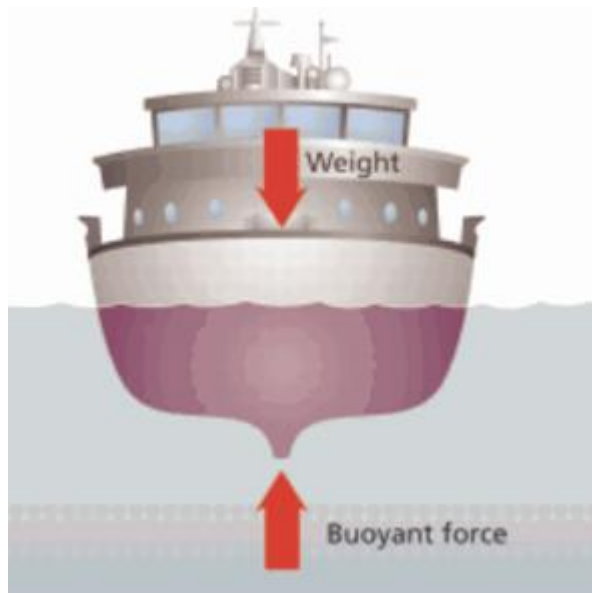


浮動和阿基米德的原則

Floatation and Archimedes' principle

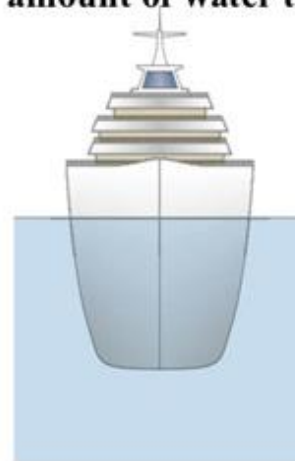
Enrichment
content

- Printing of different shape of boats and explore the how the shape could affect the water displacement volume and the centre of gravity of the boat...etc.



How Much Water Is Needed to Float a Ship?

A ship floating in the ocean is a familiar sight. But is all that water really necessary? Can an ocean vessel float in the amount of water that a swimming pool contains, for instance?



(c)

浮動和阿基米德的原則

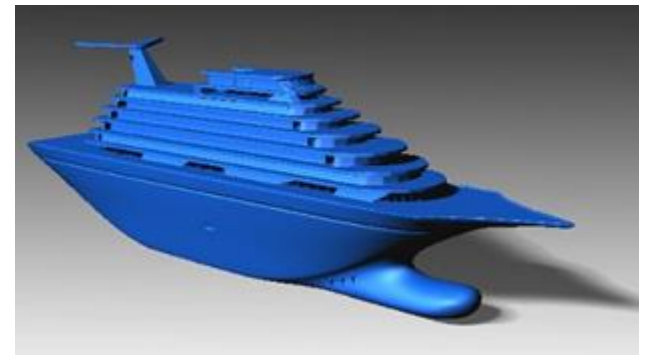
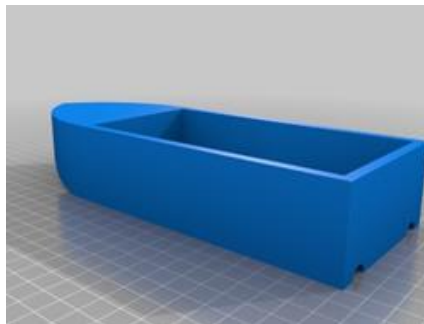
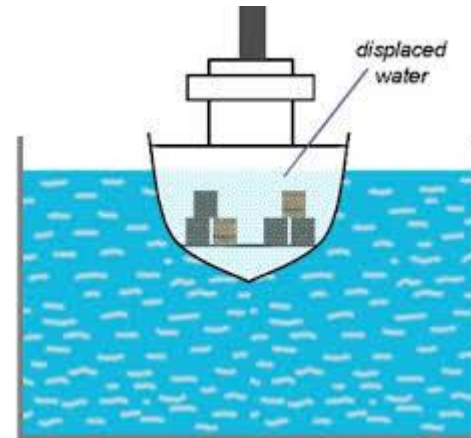
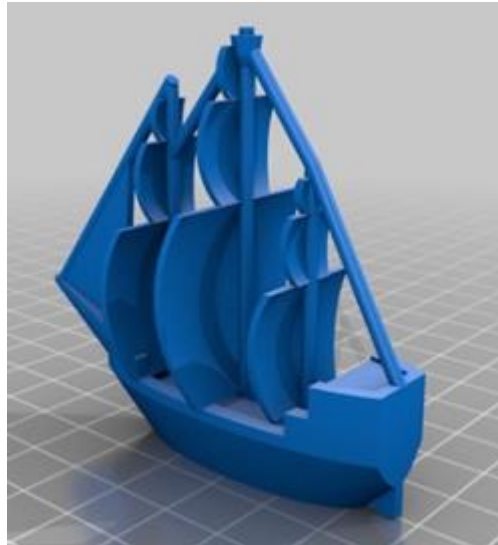
Floatation and Archimedes' principle

Enrichment
content

- Illustrated the factors that prevent boat sinking or toggling (base area, moment and centre of gravity)



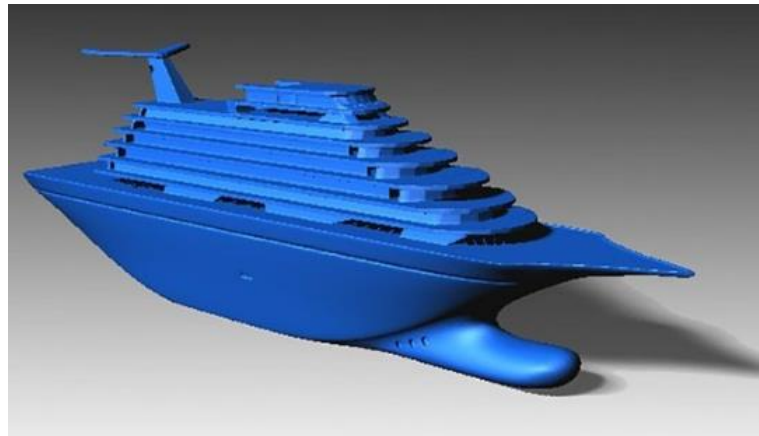
boat for wax candle



高重心的問題

Problem of a ship with high centre of gravity

- A 3D printed model of a high centre-of-gravity ship and a low one will be used to illustrate the underlying physics:
- **Newton 1st law (Inertia)** moment, centre of gravity and condition of toggling...etc.



4. Ship - Centre of gravity

- **Objective:** Student need to investigate why the ship has higher CG will sink easily
- **Time:** 20 mins
- **Apparatus:** Two different 3D printing models of ship, mass and water tank
- **Procedure:** Students try to add the loads onto the ships (one has lower CG and the other has high CG) until one of them sink.

Activity 1: Centre of Gravity – the balancing birds

Suggested
Activity



Step 1: Explain the activity to students

Step 2: Split students into groups of 2

Step 3: Distribute balancing birds to all groups **randomly**

Step 4: Allow students to experiment to find out where the center of mass is/what position to place the bird that will allow it to spin without falling off a point of contact (ie: a finger)

Step 5: Students will test their particular 3D printed balancing bird to see whether or not it is able to spin without falling off its axis of rotation

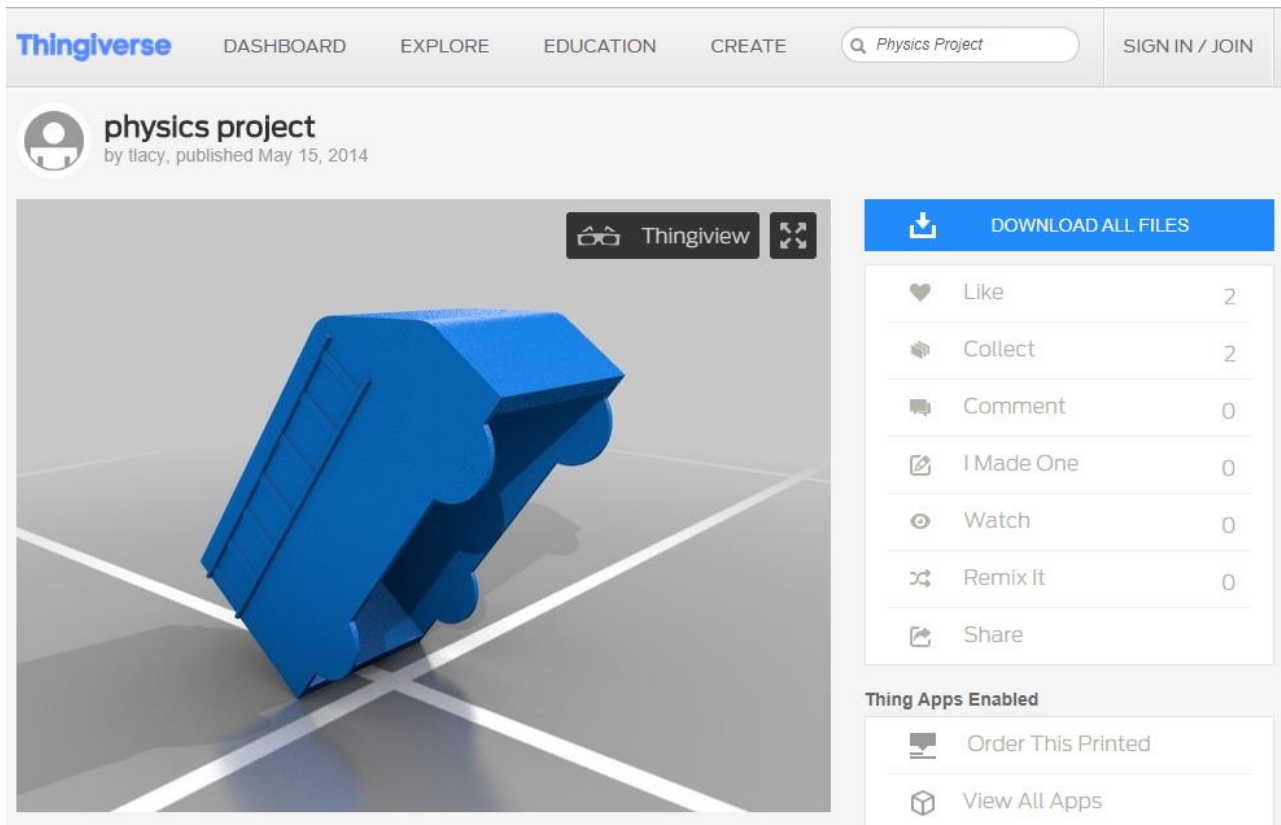
Step 6: Discuss the concept of center of gravity with the students, weighing in on evidence from the spinning bird experiment.

Source: <https://www.thingiverse.com/thing:1710099>

Activity 2: Centre of Gravity – other objects

Suggested Activity

<https://www.thingiverse.com/thing:332676>



自製電子船

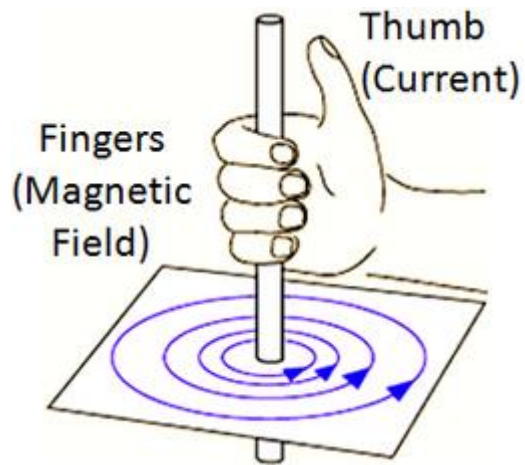
Make your Motor Boat

<https://www.thingiverse.com/thing:320485>

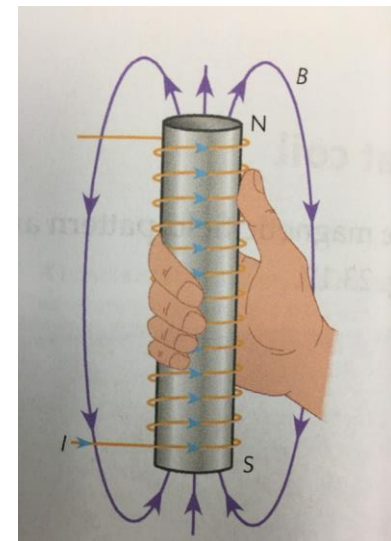
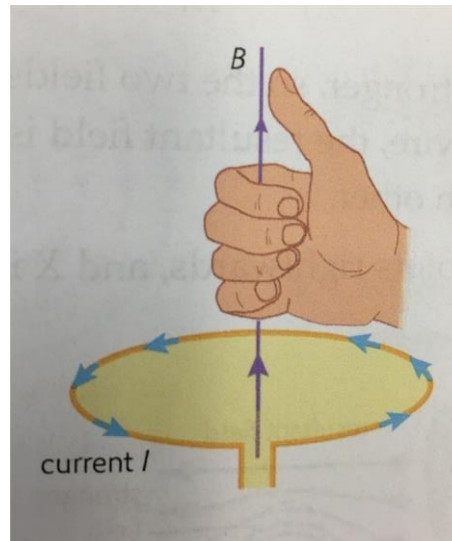


5. Right hand grip rule – EM

- Sometimes, students may not really understand the right hand grip rule. We would like to design a model to let them learnt easily.
- Students sometime mix up the use of right hand grip rule for solenoid and for straight wire



<http://www.excelatphysics.com/magnetic-effect-of-a-current.html>

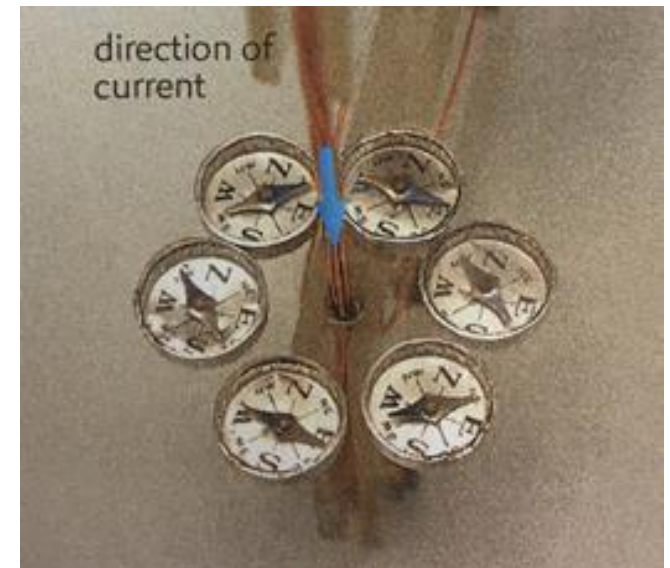
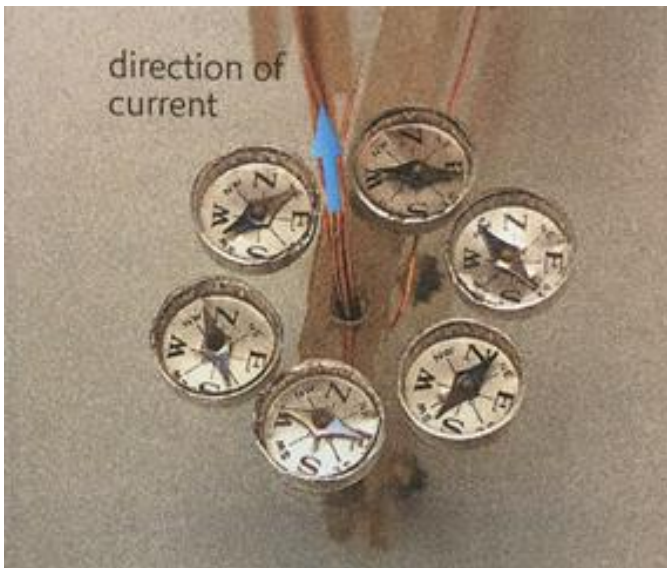


5. Right hand grip rule – EM

- **Objective:** Students need to find out the relationship between Current (I) and Magnetic field (B) when the current passing through the wire / solenoid by seeing the compass signs.
- **Time:** 20 mins
- **Apparatus:** Five different 3D printing models (Right hand, Thumb (represent for current), Four fingers (represent for Magnetic field), Thumb (represent for Magnetic field), Four fingers (represent for current)), solenoid, batteries, wires, small compass and magnetic (with label north and south pole).

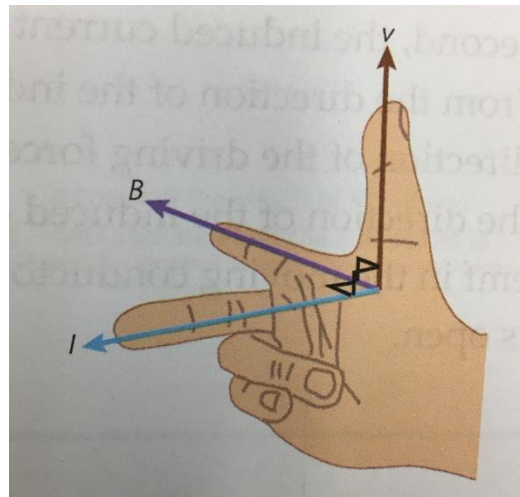
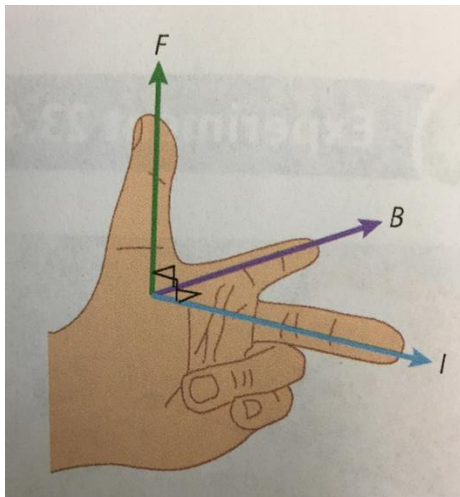
5. Right hand grip rule – EM

- **Procedure:** Put several small compass round the wire and then apply a current passing through it. By observe the needle direction and they need to use the 3D printing models to connect them together to show the relationship between Magnetic field (B) and Current (I).



6. Fleming's Left hand rule & Right hand rule (FBI) – EM

- Sometimes, students may not really understand and not well use their fingers on the Fleming's Left hand rule & Right hand rule (FBI) . We would like to design a model to let them learnt easily.
- They sometimes move their fingers incorrectly.

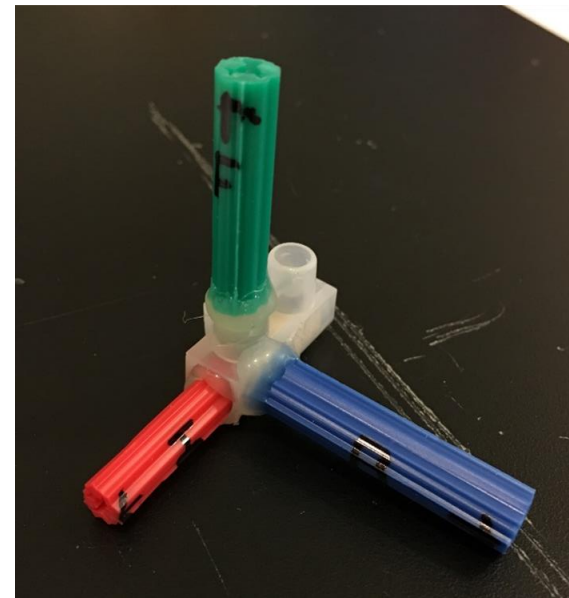
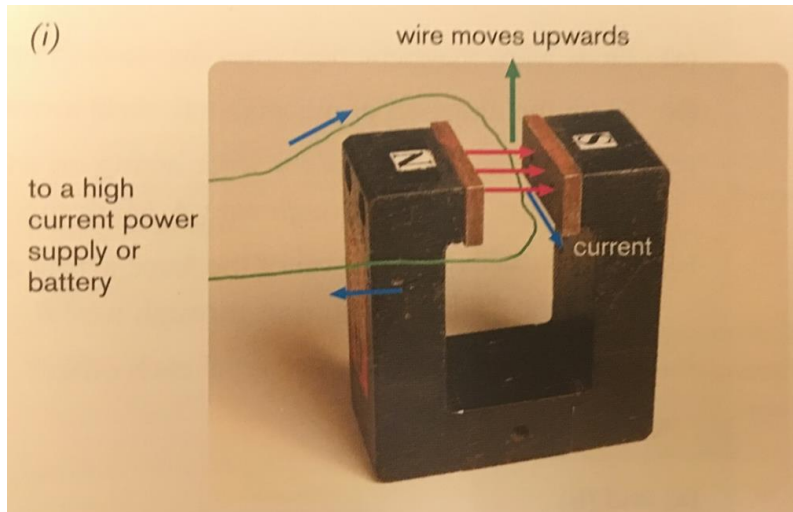


6. Fleming's Left hand rule & Right hand rule (FBI) – EM

- **Objective:** Students need to find out the relationship between Force (F), Magnetic field (B) and Current (I) when the current put into the magnetic with current pass through the wire.
- **Time:** 20 mins
- **Apparatus:** Four different 3D printing models (a stand, Force (F) arrow, Magnetic field (B) arrow and Current (I) arrow), copper wires, batteries, wires and magnetic (with label north and south pole).

6. Fleming's Left hand rule & Right hand rule (FBI) – EM

- **Procedures:** Put the wire in the middle of the magnetic and then connect it with the batteries. The wire will be move upwards as the figure shown. Student need to use the 3D printing models to connect them together to show the relationship between Force (F), Magnetic field (B) and Current (I).



7. DC motor – EM

- The working mechanism of DC motor is also so abstract. We would like to ask student to make a DC motor by themselves and using the Fleming's Left hand rule 3D model to familiar in depth. Moreover, they need to balance the weight of the wire and no. of turn to make the DC motor turning faster.



7. DC motor – EM

- **Objective:**

- To build up a DC motor.
- To apply Fleming's Left hand rule in DC motor so that students could understand the turning effect in different situations.
- To find out how no. of turns of coil affects the turning speed

- **Time:** 35 mins

- **Apparatus:** DC motor kit, 3D Fleming's Left hand rule model (example 6)

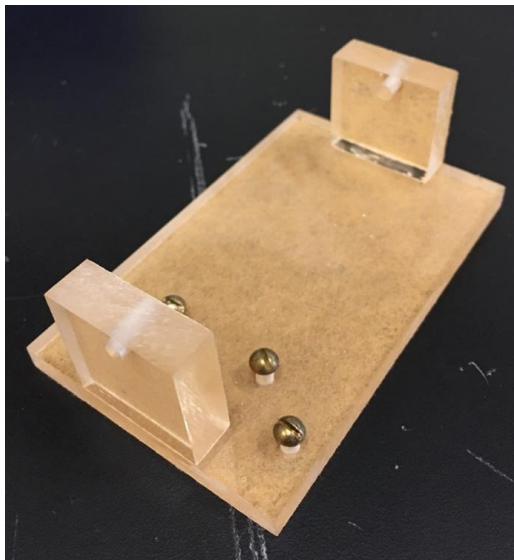
7. DC motor – EM

- **Procedures:**

1. Students are requested to build their own DC motor with guidance of teachers.
2. Students need to address the main structure of DC motor.
3. Students are asked to use 3D Fleming's Left hand rule model to find the Force when the coil in perpendicular and vertical position. Therefore, they may appreciate the design of DC motor e.g. accumulator. (Teachers at this point are suggested to show a practical DC motor to students to address their differences)

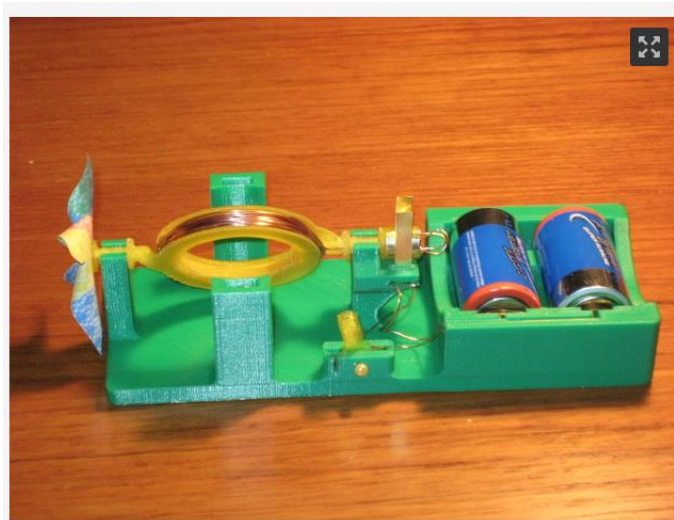
7. DC motor – EM

4. To compare the turning speed a coils with different no. of turns. Then, ask students to explain the results. (Further Q: how we could measure the turning speed of the coil quantitatively ? One of the methods may use a cotton rope adhere on the axis)



7. DC motor – EM

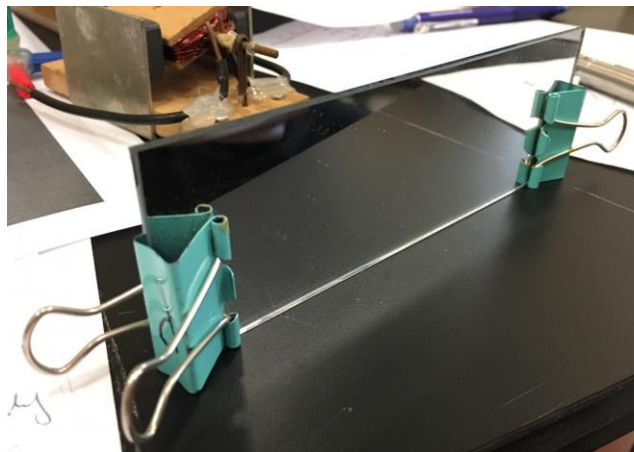
	Length of rope (m)	Time taken (s)	Turning speed (ms^{-1})
no. of turns of coil (N=10)			
no. of turns of coil (N=30)			



<https://www.thingiverse.com/thing:1613211>

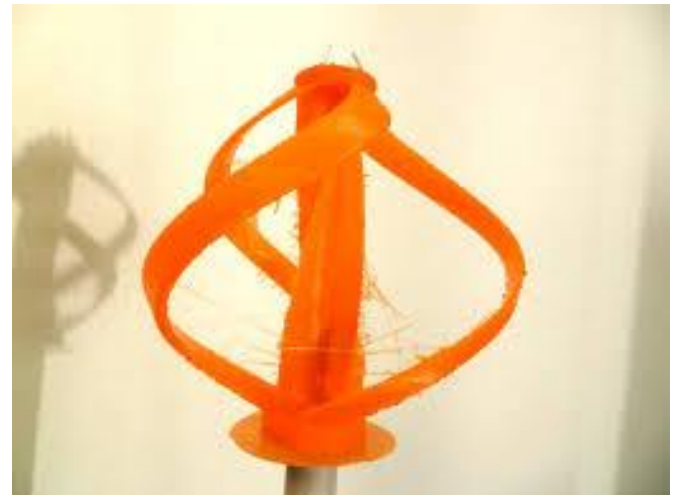
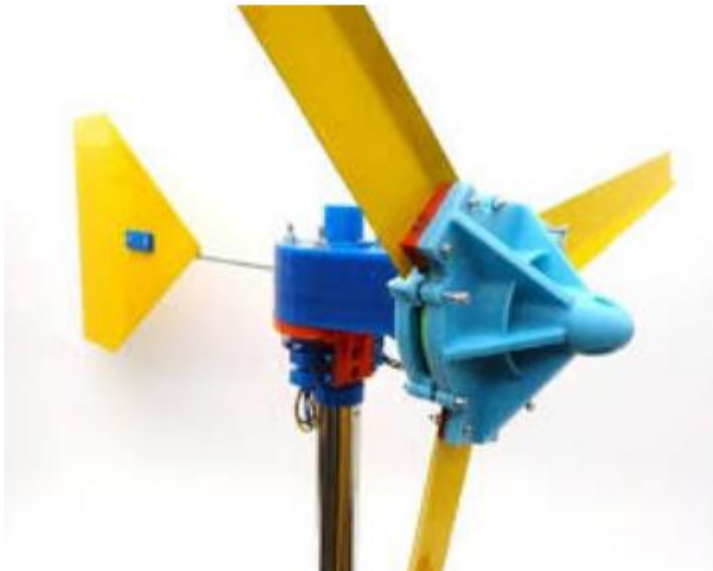
8. Mirror stand – Optics

- We found that it is not easy to stand a mirror perpendicularly for optics experiments. We would like to design a sample tools to help students on doing these type experiments.
- This example just illustrate how 3D printer may help you to handle your experiment nicely.



9. Wind turbine – Energy (Design of wind turbines and propellers) (For Elective)

- Explore how the number of blade, tilt angle and surface area affect the efficiency of the wind turbine.



風力發電機組的定量模型

Quantitative Model of Wind turbine

- The following table shows the definition of various variables used in this model:

E = Kinetic Energy (J)	ρ = Density (kg/m ³)
m = Mass (kg)	A = Swept Area (m ²)
v = Wind Speed (m/s)	C_p = Power Coefficient
P = Power (W)	r = Radius (m)
x = distance (m)	t = time (s)
dm/dt = Mass flow rate (kg/s)	
dE/dt = Energy Flow Rate (J/s)	

風力發電機組的定量模型

Quantitative Model of Wind turbine

- Under constant acceleration, the kinetic energy of an object having mass m and velocity v is equal to the work done W in displacing that object from rest to a distance s under a force F , i.e.:

$$E = \text{Force} \times \text{Distance} = Fs$$

- According to Newton's 2nd Law, we have: $F = ma$
- Hence, $E = \text{mass} \times \text{acceleration} \times \text{distance} = mas$

風力發電機組的定量模型

Quantitative Model of Wind turbine

- Using the third equation of motion: $v^2 = u^2 + 2as$
- we get: $a = (v^2 - u^2)/2s$
- Since the initial velocity of the object is zero, i.e. $u = 0$, we get:

$$a = v^2/2s$$

風力發電機組的定量模型

Quantitative Model of Wind turbine

- Substituting it in equation (1), we get that the kinetic energy of a mass in motions is:

$$E = \frac{1}{2} m v^2 \dots (2)$$

- The power in the wind is given by the rate of change of energy:

$$P = dE / dt = \frac{1}{2} v^2 dm / dt$$

風力發電機組的定量模型

Quantitative Model of Wind turbine

- As mass flow rate is given by:

$$dm/dt = \rho A dx/dt$$

dx/dt



Cross section area A



風力發電機組的定量模型

Quantitative Model of Wind turbine

- and the rate of change of distance is given by:

$$dx/dt = v$$

- we get: $dm/dt = \rho A v$

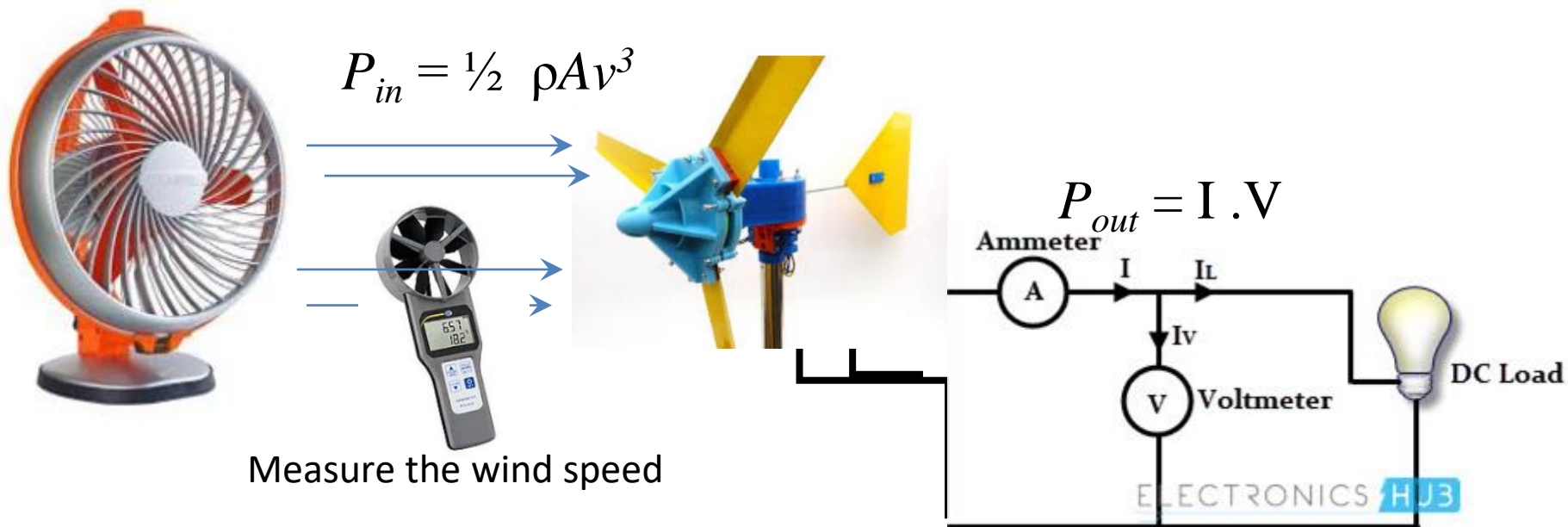
- Hence, from equation, the power can be defined as:

$$P = \frac{1}{2} \rho A v^3$$

測試3D打印風力發電機的性能

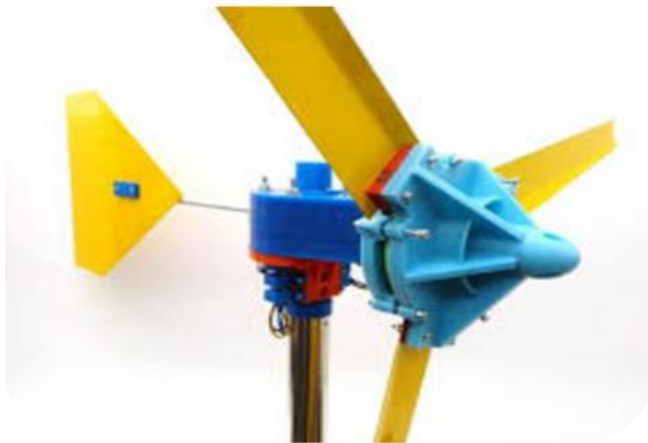
Test the performance of the 3D printed wind turbine

- Measure the wind speed and calculate the theoretical wind power
- Measure the current and voltage of the load circuit
- Find out the efficiency of power conversion = P_{out}/P_{in}

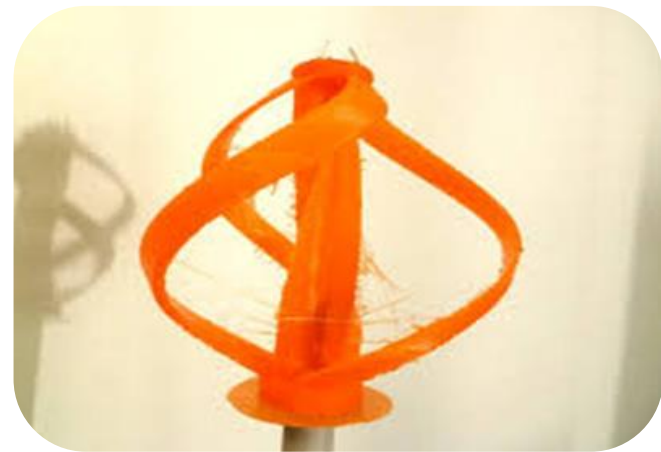


比較風力機的性能差異類型

Compare the performance difference types of wind turbine



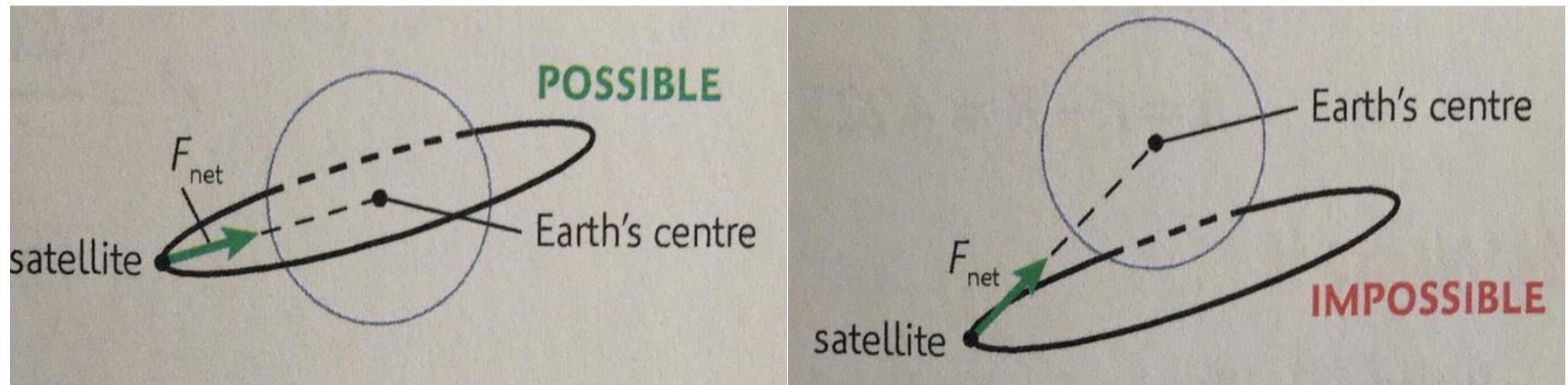
Vertical-axis
turbine



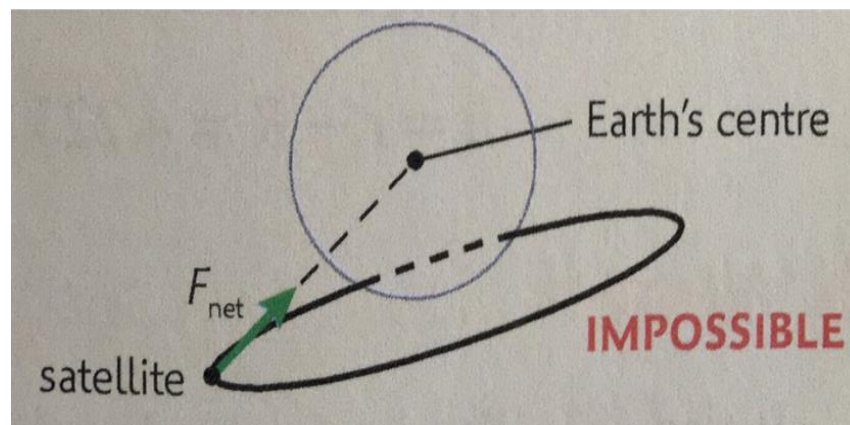
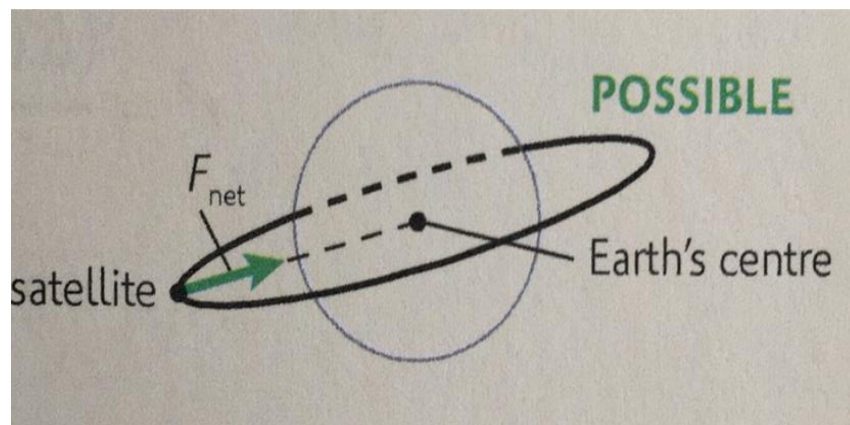
Horizontal-axis
turbine

10. Stationary satellite (Geostationary satellite) – Gravitation

- Geostationary satellite is an artificial satellite that always remains at the same spot when viewed from the Earth.
- It is very difficult to let students know why the geostationary satellite orbit directly over the equator. We would like to design two 3D models with force directions to explain this concept.



運用地球儀協助解釋概念

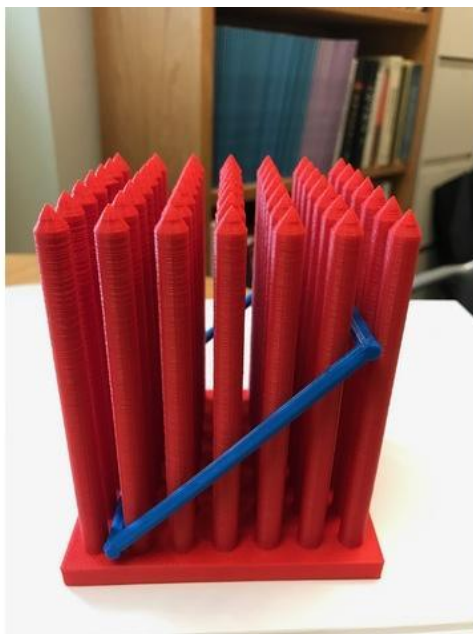


其他網上現成的教學工具介紹

Online resources for other teaching tools

Example 1: Electric Flux

示例1：電通量



Summary

Electric Field and Flux lab demo.

Overview and Background

Electric Flux

We have a physics lab where students use a loop over lines of electric flux, and record the number of lines as a function of normal vector angle of the loop area. Plotting these, they discover the flux $\Phi = AB \cos(\theta)$. Previously we used sticks in styrofoam and a pipecleaner loop. I thought I'd try to make something a bit nicer. This is about 10x10x13, and takes about 180 m of filament for the main thing. I suggest printing the 'loop' using a different color for contrast.

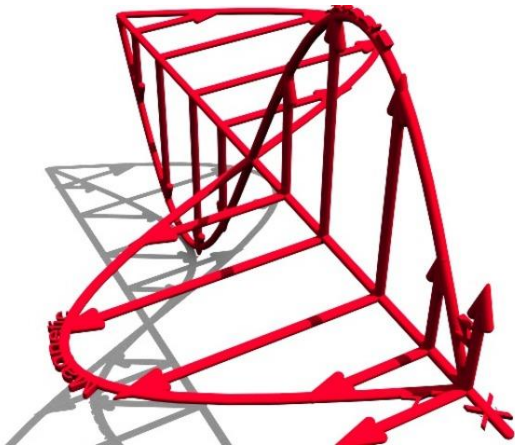
Lesson Plan and Activity

See Tutorials in Introductory Physics by McDermott et al (Dept Physics, U Washington), p. 77 "Electric Field and Flux"

<https://www.thingiverse.com/thing:2278336>

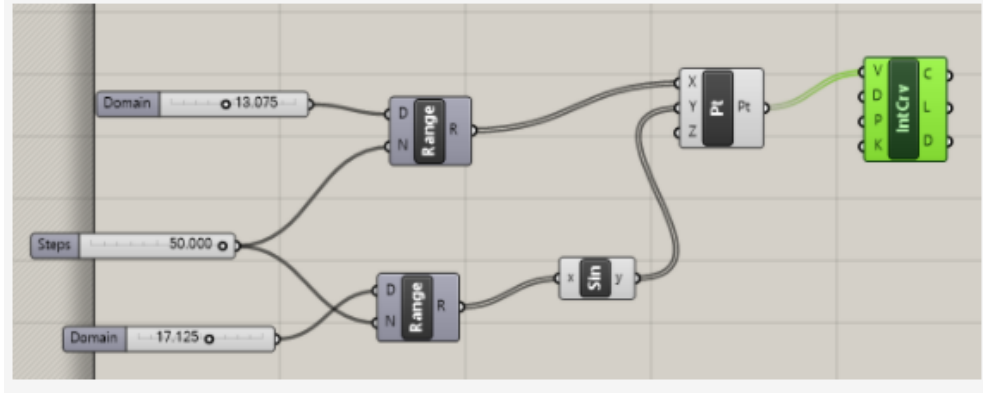
Example 2: 電磁波

示例 2 : Electromagnetic Wave



How I Designed This

Used Rhinoceros 3D in conjunction with Grasshopper plugin to build the sine curve.

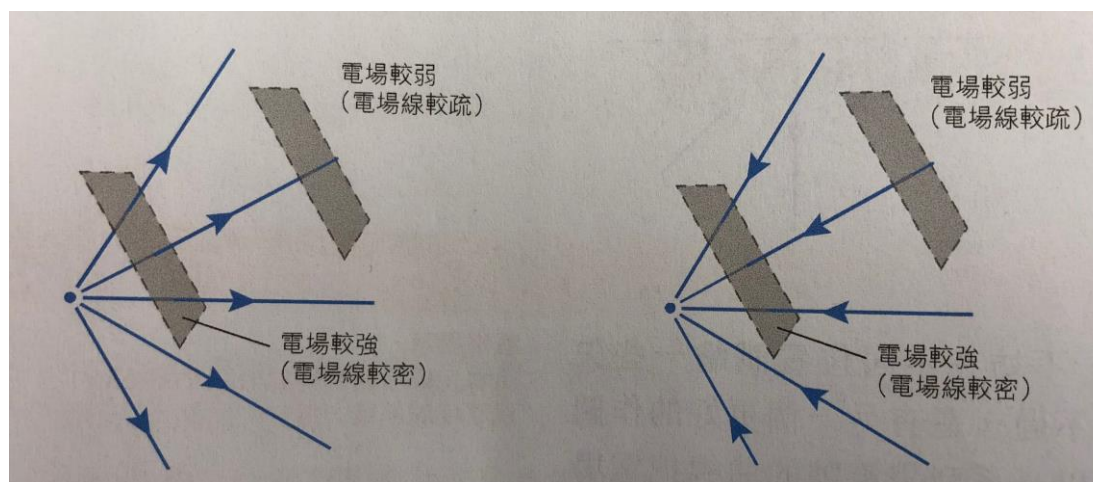
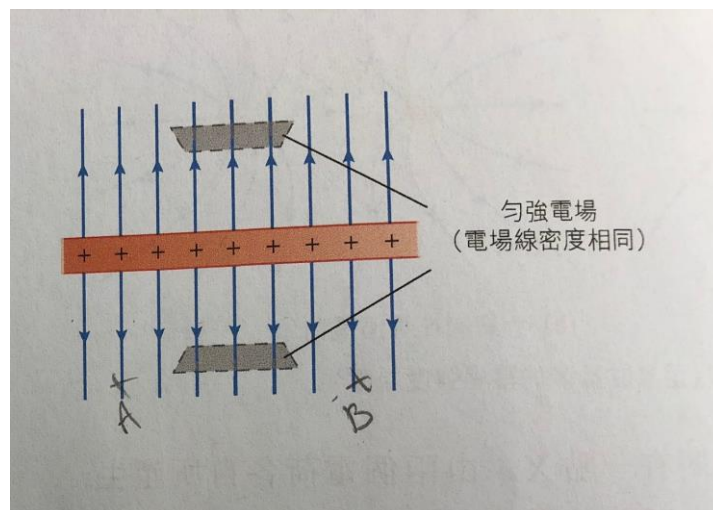


<https://www.thingiverse.com/thing:1105344>

The electromagnetic waves that compose electromagnetic radiation can be imagined as a self-propagating transverse oscillating wave of electric and magnetic fields. This diagram shows a plane linearly polarized EMR wave propagating from left to right. The electric field is in a vertical plane and the magnetic field in a horizontal plane. The electric and magnetic fields in EMR waves are always in phase and at 90 degrees to each other.

Source: https://en.wikipedia.org/wiki/Electromagnetic_radiation

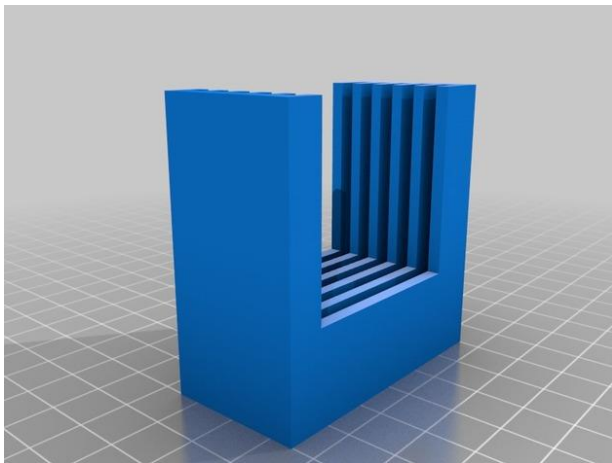
工作紙 輔助實驗學習



Example 3: 物理衍射幻燈片支架和激光筆支架

示例 3 : Physics Diffraction Slide Holder and Laser Pen Holder

<https://www.thingiverse.com/thing:2376585>



Summary

This is a slide stand and a laser pen holder to allow students and teachers to conduct/demonstrate the double slit experiment with different wavelength laser lights. The slide holder doubles as a storage holder for your slides. The laser pen holder suits a common laser pen sold online in sets of 3 different wavelengths. This was originally designed to help a student conduct their extended experimental investigation.

Print Settings

Printer Brand:
SeeMeCNC

Printer:
Rostock MAX v2

Rafts:
Doesn't Matter

Supports:
Doesn't Matter

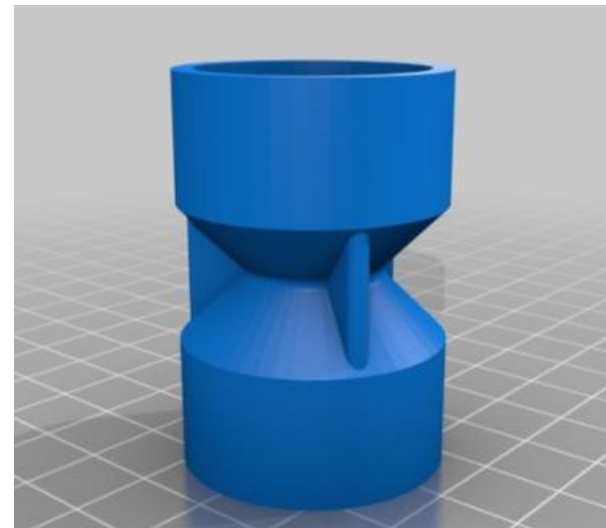
How I Designed This

Designed using OpenSCAD
Designed using OpenSCAD using caliper measurements.

Example 4: Tornado in a Bottle 示例 4：水樽中的龍捲風

<https://www.thingiverse.com/thing:130922>

- Other applications for learning 3D打印的其他教學應用
- For fun, competition & event 娛樂,比賽和事件



第二節 總結 Conclusion

- Capture 3D objects using Mobile devices (i.e. Qlone)
- Physics experiments / Tools
 - Open bottle cap – Turning effect of a force
 - An ‘anti-siege’ machine - Turning effect of a force
 - Balance bottle holder – Free body diagram
 - Ship - Centre of gravity
 - Right hand grip rule – EM
 - Fleming’s Left hand rule & Right hand rule (FBI) – EM
 - DC motor – EM
 - Mirror stand – Optics
 - Wind turbine – Energy
 - Stationary satellite (Geostationary satellite) – Gravitation

Join our “3D Printing for Physics” community (Whatsapp Group)

課堂的延伸討論

分享最新的3D Printing 資訊



分享最新的電子教學活動資訊

FAQ

1. How to select a buyer of technological equipment?
 1. Reputation
 2. Efficiency of support
 3. Maintenance fee
2. Any channel to print your 3D objects?
 1. Makerbot
 2. Hong Kong Productivity Council 3D Printing services for schools
 3. Services provider found on Taobao.com

2. Recommended 3D Printer
 2. Ultimaker 3
 3. UP
 4. Zmorph
3. Recommended 3D Scanning
 2. HP Sprout
 3. Apple Structure Sensor
 4. Sony XZ

提交教育局的課程評估表

- 請填寫教育局的課程評估表，並於離開前提交。
- Please fill in the EDB Course Evaluation Form and submit it by the end of the class.

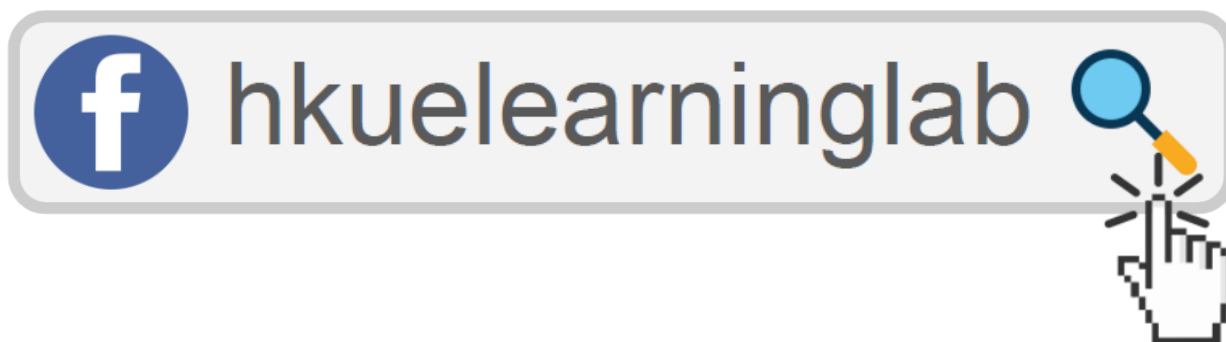
提交香港大學課程評估及跟進表格

HKU Training Evaluation & Follow-up



<https://goo.gl/forms/O7qiudh0lZWqFrdl2>

追蹤電子教學資訊和實驗室最新動向 Facebook 專頁



Q&A

聯絡我們

電郵: eltraining@eee.hku.hk

電話: 2219-4282 (何小姐)

網址: <http://elearning.eee.hku.hk/>

謝謝

Thank you