



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

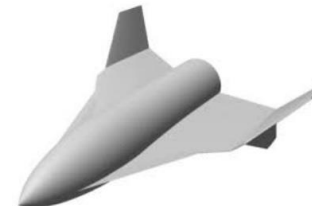
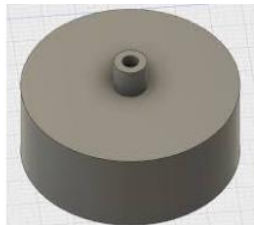
資訊科技教育與學科有關係列：  
運用3D打印機和資訊科技工具促進物理科的學與教

# IT in Education Subject-related Series: Using 3D Printers and IT Tools to Enhance Learning and Teaching of Physics (SESSION 1)

Instructors:

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# 課程目標

新興立體 (3D) 打印技術日漸普及，此技術能讓學生和教師設計和製作用於物理演示和實驗的物件或零件。借助3D打印技術，教師和學生可以特製不同形狀、尺寸和質量的物件或零件，進行更多學校實驗室標準設備或儀器無法實現的演示和實驗。透過掌握3D打印技術，學生不但可學習物理科的知識和技能，還可在學習過程中展示其創新、創意及解難能力。透過本課程讓學員：

- (一) 透過應用於物理科探究活動的3D打印技術，掌握設計及製作物件或零件的基本技巧；
- (二) 利用3D打印技術設計教學活動，以提升學生對物理現象與應用的興趣和理解；及
- (三) 利用資訊科技工具，以提升學生整合及應用STEM相關學科知識和技能的能力。

# 第一節 課程流程 (3 小時)

- A. 介紹使用基本的3D打印技術 (10 mins)
- B. 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 (例如：飛輪，3D平衡的酒瓶架) (20 mins)
- C. 介紹有關3D打印物件或零件等綜合活動的例子(20 mins)
  - a. 介紹3D物件線上資源
  - b. 介紹捕捉3D物件的方法
- D. 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
  - a. 介紹TinkerCAD (10 mins)
  - b. Project 1: 簡單的直流電機線圈Simple DC motor coil (40 mins)
  - c. Project 2: FBI教學包 FBI teaching kits (30 mins)
- E. 如何使用3D打印機打印3D物件 (包括使用Repetier-Host) (25 mins)
  - a. 小組討論和個人作業 (10+10 mins)
- F. 總結 (10 mins)

# 第二節的物理科實驗例子介紹時序

## Schedule of Physics experiments

1. 打開瓶蓋 - 一個力量的轉動效果Turning effect of a force
2. “反圍攻” 機器 ‘anti-siege’ machine - 一個力量的轉動效果Turning effect of a force
3. 平衡瓶架Balance bottle holder – 自由體圖Free body diagram
4. 船舶 - 重心和浮力中心
5. 右手握法則– EM
6. Fleming左手法則和右手法則 (FBI) – EM
7. 直流電機 DC motor – EM
8. 鏡架 - 光學Mirror stand – Optics
9. 風力發電機組 - 能源Wind turbine – Energy
10. 衛星 ( 地球靜止衛星 ) - 引力 Stationary satellite (Geostationary satellite) – Gravitation

# A. 介紹基本的3D打印技術

## Introduction of using basic 3D-Printing technology (15 mins)

1. 兩種主要3D打印機的操作原理：
  - a. 笛卡爾坐標系XYZ-axis type 3D打印機
  - b. 三角型Delta type 3D打印機
  - c. 兩種3D打印機的優缺點

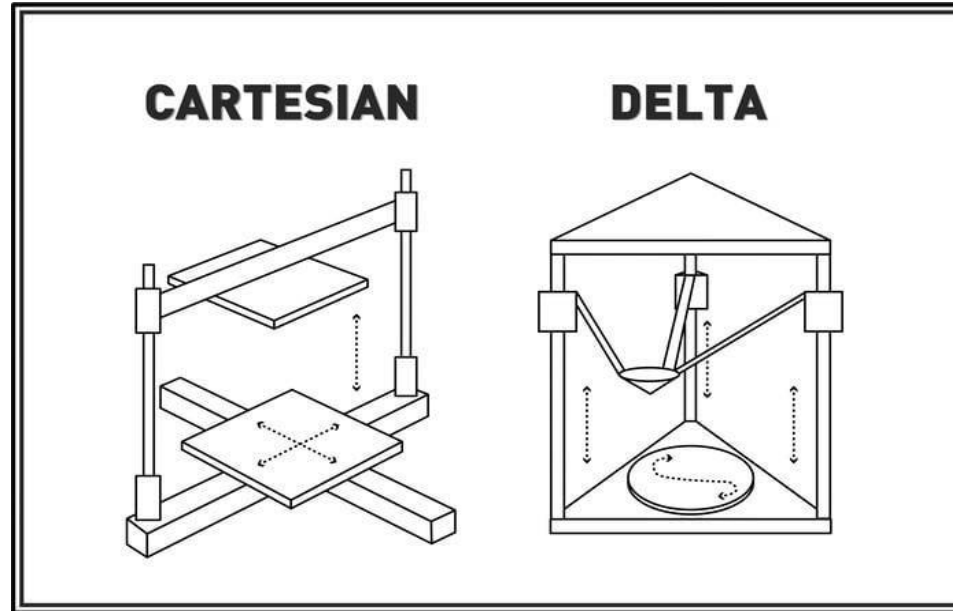
# 兩種主要3D打印機的操作原理

## Operating principal of the two major types of 3D printer

### 1. Cartesian (xyz-axis type) 3D-printer

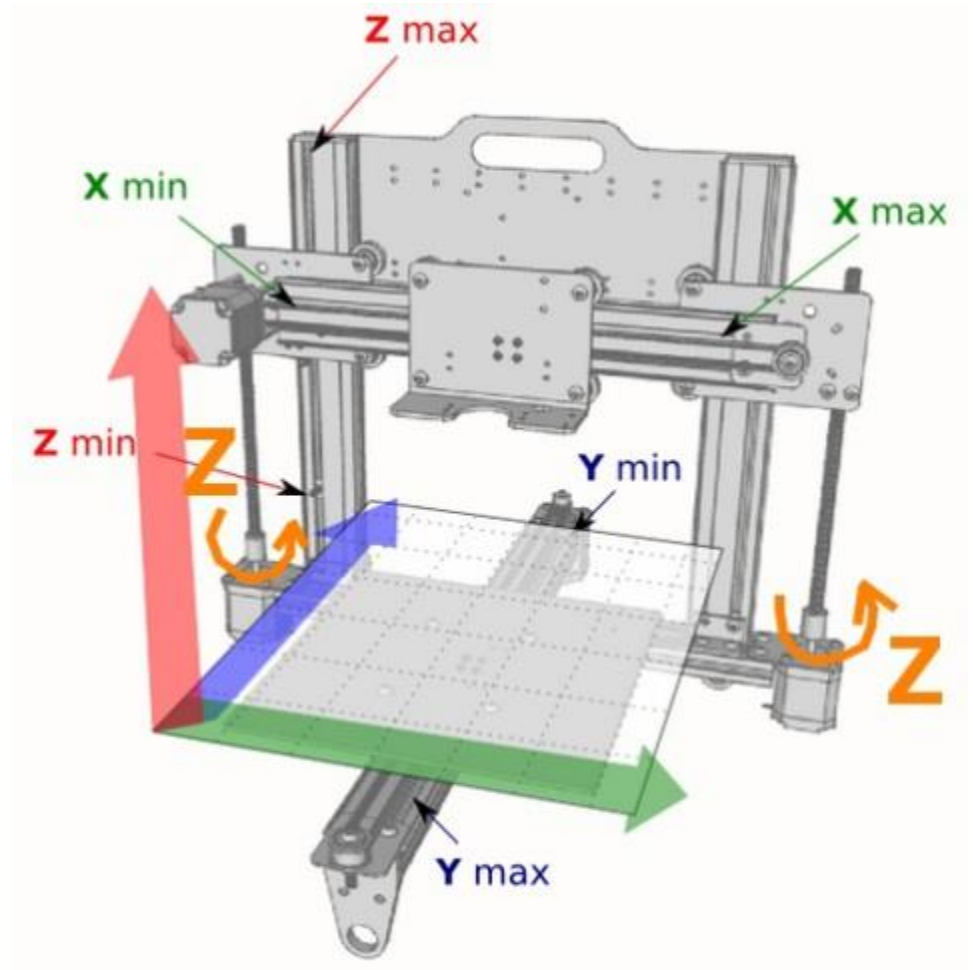
直角坐標系 (笛卡爾坐標系)  
3D打印機

### 2. Delta type 3D-printer (三角型3D打印機)



# 1. 直角坐標系 ( 笛卡爾坐標系 ) 3D打印機 XYZ-axis (Cartesian) type 3D-printer

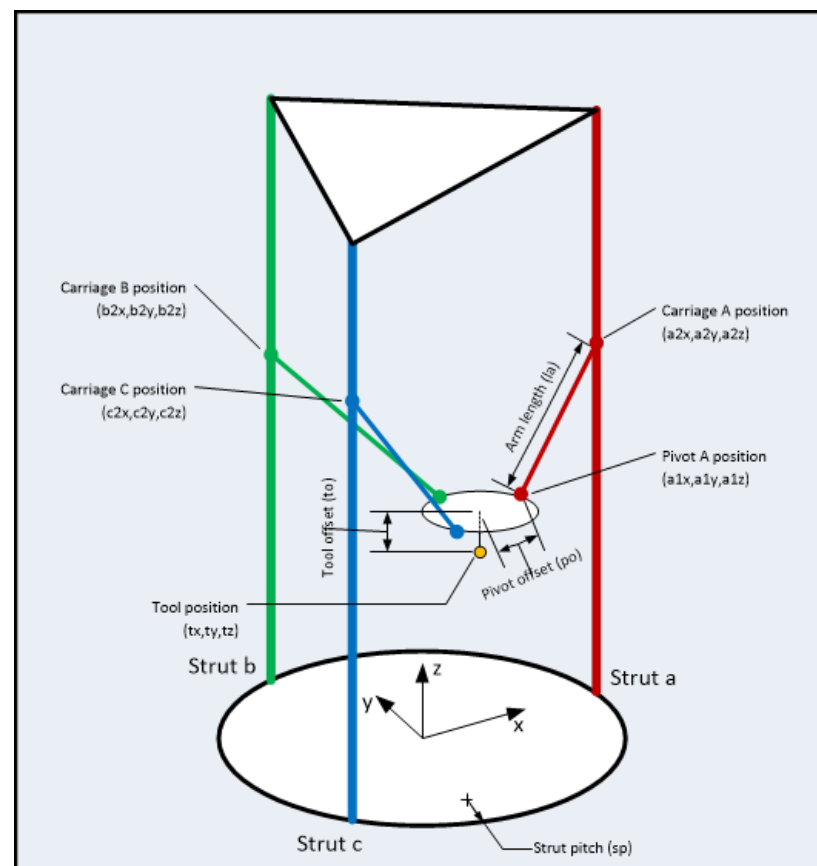
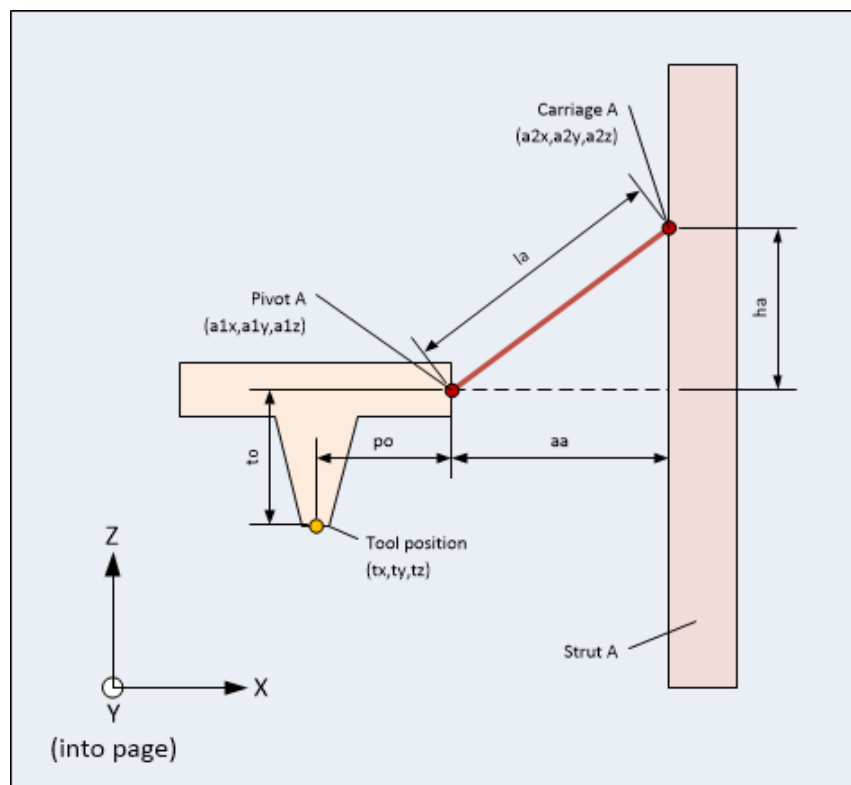
- 笛卡爾3D打印機以三維坐標系命名 - X，Y和Z軸 - 用於確定三維移動的位置和方式。
- 笛卡爾3D打印機通常具有僅在Z軸上移動的打印床。擠出機坐落在X軸和Y軸上，可以在龍門架上沿四個方向移動。



## 2. 三角型3D打印機 Delta type 3D-printer

- 如何設計3D Delta打印

(<http://www.robotmaker.eu/ROBOTmaker/3d-printing/3d-delta-printing-designs>)





# 直角坐標系笛卡爾打印機的優點和缺點

## Introduction of Pros & Cons of Cartesian Printer

- 優點:
  - 簡單的校準和錯誤分析/校正
  - 大多數切片軟件(slicing software)的設計都考慮到了笛卡爾，特別是關於它們固有的弱點。
  - 通常使用龍門式擠出機 (gantry-mounted extruders)。
  - 比較常見雙重擠壓 (Dual extrusion )
  - 能夠承受高加速度並且速度非常快。
  - 更常見和更多的社區資源可用。

# 直角坐標系笛卡爾打印機的優點和缺點

## Introduction of Pros & Cons of Cartesian Printer (Cont')

- 缺點：
  - Z軸運動非常緩慢。
  - 底板在大多數設計中都會移動，並且施工錯誤通常會導致無意的X-Y移位產生“Z-banding”。
  - 所有設計在每個運動軸上都有不同的慣量(inertias)。
  - 這可能會影響加速度 (acceleration)
  - 必須仔細監控皮帶張力以防止X-Y間隙（這將導致橢圓形(elliptical circles)和其他偽影(fun artifacts)）。

# 三角型3D打印機的 優點和缺點

## Introduction of Pros & Cons of Delta type 3D-printer

- 優點:
  - 非常高的加速度和速度。
  - 結構簡單，組裝、維修等都較為方便
  - 沒有固有的首選移動方向。
  - 微小的校准或機械錯誤通常是看不可見的。
  - 對與絲杆、光軸的切割精度要求不高
  - 一旦組裝好，維護成本低。
  - 需要的部件较少

資料來源:

[https://www.reddit.com/r/3Dprinting/comments/2rpx98/advice\\_delta\\_vs\\_cartesian/?st=j9zus4c8&sh=32632b70](https://www.reddit.com/r/3Dprinting/comments/2rpx98/advice_delta_vs_cartesian/?st=j9zus4c8&sh=32632b70)

<http://www.dayinpai.com/topic/post/f8504>

# 三角型3D打印機的 優點和缺點

## Introduction of Pros & Cons of Delta type 3D-printer

- 缺點:
  - 機體的製作精度較低，通常只能達到mm級，需要更高的精度需要很大的力氣去調試
  - 列印時，列印物體隨熱床在Y軸前後移動電源、控制板放的位置比較隨意，不好看。
  - 更長的校準(calibration)時間
  - 必須使用Bowden style擠出機來獲得高速度的好處（直接是可能的，但不常見和沉重）。
  - 雙重擠出需要修改（沒有套件或打印機支持它）。
  - 圓形建築區域有時會令人討厭

## B. 介紹如何將3D物件用於物理實驗

增潤內容  
Enrichment  
content

### 例子1：飛輪 Example 1: Flywheel

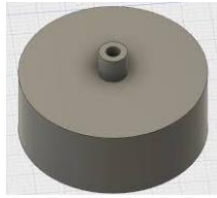
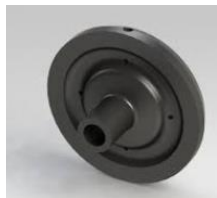
- 實驗目標：為了演示不同設計對飛輪慣性矩movement of inertia的影響。

$$I = \sum m_i r_i^2$$

- 設計：設計一個旋轉持續很長的飛輪
- 設計2-3個具有不同直徑寬度和質量分佈的飛輪。
- 基本要素：旋轉對稱，圓陣

參考設計可以從iClass下載:

<https://www.thingiverse.com/thing:44031>



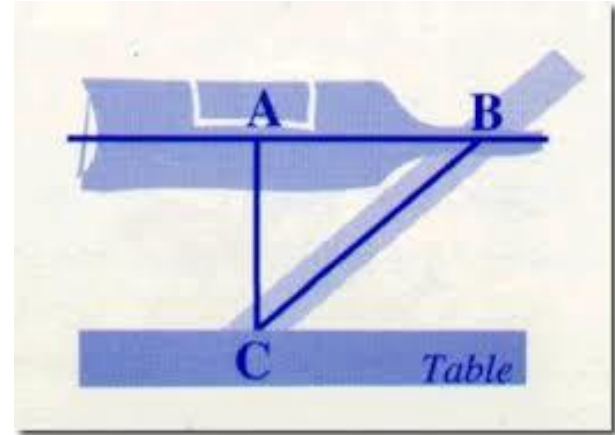
## 例子2：平衡的酒瓶架

### Example 2: self-balanced wine bottle holder

- 設計目標：引入重心概念

$$x = \sum m_i x_i / \sum m_i$$

$$y = \sum m_i y_i / \sum m_i$$





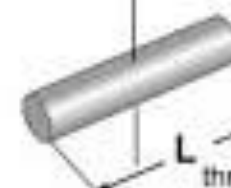
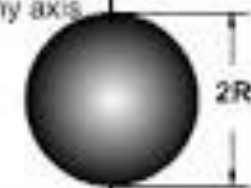
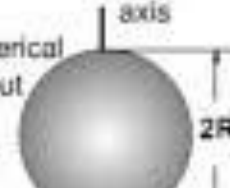

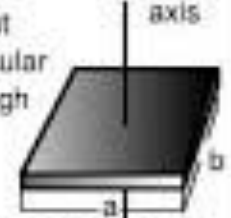


- 運用 3D打印一些樣品 (samples)以供展示及說明
- 參加者需要使用TinkerCAD來設計一個簡單的自動平衡葡萄酒瓶架



# 慣性矩的例子

## Additional Examples of Moment of Inertia

|   |  |   |
|---|--|---|
|  <p>Hoop about central axis</p> $I = MR^2$   |  <p>Annular cylinder about central axis</p> $I = \frac{1}{2} M(R_1^2 + R_2^2)$             |  <p>Solid cylinder about central axis</p> $I = \frac{1}{2} ML^2$                       |
|  <p>Solid cylinder about central diameter</p> $I = \frac{1}{4} MR^2 + \frac{1}{12} ML^2$ |  <p>Thin rod about axis through center perpendicular to length</p> $I = \frac{1}{12} ML^2$ |  <p>Solid sphere about any axis</p> $I = \frac{2}{5} MR^2$                             |
|  <p>Thin spherical shell about any diameter</p> $I = \frac{2}{3} MR^2$                  |  <p>Hoop about central axis</p> $I = MR^2$  |  <p>Slab about perpendicular axis through center</p> $I = \frac{1}{12} M(a^2 + b^2)$ |



## C. 如何提供/創建物理科教學活動的物件或零件

### How to source/capture objects/parts for learning and

#### 1. 下載3D library

- e.g. 3D Warehouse, 3D object library

#### 2. 掃描真實物件

- 如何使用3D掃描儀或智能手機來捕捉3D模型

#### 3. 使用免費軟件設計和構建3D物件

- e.g. TinkerCAD (a freeware)

# 1. Download from 3D library

## 如何從網上資源下載3D object 用於創建AR應用程式

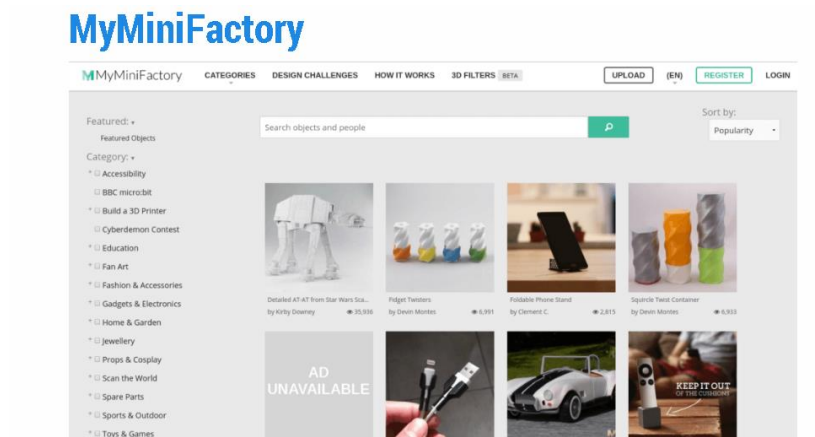
網上平台資源 Available web-resource platforms:

### 1. 3D Warehouse

<https://3dwarehouse.sketchup.com/>

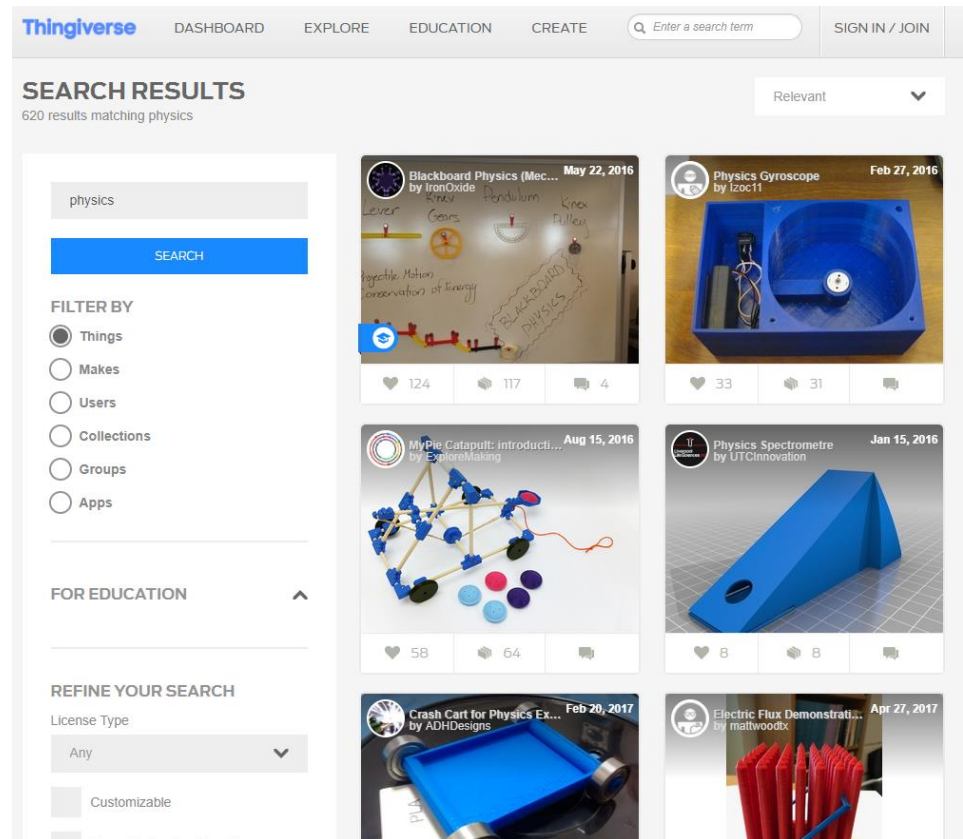
### 2. 3D Printing object libraries

<https://all3dp.com/1/free-stl-files-3d-printer-models-3d-print-files-stl-download/>



# 3D模型的在線資源 Thingiverse

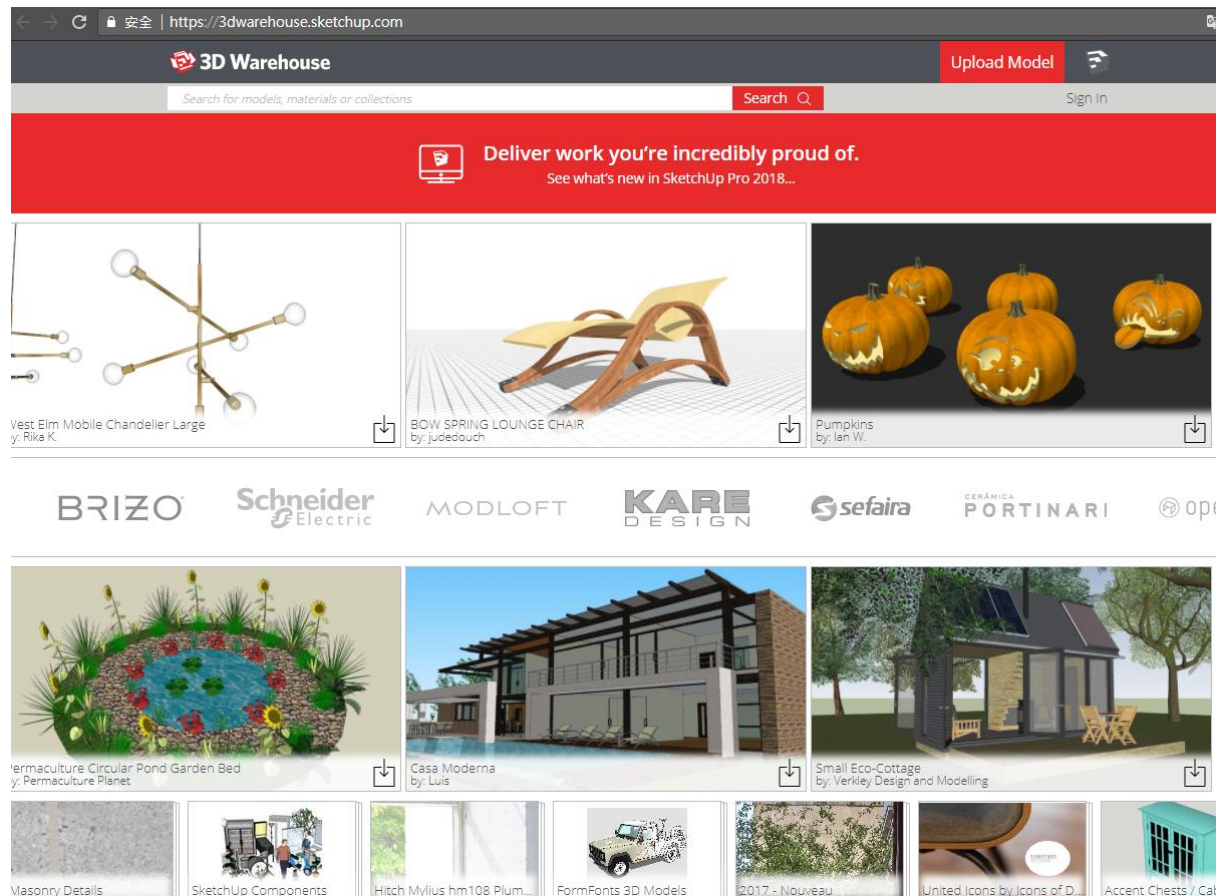
<https://www.thingiverse.com/>  
有三維模型的相關教材提供



# 3D模型的在線資源

## 3D Warehouse

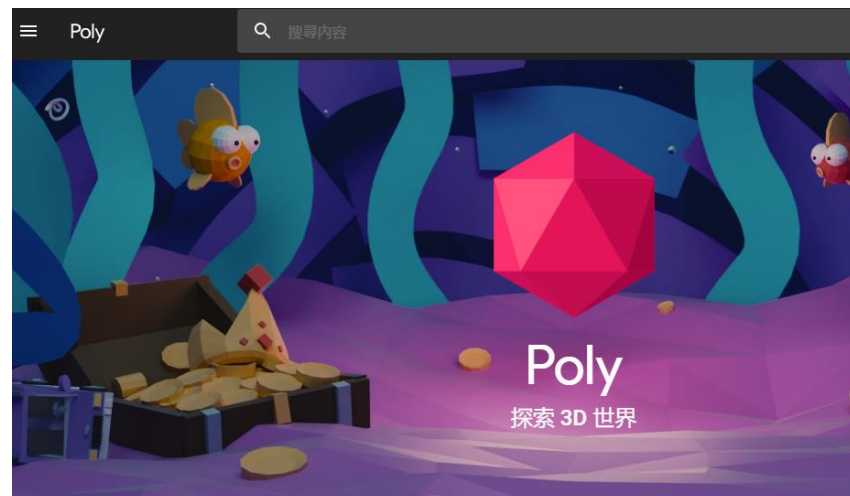
<https://3dwarehouse.sketchup.com/?hl=en>



# 3D模型的在線資源

## Google Poly

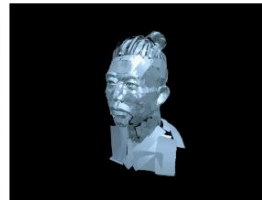
<https://poly.google.com/>  
載有3D Model, AR 和VR等資源



精選



"Hostile Planet", final version  
Rein Bijlsma  
© 2018年



VR version Kan's portrait  
Olga Nabatova  
© 2018年



Angry Robo Dancer  
Eric Finn  
© 2018年

# 其他3D 物件的網上資源

- 更多資訊:

- <https://all3dp.com/1/free-3d-models-download-best-sites-3d-archive-3d/>

| Site                                    | 3D Printing | Engineering | Architecture/<br>Visualization | Animation | Gaming | Graphic Design | Archive/<br>Documentation |
|---|-------------|-------------|--------------------------------|-----------|--------|----------------|---------------------------|
| <a href="#">3D Digital Doubles</a>      | X           | X           | X                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">3D Scanstore</a>            | X           | X           | X                              | ✓         | ✓      | X              | X                         |
| <a href="#">3D Warehouse</a>            | ✓           | X           | ✓                              | ✓         | ✓      | X              | X                         |
| <a href="#">3DContentCentral</a>        | X           | ✓           | X                              | X         | X      | X              | X                         |
| <a href="#">3Delicious</a>              | X           | X           | ✓                              | ✓         | X      | ✓              | X                         |
| <a href="#">3DExport</a>                | ✓           | X           | X                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">3DModelFree</a>             | X           | X           | ✓                              | ✓         | X      | ✓              | X                         |
| <a href="#">3DShook</a>                 | ✓           | X           | X                              | X         | X      | X              | X                         |
| <a href="#">3dsky</a>                   | X           | X           | ✓                              | ✓         | X      | ✓              | X                         |
| <a href="#">Archive 3D</a>              | X           | X           | ✓                              | ✓         | X      | ✓              | X                         |
| <a href="#">Autodesk Online Gallery</a> | ✓           | ✓           | ✓                              | X         | X      | X              | X                         |
| <a href="#">Bitgem</a>                  | X           | X           | X                              | X         | ✓      | X              | X                         |
| <a href="#">blankRepository</a>         | X           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">Blendswap</a>               | ✓           | X           | X                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">CADNav</a>                  | X           | ✓           | ✓                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">CGTrader</a>                | X           | X           | X                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">Clara.io</a>                | ✓           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">Cults</a>                   | ✓           | X           | X                              | X         | X      | X              | X                         |

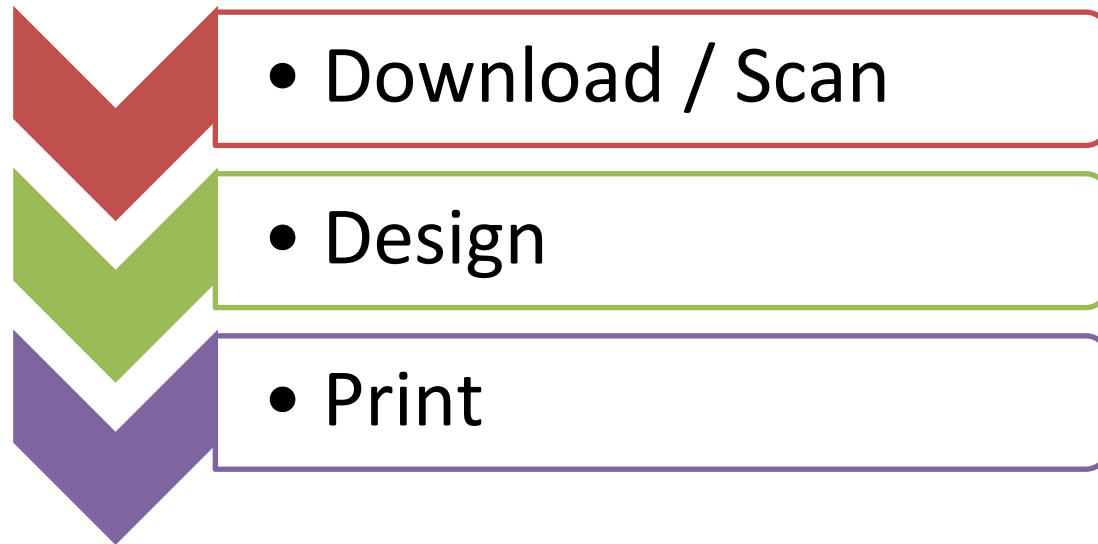
| Site                               | 3D Printing | Engineering | Architecture/<br>Visualization | Animation | Gaming | Graphic Design | Archive/<br>Documentation |
|------------------------------------|-------------|-------------|--------------------------------|-----------|--------|----------------|---------------------------|
| <a href="#">Design Connected</a>   | X           | X           | ✓                              | X         | X      | ✓              | X                         |
| <a href="#">Dimensiva</a>          | X           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">Evermotion</a>         | X           | X           | ✓                              | ✓         | X      | ✓              | X                         |
| <a href="#">FlyingArchitecture</a> | X           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">Free3D</a>             | X           | X           | ✓                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">GB3D Type Fossils</a>  | ✓           | X           | X                              | X         | X      | X              | ✓                         |
| <a href="#">gCreate</a>            | ✓           | X           | X                              | X         | X      | X              | X                         |
| <a href="#">GrabCAD</a>            | ✓           | ✓           | X                              | X         | X      | X              | X                         |
| <a href="#">Human Alloy</a>        | X           | X           | ✓                              | X         | X      | ✓              | X                         |
| <a href="#">Instructables</a>      | ✓           | X           | X                              | X         | X      | X              | X                         |
| <a href="#">Kenney</a>             | X           | X           | X                              | X         | ✓      | X              | X                         |
| <a href="#">MorphoSource</a>       | ✓           | X           | X                              | X         | X      | X              | ✓                         |
| <a href="#">MyMiniFactory</a>      | ✓           | X           | X                              | X         | X      | X              |                           |
| <a href="#">NASA 3D Resources</a>  | ✓           | X           | X                              | X         | X      | X              | ✓                         |
| <a href="#">OpenGameArt</a>        | X           | X           | X                              | X         | ✓      | X              | X                         |
| <a href="#">Orchard</a>            | ✓           | ✓           | X                              | X         | X      | X              | X                         |

| Site                                  | 3D Printing | Engineering | Architecture/<br>Visualization | Animation | Gaming | Graphic Design | Archive/<br>Documentation |
|---------------------------------------|-------------|-------------|--------------------------------|-----------|--------|----------------|---------------------------|
| <a href="#">Pinshape</a>              | ✓           | X           | X                              | X         | X      | X              | X                         |
| <a href="#">PixelLab</a>              | X           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">Renderpeople</a>          | X           | X           | ✓                              | X         | X      | ✓              | X                         |
| <a href="#">ShareCG</a>               | X           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">Sketchfab</a>             | ✓           | X           | X                              | ✓         | ✓      | X              | X                         |
| <a href="#">Smithsonian<br/>X3D</a>   | ✓           | X           | X                              | ✓         | X      | ✓              | X                         |
| <a href="#">STLFinder</a>             | ✓           | X           | X                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">Synchronia</a>            | X           | X           | ✓                              | ✓         | X      | ✓              | X                         |
| <a href="#">Thingiverse</a>           | ✓           | X           | X                              | X         | X      | X              | X                         |
| <a href="#">TinkerCAD<br/>Things</a>  | ✓           | X           | X                              | ✓         | ✓      | X              | X                         |
| <a href="#">Trace Parts</a>           | ✓           | ✓           | ✓                              | X         | X      | X              | X                         |
| <a href="#">TurboSquid</a>            | X           | X           | ✓                              | X         | ✓      | ✓              | X                         |
| <a href="#">Unity Asset<br/>Store</a> | X           | X           | ✓                              | ✓         | ✓      | X              | X                         |
| <a href="#">Viz-People</a>            | X           | X           | ✓                              | X         | X      | ✓              | X                         |
| <a href="#">Yobi3D</a>                | ✓           | X           | X                              | ✓         | ✓      | ✓              | X                         |
| <a href="#">YouMagine</a>             | ✓           | X           | X                              | X         | X      | X              | X                         |



# 建議的3D物件的文件類型

## Suggested File Types of 3D objects



- STL file (suggested)
- SKP file (normally us “.gcode” file type)

# 3D影像/圖像掃描的主要方法



攝影測量 ( 通過圖像處理 )

Photogrammetry (by Image processing)



3D掃描儀 (通過物件深度測量) → 人面辨識效果

3D Scanner (by object depth measurement)



3D打印

3D Printing

# 攝影測量 ( 通過圖像處理 )

## Photogrammetry (by image processing)

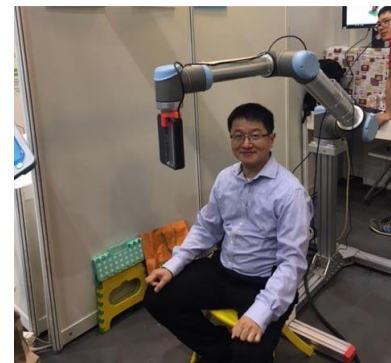
- 攝影測量軟件Photogrammetry Software e.g. Qlone, SCANN3D, Trnio  
(Qlone , SCANN3D的操作將在第二節介紹)



# 3D掃描儀 (通過對象深度測量)

## 3D Scanner (by object depth measurement)

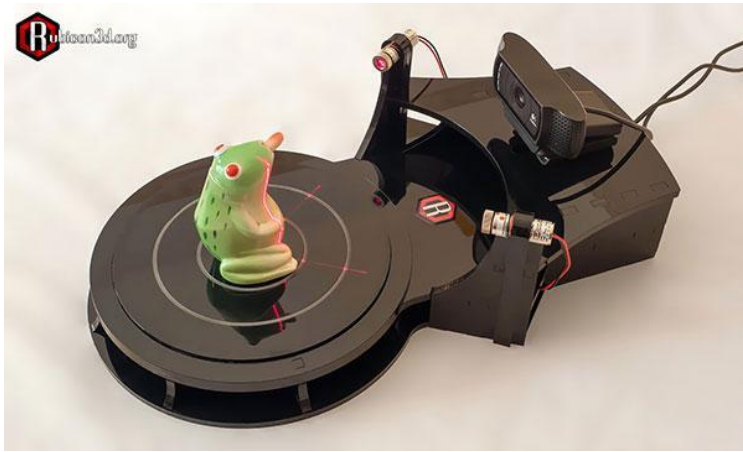
- 檢測物件的深度 ( 從掃描儀到物體的距離 ) Detect the depth of the object (distance from the scanner to the object)



# 圖像辨識的3D掃描儀

## Image-based 3D Scanner

- 360度旋轉轉台 Turn table rotate 360 degree
- 通過照片相機拍攝 Capture by photo camera



# 攝影測量 和 3D掃描儀 之分別

## Difference between Photogrammetry and 3D scanner

- <https://youtu.be/20jvnEtgRIU>

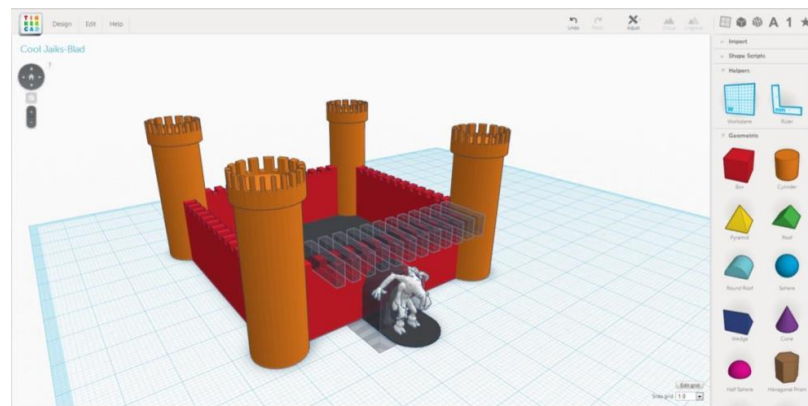
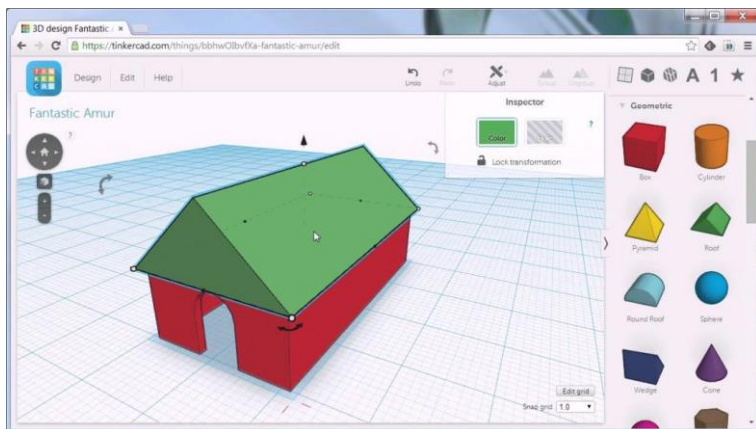




# D.介紹如何運用Tinkercad創建3D對象？

## Introduction of how to design 3D objects using Tinkercad

- Tinkercad
  - 官方網站: <https://www.tinkercad.com/>
  - 教學影片: <https://www.youtube.com/user/Tinkercad>





## Step 1: Open TinkerCAD Website

第一步：開啟TinkerCAD網站

URL:

<https://www.tinkercad.com>



建議瀏覽器Suggested Browser:  
Google Chrome





## Step 2: Create an account 第二步：創建TinkerCAD用戶

2.1 於右上角按「註冊」(Sign Up)

2.2 按指示輸入所需的資料，直至顯示「帳戶已建立」的信息。



### 建立帳戶

國家/地區

香港

生日

一月

1

2007

下一步

已擁有帳戶？[登入](#)



### 建立帳戶

電子郵件

XXXXXX@abc.com

密碼

|

- 至少需包含 1 個字母
- 至少需包含 1 個數字
- 最少需 8 個字元
- 至少要有 3 個唯一的字元

☒ 我同意 [Tinkercad 服務條款](#) 和 [Autodesk 隱私權聲明](#)。

建立帳戶

已擁有帳戶？[登入](#)

### 帳戶已建立

此單一帳戶可讓您存取您所有的 Autodesk 產品



☐ 我想要收到 Autodesk 的電子郵件通訊

完成

# Step 3: Dashboard

## 第三步：進入主頁

The screenshot shows the Tinkercad web interface. At the top, the Tinkercad logo is on the left, followed by the text "TINKERCAD FOR..." and navigation links for "圖庫" (Library), "COMMUNITY", "學習" (Learn), and "教授" (Teach). A search bar and a user profile icon are on the right.

The main content area is divided into a left sidebar and a central grid. The sidebar for user "Peter Chung" includes a profile picture, a search bar labeled "搜尋設計...", a "設計" (Design) button, and sections for "Circuits", "課程" (Courses), "專案" (Projects) with a "+ 建立專案" (Create Project) button, and "推文" (Tweets) with a "關注" (Follow) button. A tweet from Tinkercad (@tinkercad) is visible, mentioning #CASTEAM2017.

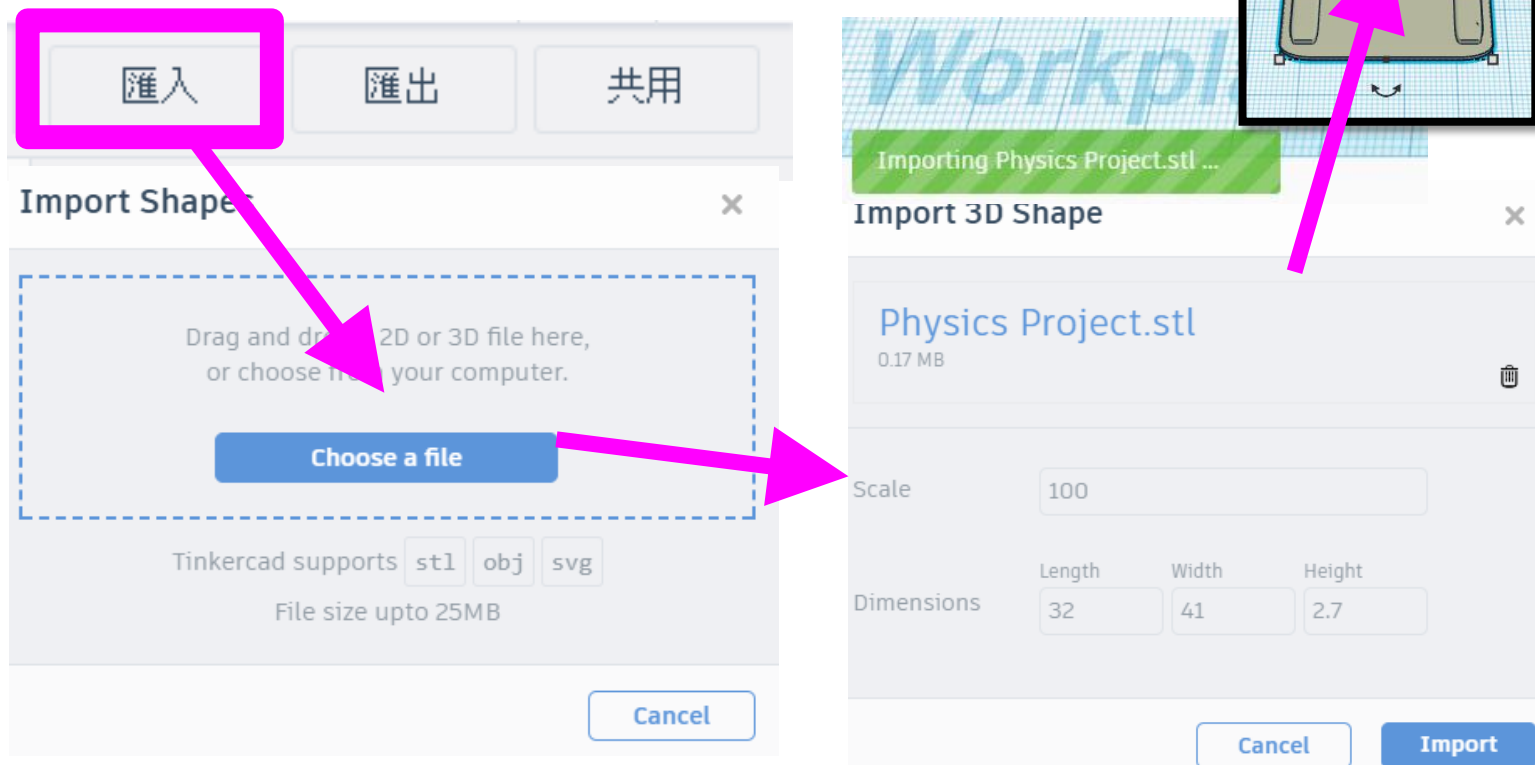
The central area is titled "我最近的設計" (My Recent Designs) and features a "建立新設計" (Create New Design) button. Below this, there are six design thumbnails arranged in two rows of three. Each thumbnail shows a 3D model of a circuit component and includes the title, time since creation (all "10 小時前"), and privacy status (all "私人" - Private).

- Row 1:
  - FINISHED\_MOTOR\_COIL
  - FINISHED\_MOTOR\_BASE
  - Copy of Simple dc motor...
  - Simple dc motor coil
- Row 2:
  - Copy of physics electric ...
  - Copy of Simple Electric ...

# 如何匯入已下載的3D物件作簡單改動

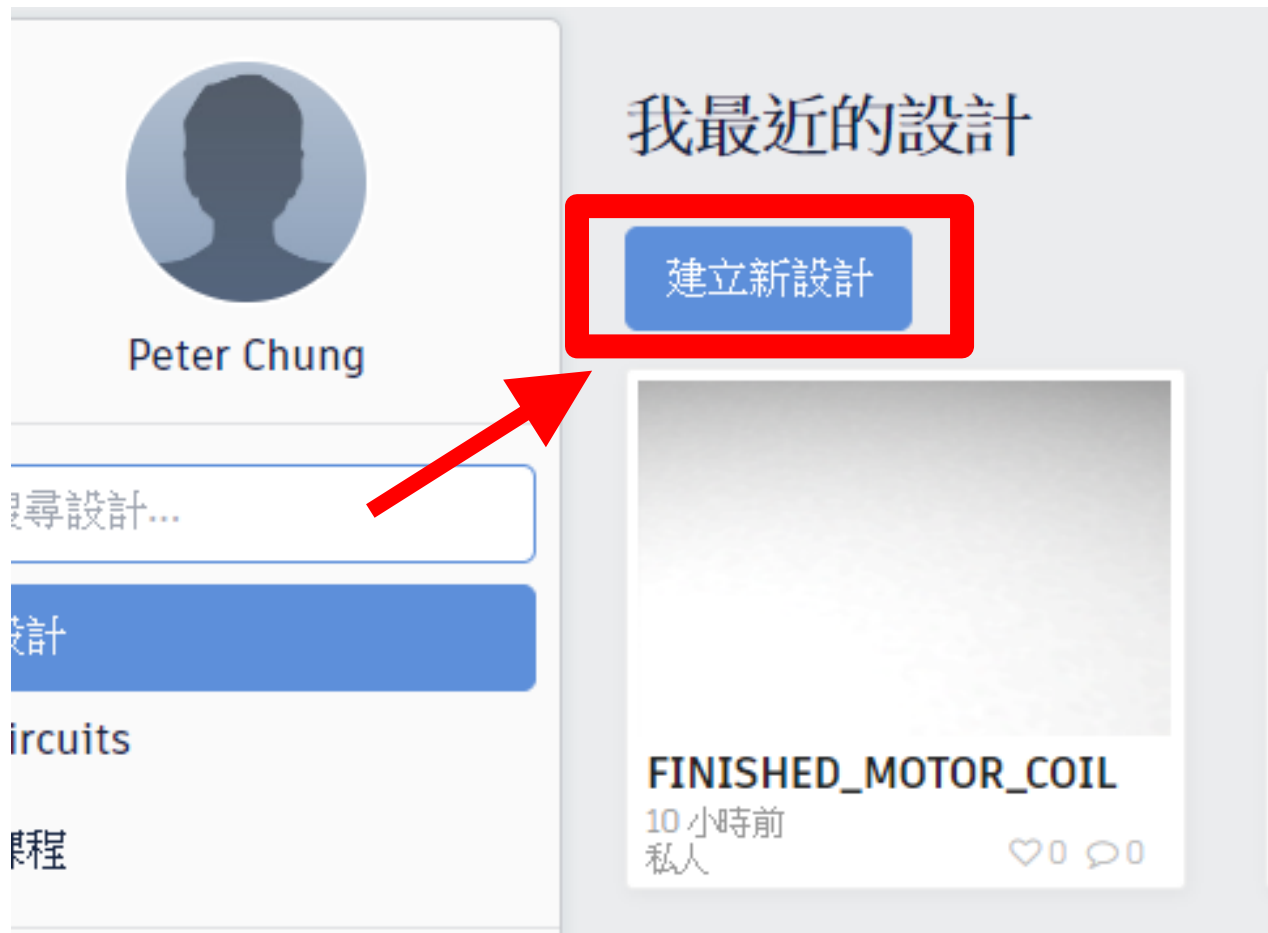
## Import the downloaded 3D Object for simple adjustment

Step 1: Download file from <https://www.thingiverse.com/> (or any other); Step 2: 匯入 Import; Step 3: Choose a file; Step 4: 匯入 Import



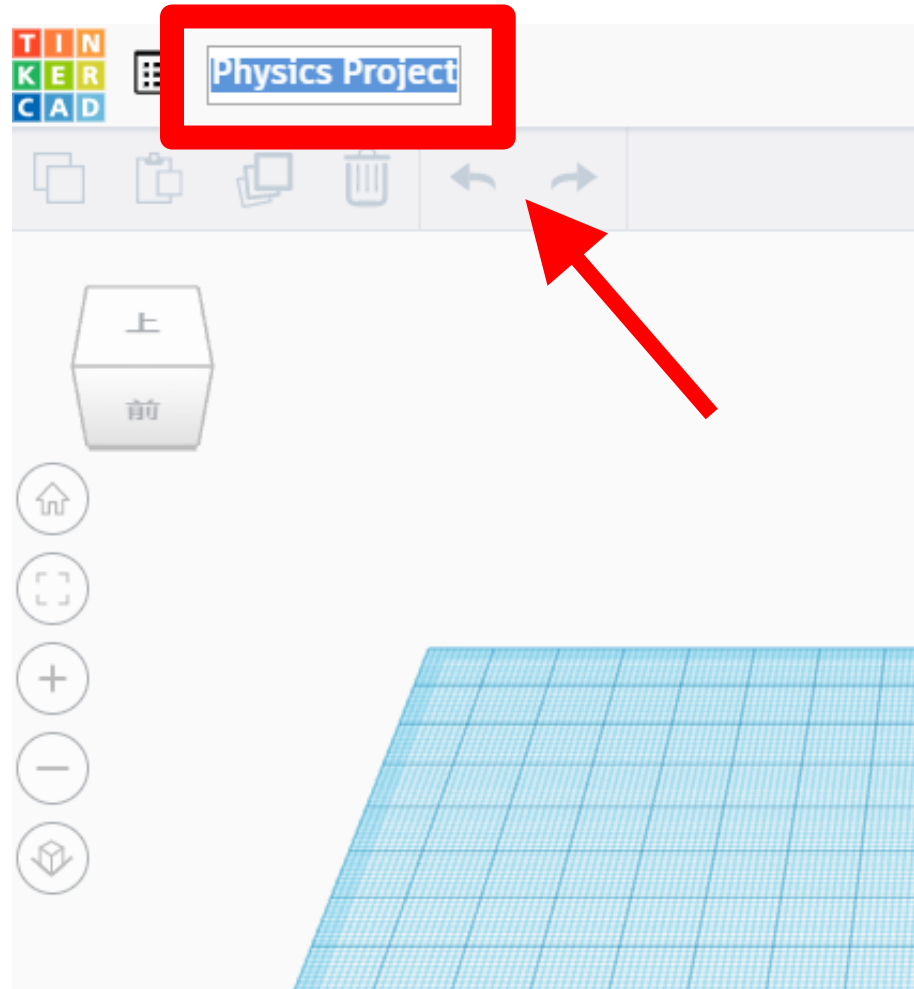
# Step 4: Create a design

## 第四步：建立新設計



# Step 5: Rename the design

## 第五步：重新命名設計名稱



# 滑鼠控制 Mouse Control

## 放大/縮小, 移動

**ZOOM in and out** — roll the roller

**MOVE THE WORKPLANE** up and down and side to side — hold down the roller and move the mouse.

**SELECT A SHAPE OR A FUNCTION**  
such as **Group** — left click.

**MOVE A SHAPE** or to **resize a shape** — hold down left side of the mouse and drag it.




























## 選取/移動



**ORBIT THE WORKPLANE** to rotate the screen to view your design from different angles — hold down right side of the mouse and move the mouse.

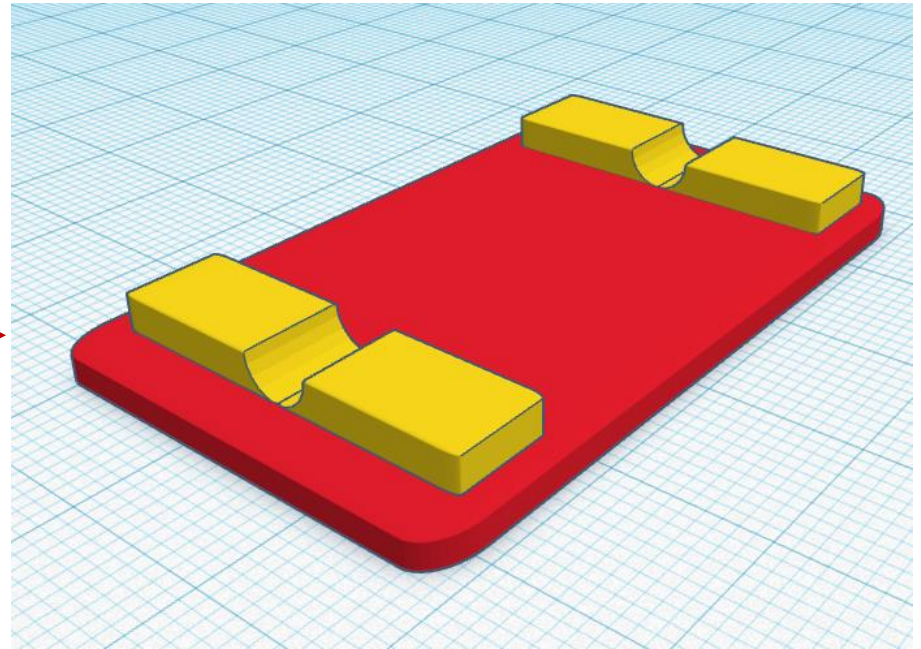
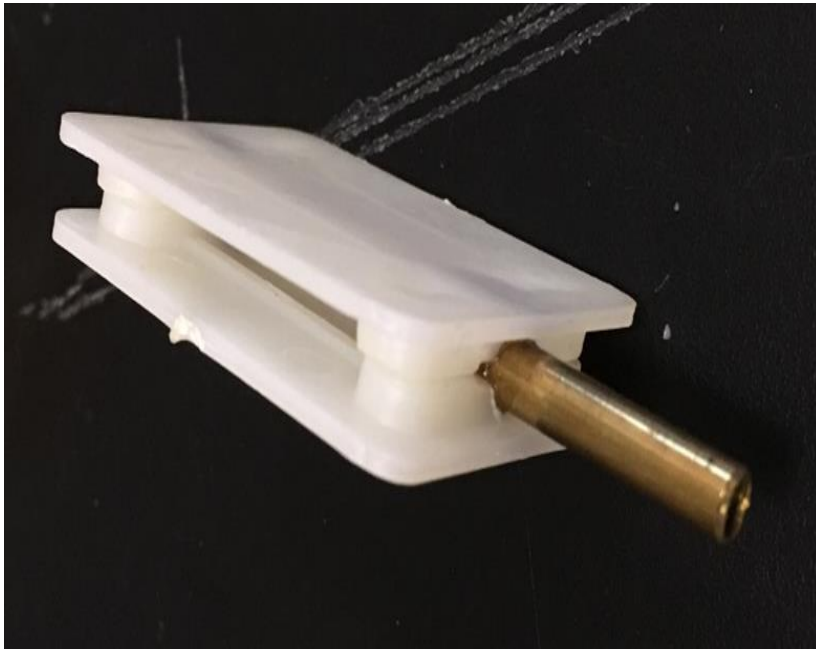
## 旋轉不同角度

# 鍵盤快捷鍵 Keyboard shortcuts

|  |  |  |  |
|--|--|--|--|
|    | <b>Copy:</b> ctrl/cmd + C<br>Press ctrl/cmd + C to copy selected object/objects                        |    | <b>Move on workplane:</b> all arrows<br>Nudge selection on workplane, x&y-axis   |
|    | <b>Paste:</b> ctrl/cmd + V<br>Press ctrl/cmd + V to paste object/objects                               |    | <b>Move up &amp; down:</b> ctrl/cmd + up&down arrows<br>Nudge selection up & down, z-axis  |
|    | <b>Undo:</b> ctrl/cmd + Z<br>Press ctrl/cmd + Z to undo  |    | <b>Move x10 on workplane:</b> shift + all arrows<br>Nudge selection 10 x snap on workplane, x&y-axis   |
|    | <b>Redo:</b> ctrl/cmd + shift + Z<br>Press ctrl/cmd + shift + Z to redo                                |    | <b>Move x10 up &amp; down:</b> ctrl/cmd + shift + up&down arrows<br>Nudge selection 10 x snap up & down, z-axis  |
|    | <b>Group:</b> ctrl/cmd + G<br>Press ctrl/cmd + G to group objects                                      |    | <b>Moving straight on workplane:</b> shift + move<br>Hold shift while moving to constrain movement to main direction                                     |
|    | <b>Ungroup:</b> ctrl/cmd + shift + G<br>Press ctrl/cmd + shift + G to ungroup objects                  |    | <b>Duplicate:</b> alt + move<br>Hold alt while starting to move to duplicate selection   |
|    | <b>Duplicate in place:</b> ctrl/cmd + D<br>Press ctrl/cmd + D to duplicate selection in the same place |    | <b>45°-step rotation:</b> shift + rotate<br>Hold shift while rotating to constrain rotation to 45 degree steps   |
|    | <b>Lock:</b> ctrl/cmd + L<br>Press ctrl/cmd + L to lock selection                                      |    | <b>1D scale</b> (scaling from center of the object): alt + side scale<br>Hold alt while scaling to scale proportionally on one direction                 |
|    | <b>Select all:</b> ctrl/cmd + A<br>Press ctrl/cmd + A to select all objects                            |    | <b>2D scale</b> (scaling from bottom center of the object): alt + c.scale<br>Hold alt while scaling to scale proportionally on all directions            |
|   | <b>Delete:</b> backspace<br>Press backspace to delete object   |   | <b>3D scale</b> (scaling from opposite corner): shift + corner scale<br>Hold shift while scaling to scale proportionally on all directions               |
|  | <b>Workplane:</b> W<br>Press W to place workplane  |  | <b>3D scale</b> (scaling from bottom center of the object): shift + alt<br>Hold shift + alt while scaling to scale proportionally on all directions      |
|  | <b>Ruler:</b> R<br>Press R to place ruler  |  | <b>3D scale</b> (scaling from center of the object): shift + alt + top scale<br>Hold shift + alt while scaling to scale proportionally on all directions |
|  | <b>Fit view to selection:</b> F<br>Press F to fit the view on selected object                          |  | <b>Pan view:</b> shift + right mouse button<br>Hold shift + right mouse button to view panoramic   |
|  |  |  | <b>Multi selection:</b> shift + left mouse button<br>Hold shift + left mouse button to select multiple objects   |



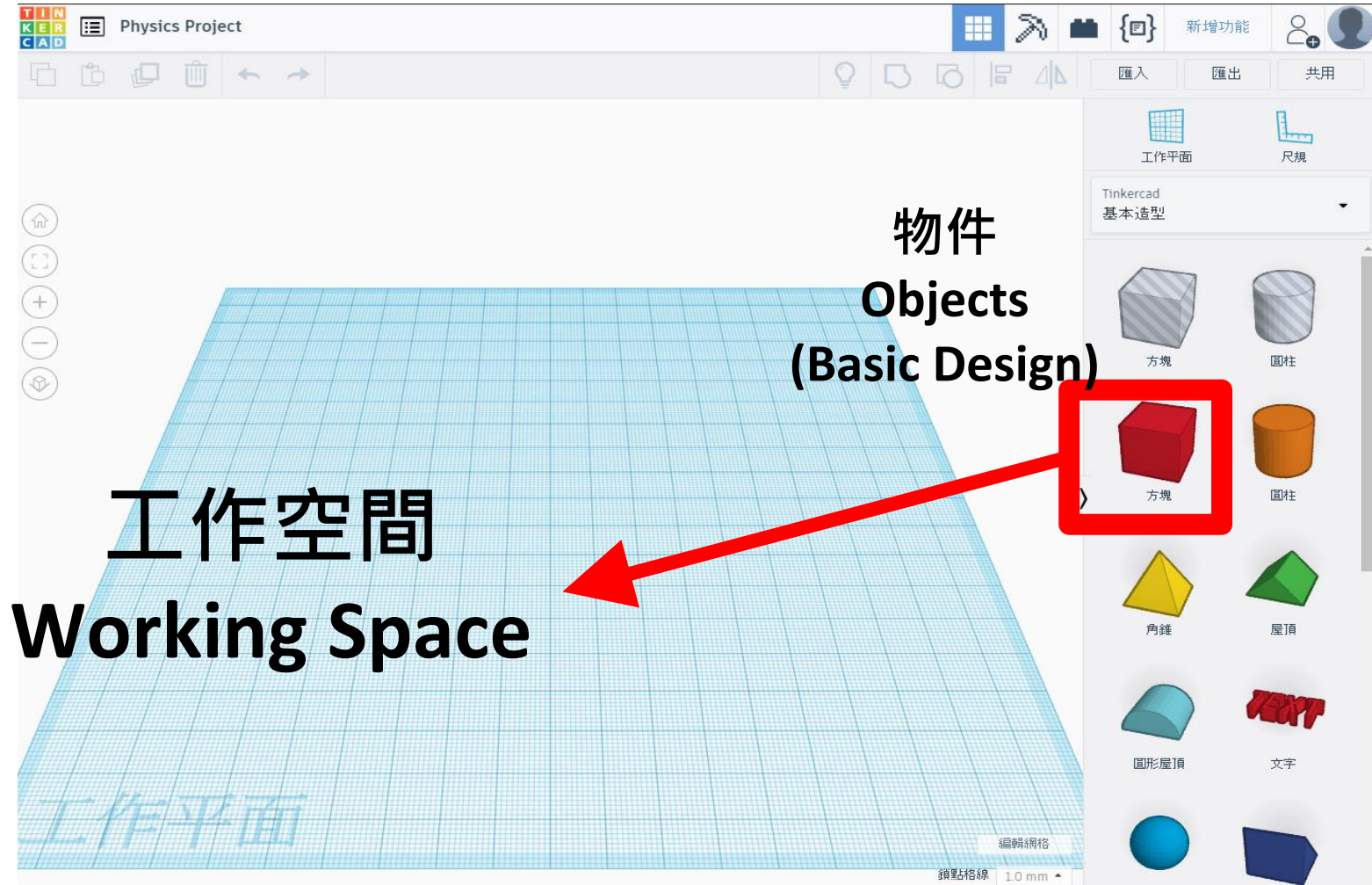
# 項目1：創建一個簡單的直流電機線圈 Project 1: Create a simple DC motor coil





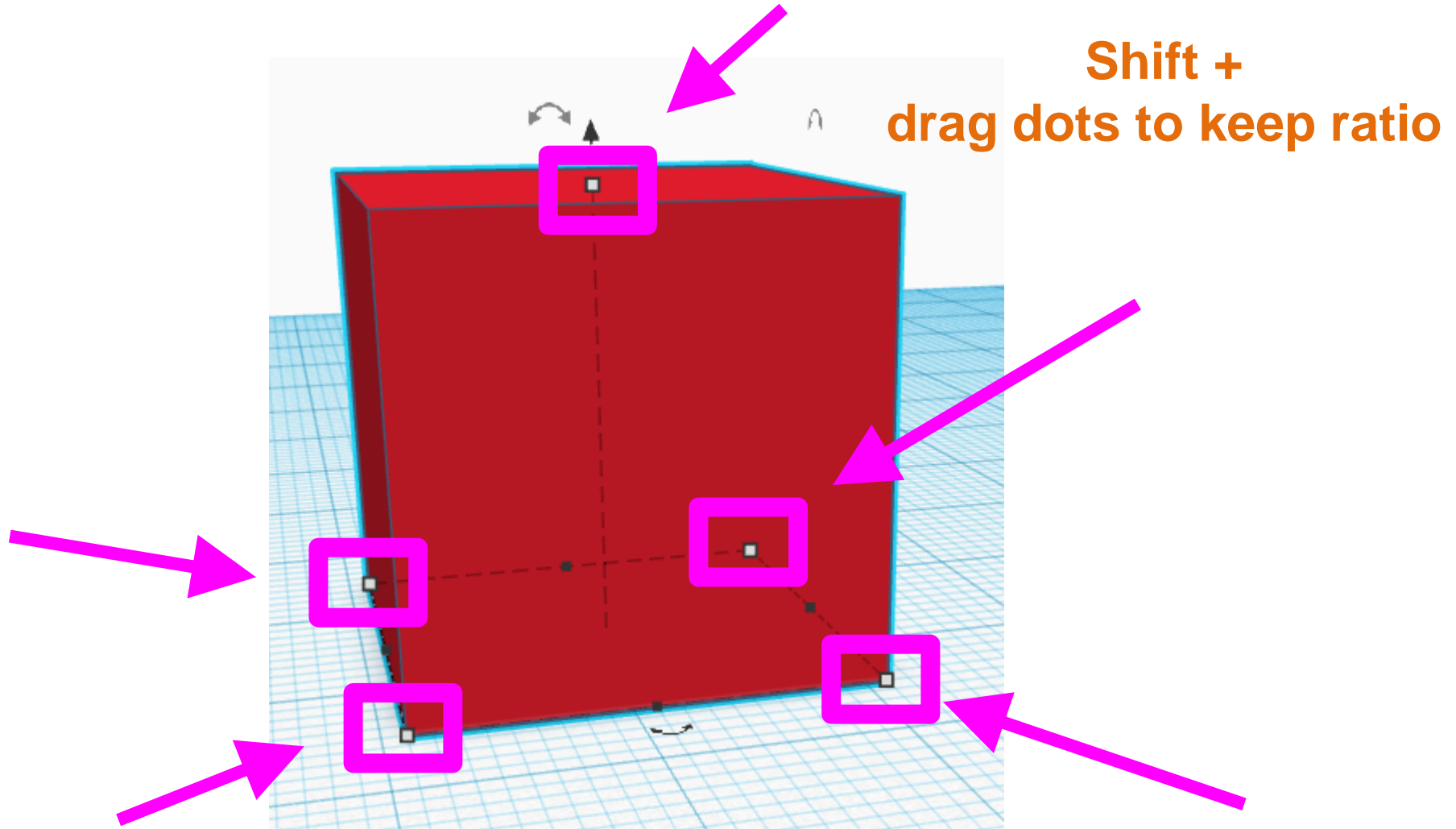
Step 6: Drag suitable objects from the right bar to the working space

第六步：從右方物件庫拉動適合的物件至工作空間。



# Step 7.1: Resize / Scale (by dragging dots)

## 第七(1)步：利用可拉動的點 調整大小/比例

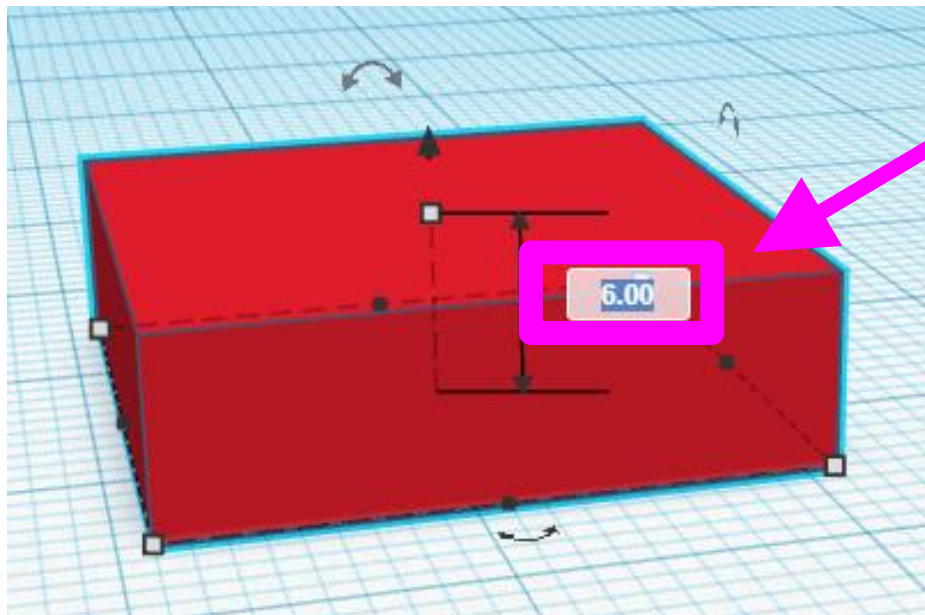


## Step 7.2: Resize / Scale (by Precise)

第七(2)步：透過輸入精確的數值 調整指定大小/比例

Note: Units Setting

注意: 單位設定

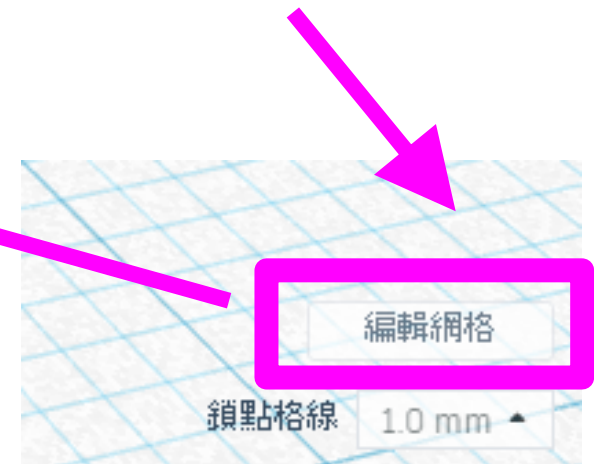


# Step 8: Setting of the grid

## 第八步：單位設定

8.1 按右下角的「編輯網絡」

8.2 改變單位值至 (毫米 mm) (按需求而定)

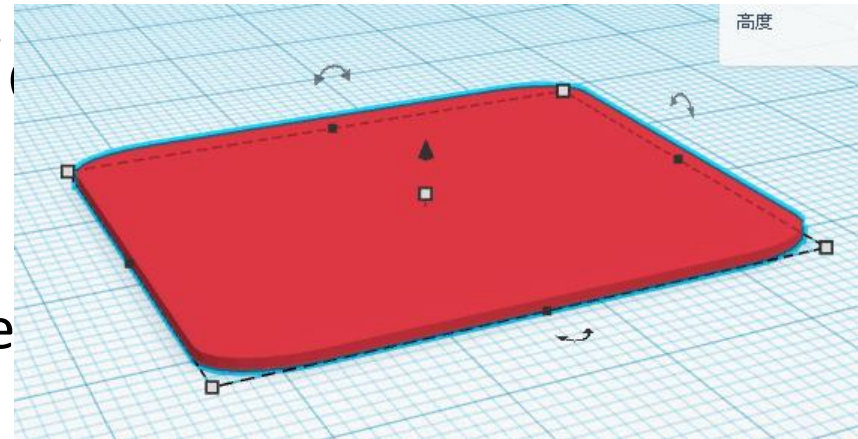


# Step 9: Shape (Property)

## 第九步：造型設定

9.1 點擊矩形 Click on the rectangle

9.2 Set Radius (半徑) on  
the 設置面板 setting panel (as right)



### 參考尺寸：Reference dimensions:

半徑 Radius of rounded corners = 3 ;

步驟 Steps = 6 ;

長度 Length = 31.12 ;

寬度 Width = 20 ; and

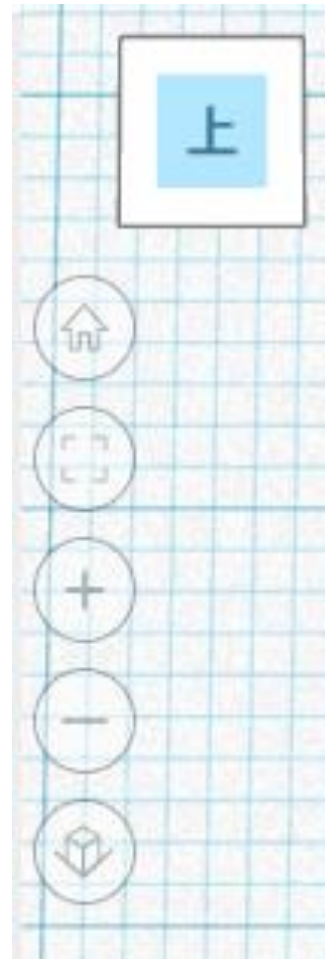
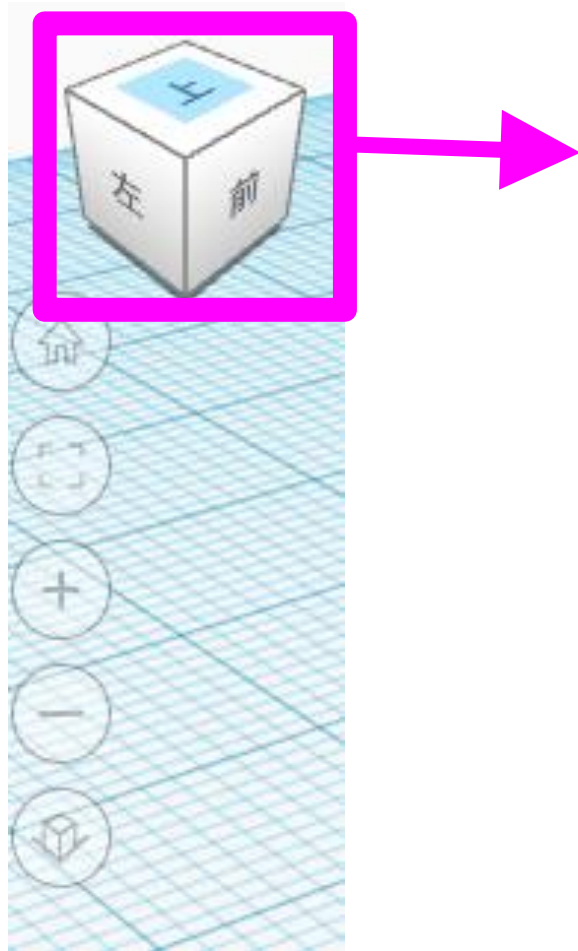
高度 Height = 20 ;



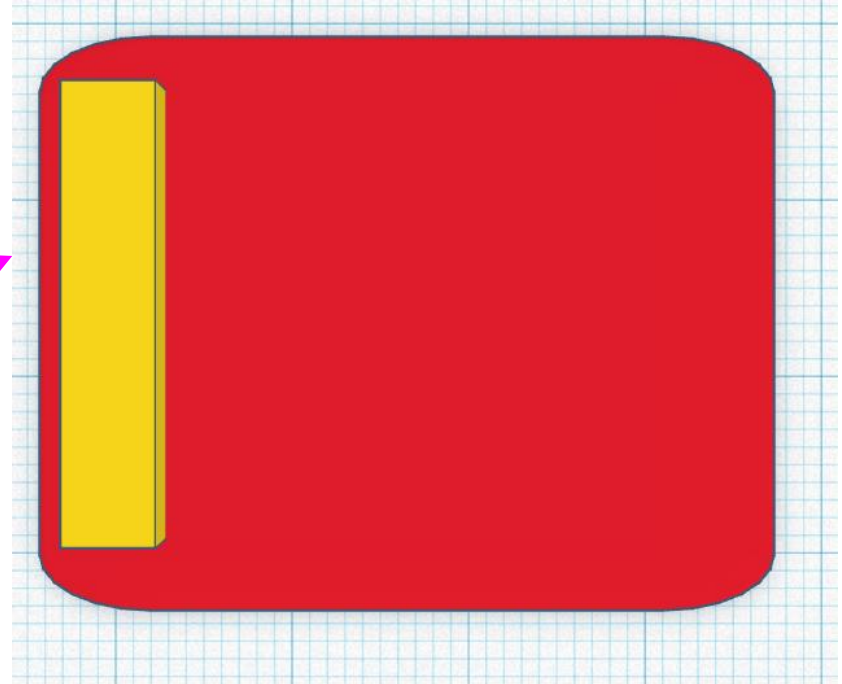
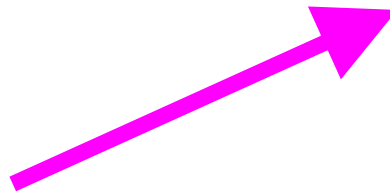
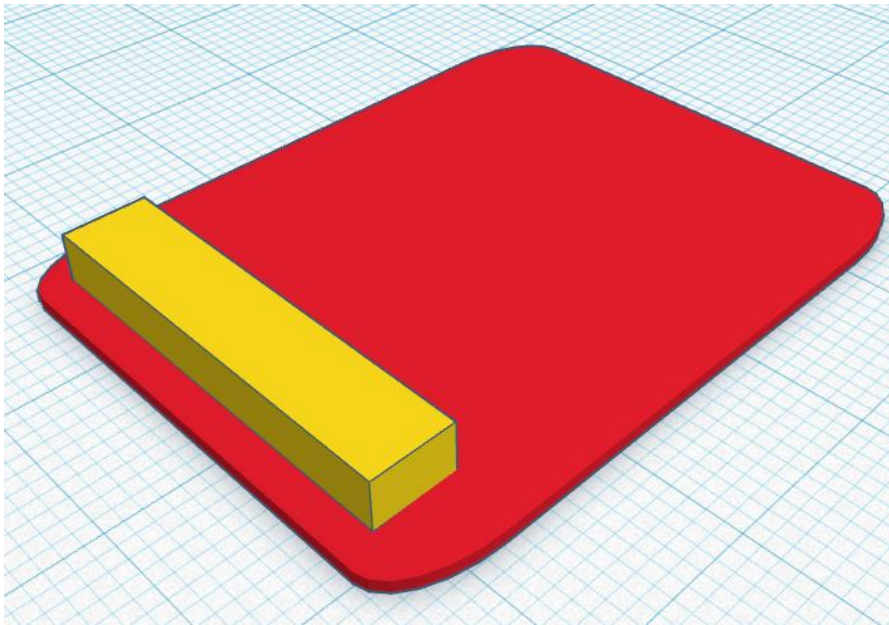


# Camera controls (View)

## 利用視圖功能檢視物件方位



# Top view 上方



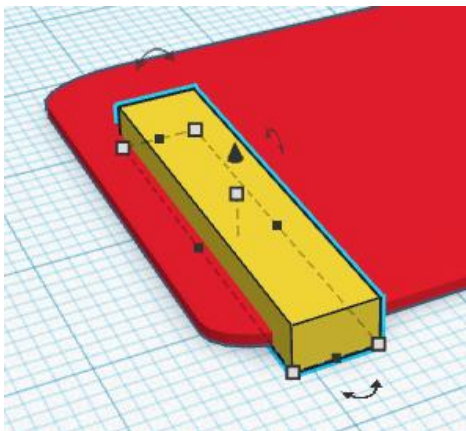
# Step 10: Set a colour

## 第十步：顏色設定

10.1 創建一個矩形作為第二個物件 Create a rectangular as the second object

10.2 設置尺寸 Set Dimension: 25mm x 5mm x 3mm

10.3 將顏色設置為黃色 Set colour to yellow (or any)





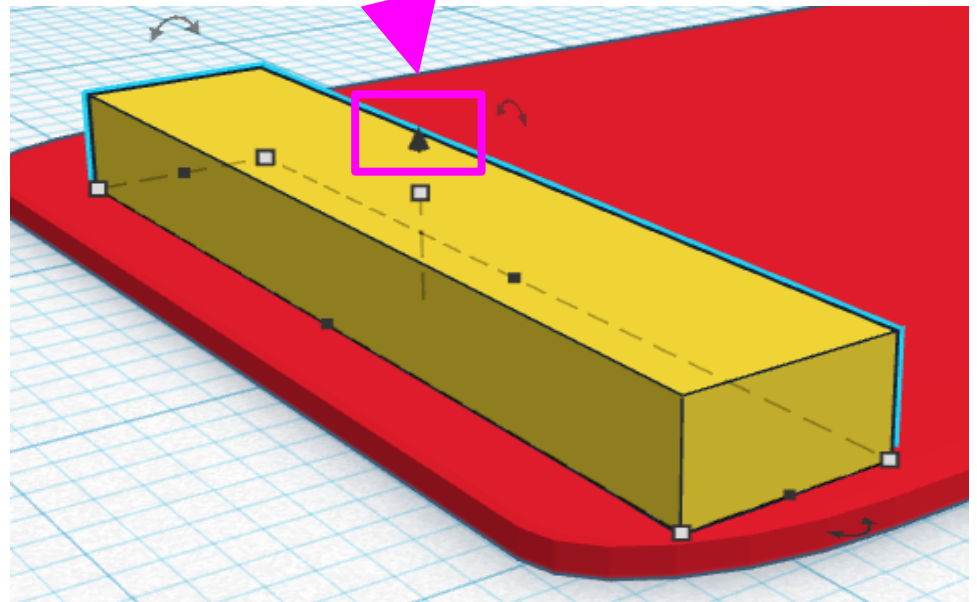
# Step 11: Move (Position) vertically

## 第十一步：移動物件上下位置

11.1 Select the Arrow 選擇箭嘴

11.2 Upward/ Downward 向上/下拖動

11.3 Select to move (left click) 選擇移動 ( 左鍵單擊 )



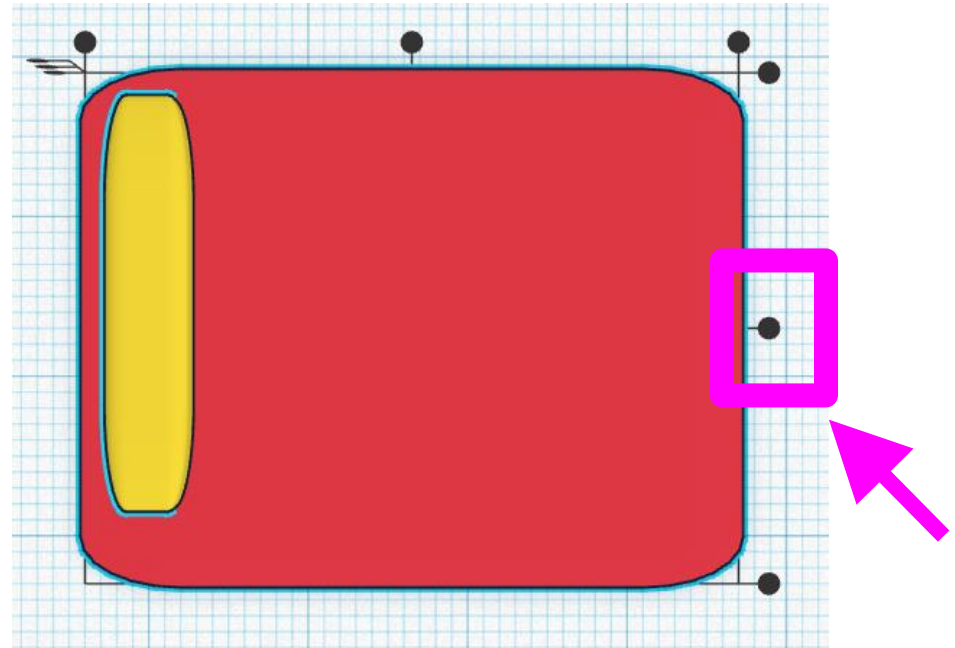
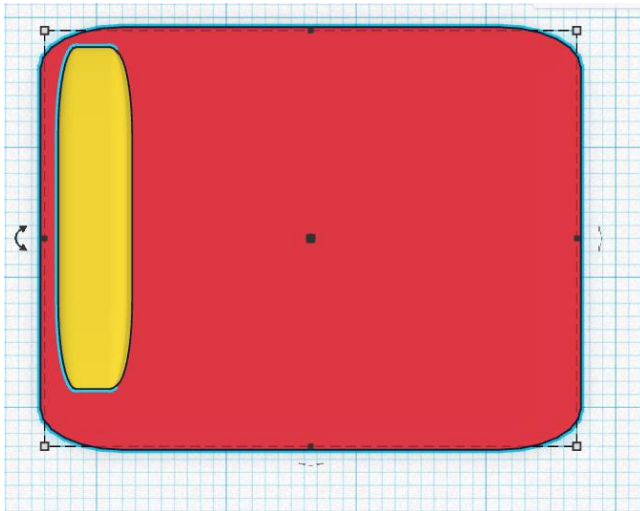
# Step 12: Alignment

## 第十二步：對齊功能



12.1 選擇現成需要對齊的物件

12.3 按 “對齊”

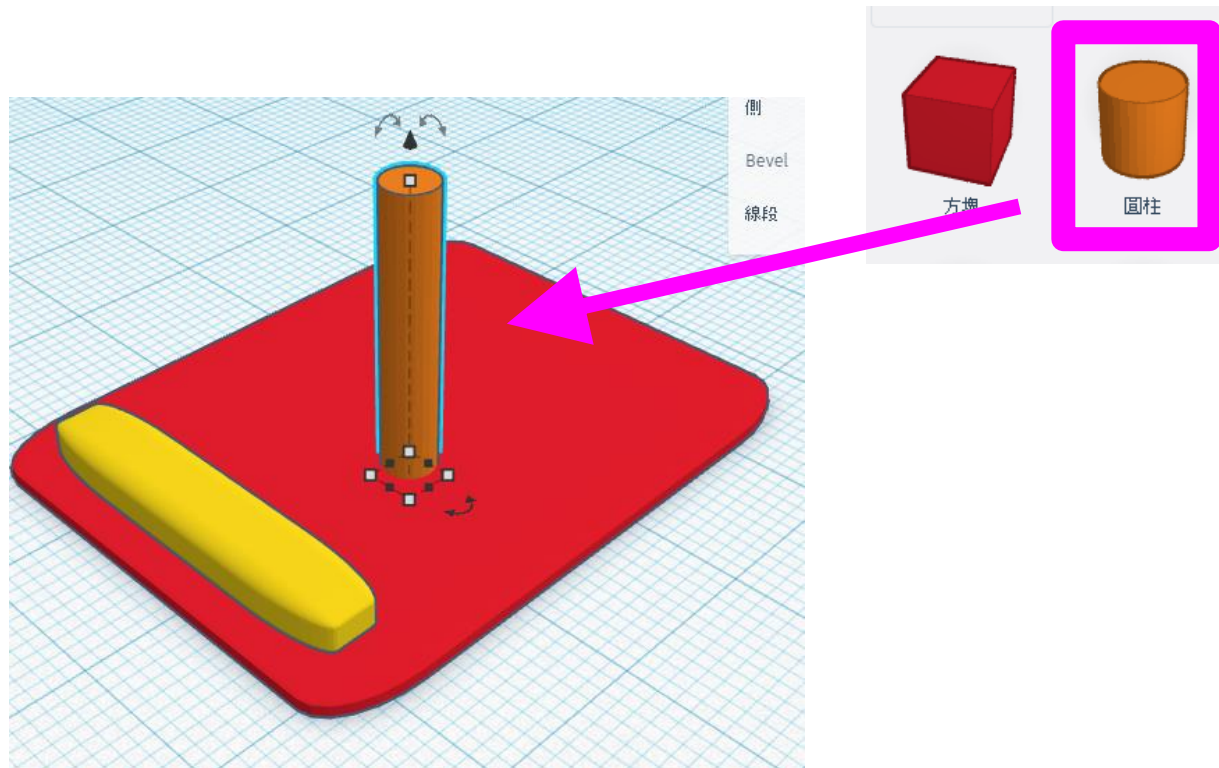


# Step 13: Diameter Setting

## 第十三步：設定圓柱直徑

13.1 Create a Cylinder創建一個圓柱體

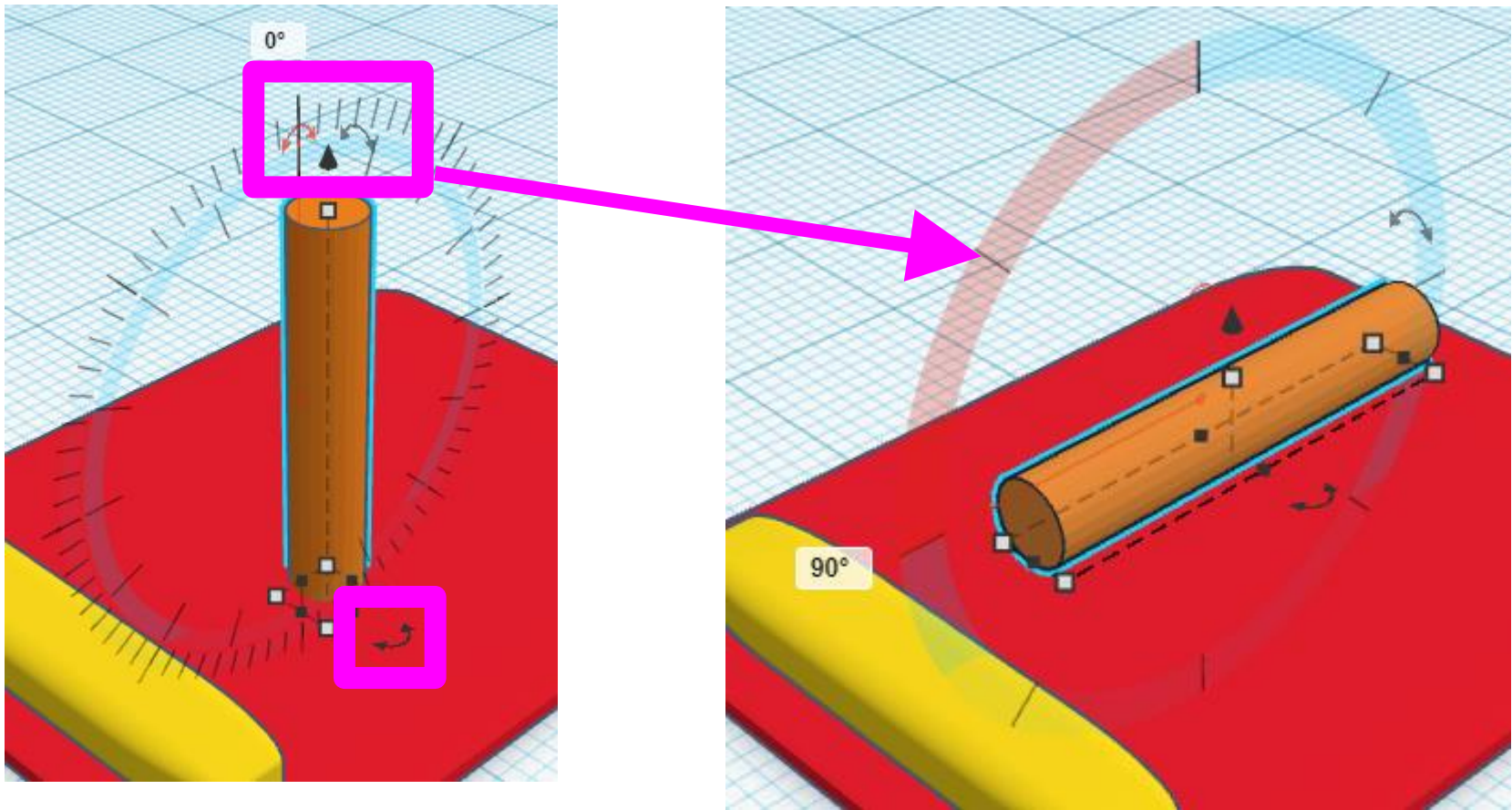
13.2 Set Diameter as 3.5 mm設置直徑為3.5毫米



# Step 14: Rotation

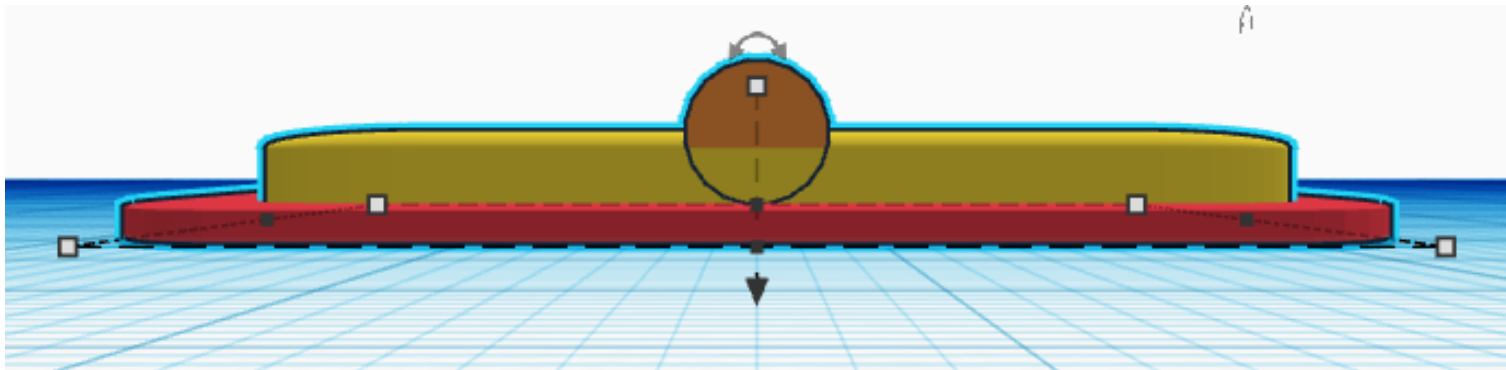
## 第十四步：旋轉

旋轉Rotation on **x-plane** / **y-plane** / **z-plane**



# 練習Practice

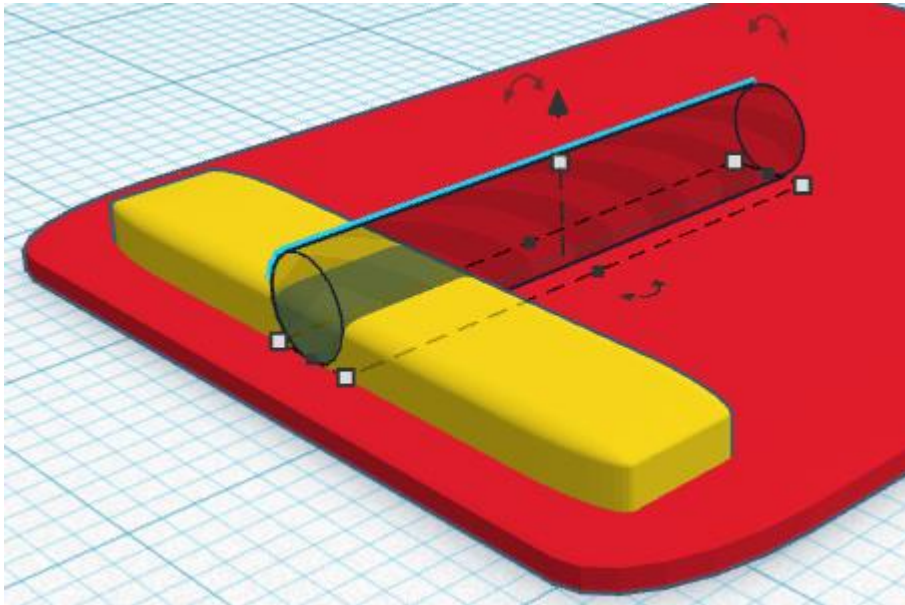
移動Move / 旋轉Rotation / 調整大小  
Resize / 對齊Alignment





# Step 15: Solid / Hole

## 第十五步：實體 和 孔



# Step 16: Grouping (Merge)

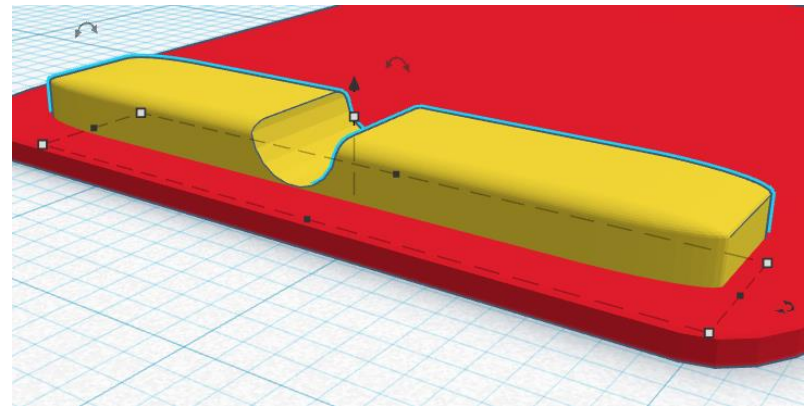
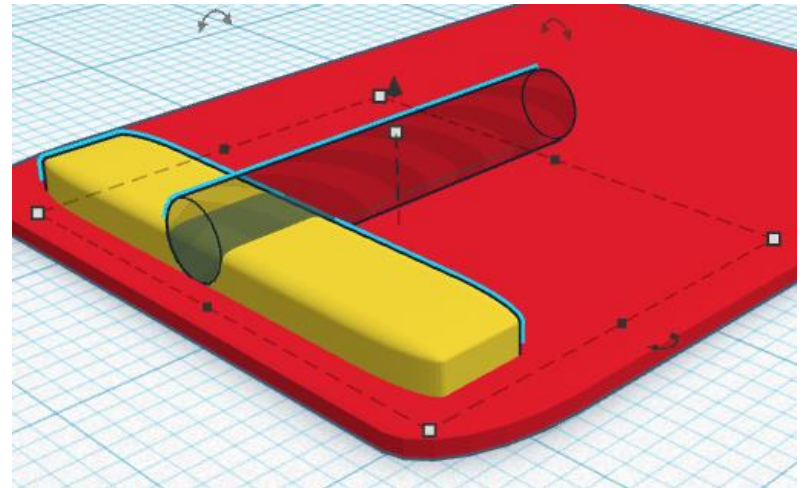
## 第十六步：群組

### 16.1 選擇需要組成群組的物件

Select the objects  
needed to be grouped

### 16.2 選擇「組成群組」

Click Group

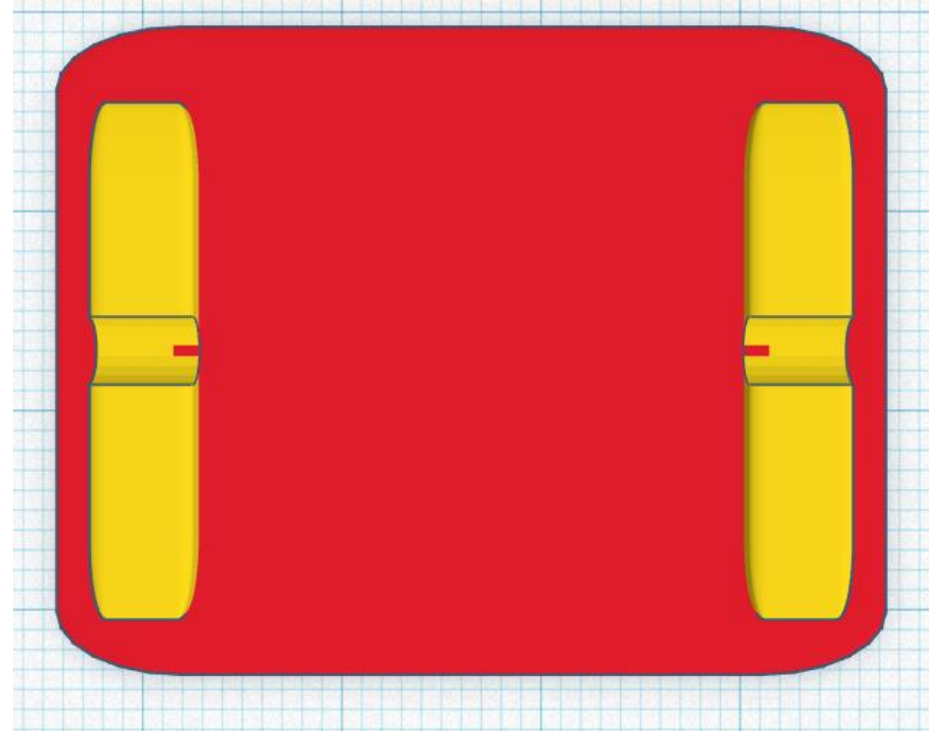
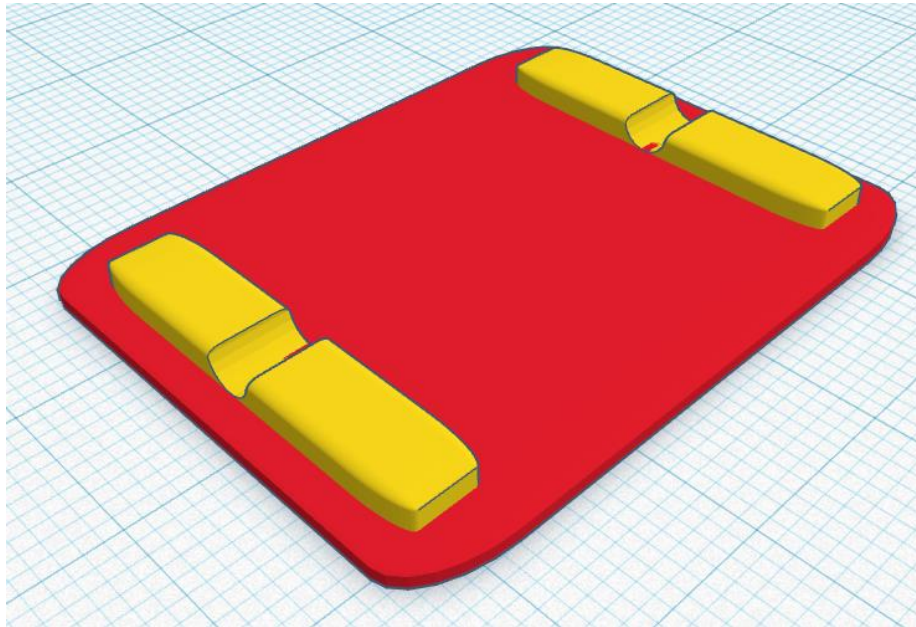


# Step 17: Copy & Paste

## 第十七步：複製 和 貼上

17.1 Select → 17.2 Copy (Ctrl+C) → 17.3 Paste (Ctrl+V)

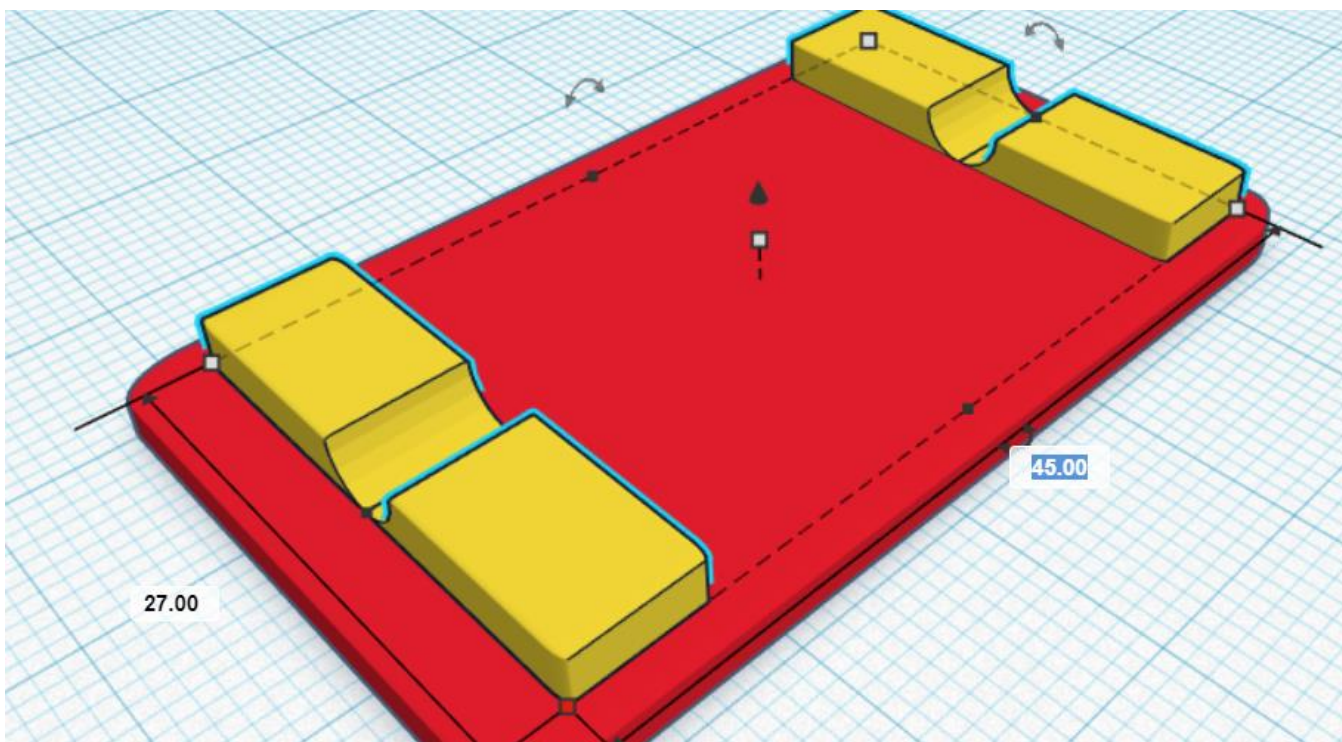
\*利用複製功能以減低設計的差異和實驗誤差。



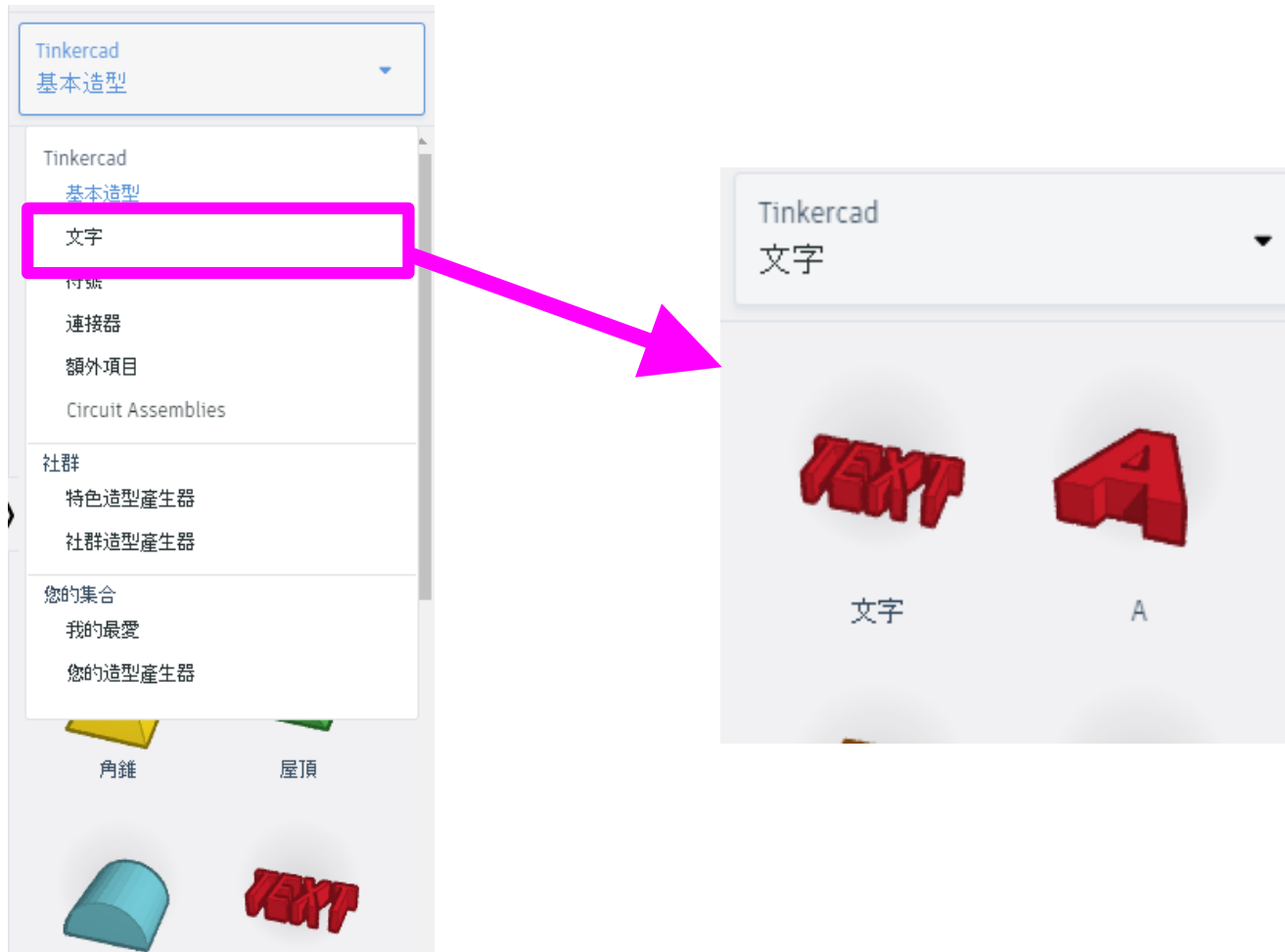


## 網格設定的概念

- 選擇2個物件Select 2 objects → 相對距離  
relative distance



# 加入文字 Input Text



## 加入文字 Input Text (Cont' d)



# Step 18: Export

## 第十八步：匯出

### 18.1 匯出 Export



### 18.2 Choose **stl** file type



### 18.3 儲存於合適位置

| 名稱  | 類型    | 大小     |
|---|-------|--------|
|  Physics Project.stl | 3D 物件 | 172 KB |

# Step 19: Share

## 第十九步：分享

共用此設計

Snapshot of your design



共用

Thingiverse

MyMiniFactory

Share over IM or email

Create with others by sharing a link to your design. People with the link may view and make changes to your design.

Invite people

Leaving Tinkercad

Your design is on its way to Thingiverse

You will be leaving Tinkercad to an external site when you click "Continue".

Continue to Thingiverse

Cancel and return to Tinkercad

Collaborate

透過 IM 或電子郵件共用此連結

具有此連結的人員可以檢視及變更你的設計

[https://www.tinkercad.com/things/gkpXYIqzh3C,](https://www.tinkercad.com/things/gkpXYIqzh3C)

複製

已建立新連結。

此連結的有效時間為 336 個小時

產生新連結



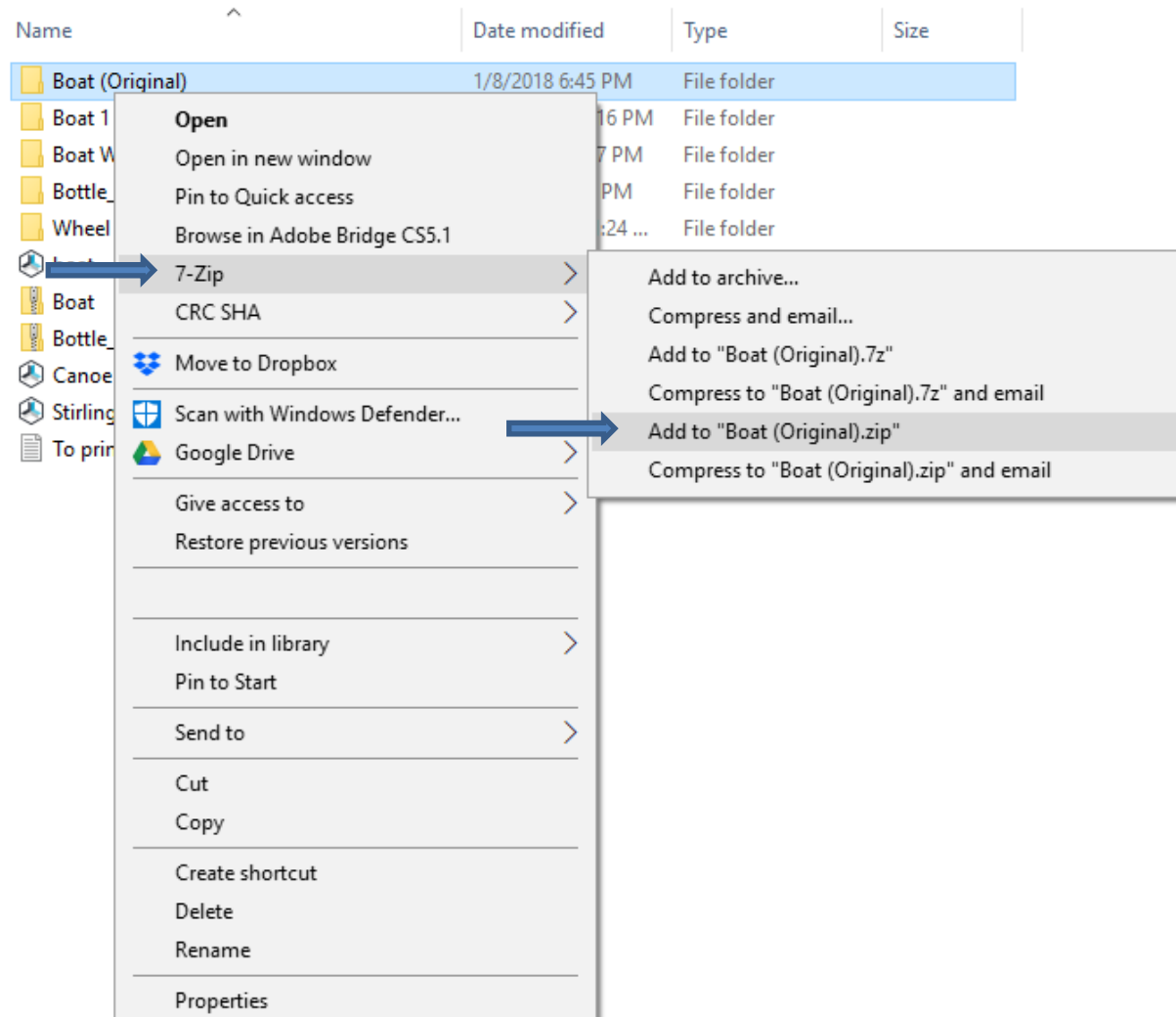
# 提交Tinkercad 設計作品STL file

1. 利用「匯出」功能下載 STL 格式的file
2. 儲存於桌面
3. 傳送至壓縮檔案 Zip File/ 7-zip
4. 傳送你的Zip file 至 [eltraining@eee.hku.hk](mailto:eltraining@eee.hku.hk)

注意命名名稱: (iClass username\_EngFullName)  
(e.g. 3dprint0101\_Chan Tai Man)

- a. 電郵標題: (iClass username\_EngFullName)  
(e.g. 3dprint0101\_Chan Tai Man)
- b. 附加壓縮檔案

# 壓縮檔案方法



# 15分鐘休息環節 Break (15 mins)

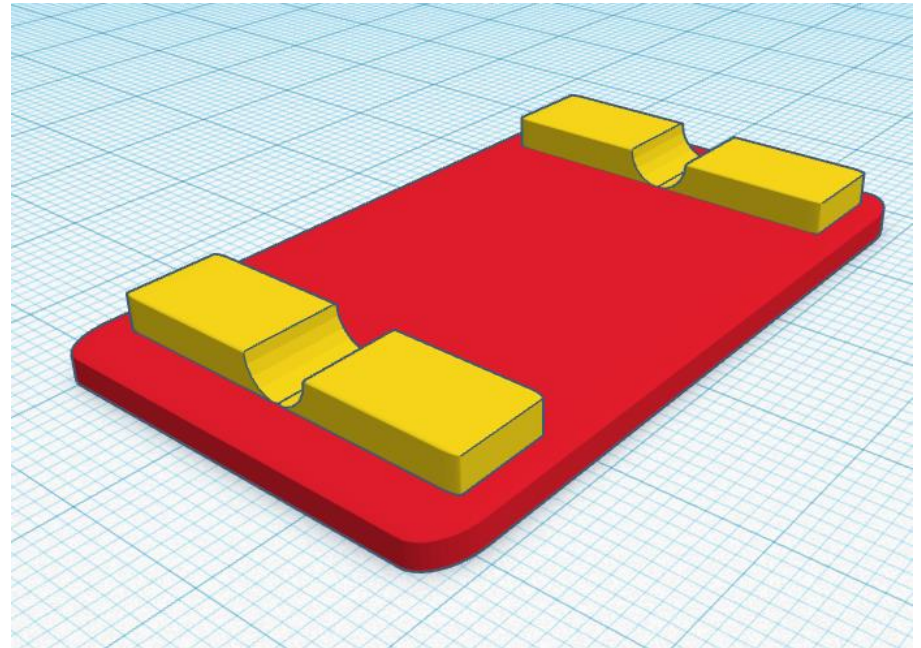
You can still try to do the practice 1!





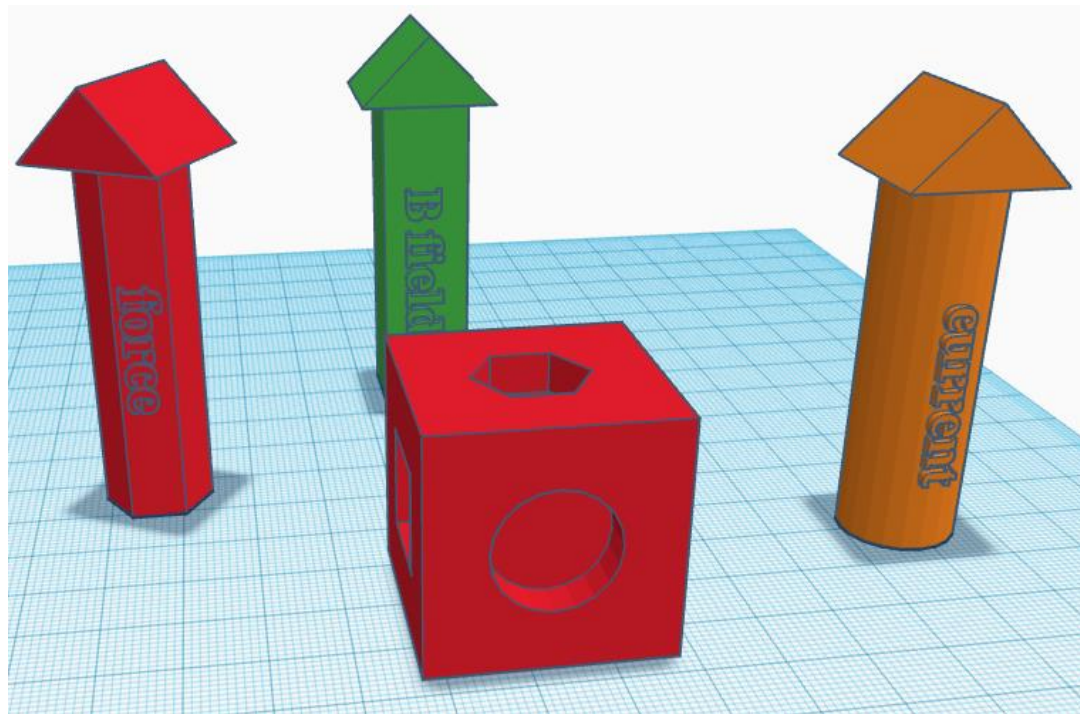
# 重溫 Revision

1. Move 移動
2. Rotation 迴轉
3. Resize 調整大小
4. Alignment 對準
5. Group 群組
6. Hole 孔
7. Export 匯出



# 項目2：設計一個教學工具包

## Project 2: Design a teaching kit (FBI)





# 小組討論作業環節 – 有效運用3D打印機和資訊科技工具 促進物理科的學與教

1. 按你任教科目分2-3人一組
2. 請就作業題目討論適合「運用3D打印機和資訊科技工具促進物理科的學與教」的課題
3. 利用iClass 開放式題目(Open-end) 活動提交你們的討論所得的想法

## 其他科目:

如你是任教其他科目，你可就你的科目設計3D 打印的教學活動，以促進該科的學與教

# 例子介紹

- 相關網站
- 水火箭
- Electric motor
- Brushless motor

# 小組討論- 課題分享 環節

## 個人作業提交(透過iClass LMS)

### 小組討論- 課題分享

#### 開放式題目

討論並分享任何能「運用**3D**打印機和資訊科技工具促進物理科的學與教」的課題。你亦可透過網上搜尋現有的相關教學資源。



分享內容可包括:

1. 可運用上述技術的課題和學習範疇
2. 適用的級別
3. 可行的教學活動
4. 網上現有的相關教學資源

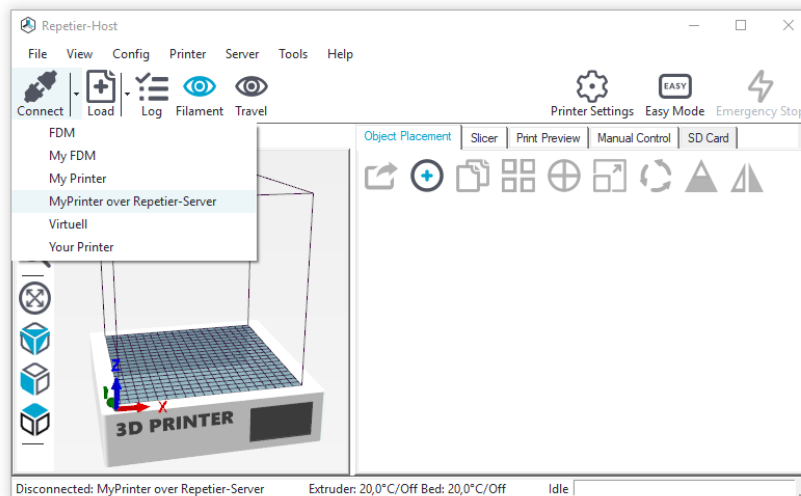
# Repetier-Host

軟件用法：將3D物件剪切成片 Software usage: To cut the 3D object into slides

打印程序 Procedure for printing

Step 1: 在網上下載 Download Repetier-Host on web  
(available in the PC of the training venue)

– <https://www.repetier.com/download-now/>



# Step 2: 打印機設置Printer Settings

Printer Settings

Printer: default

Connection Printer Extruder Printer Shape Scripts Advanced

Firmware Type: Autodetect

Travel Feed Rate: 4800 [mm/min]

Z-Axis Feed Rate: 100 [mm/min]

Manual Extrusion Speed: 2 20 [mm/s]

Manual Retraction Speed: 30 [mm/s]

Default Extruder Temperature: 200 °C

Default Heated Bed Temperature: 55 °C

☒ Check Extruder & Bed Temperature

☐ Remove temperature requests from Log

Check every 3 seconds.

Park Position: X: 0 Y: 0 Z min: 0 [mm]

☒ Send ETA to printer display

☐ Go to Park Position after Job/Kill

☒ Disable Extruder after Job/Kill

☒ Disable Heated Bed after Job/Kill

☒ Disable Motors after Job/Kill

☐ Printer has SD card

Add to comp. Printing Time 8 [%]

Invert Direction in Controls for ☐ X-Axis ☐ Y-Axis ☐ Z-Axis ☐ Flip X and Y

OK Apply Cancel

Printer Settings

Printer: default

Connection Printer Extruder Printer Shape Scripts Advanced

Printer Type: Classic Printer

Home X: 0 Home Y: 0 Home Z: 0

X Min: 0 X Max: 100 Bed Left: 0

Y Min: 0 Y Max: 100 Bed Front: 0

Print Area Width: 100 mm

Print Area Depth: 100 mm

Print Area Height: 100 mm

The min and max values define the possible range of extruder coordinates. These coordinates can be negative and outside the print bed. Bed left/front define the coordinates where the printbed itself starts. By changing the min/max values you can even move the origin in the center of the print bed, if supported by firmware.

Y Max

D

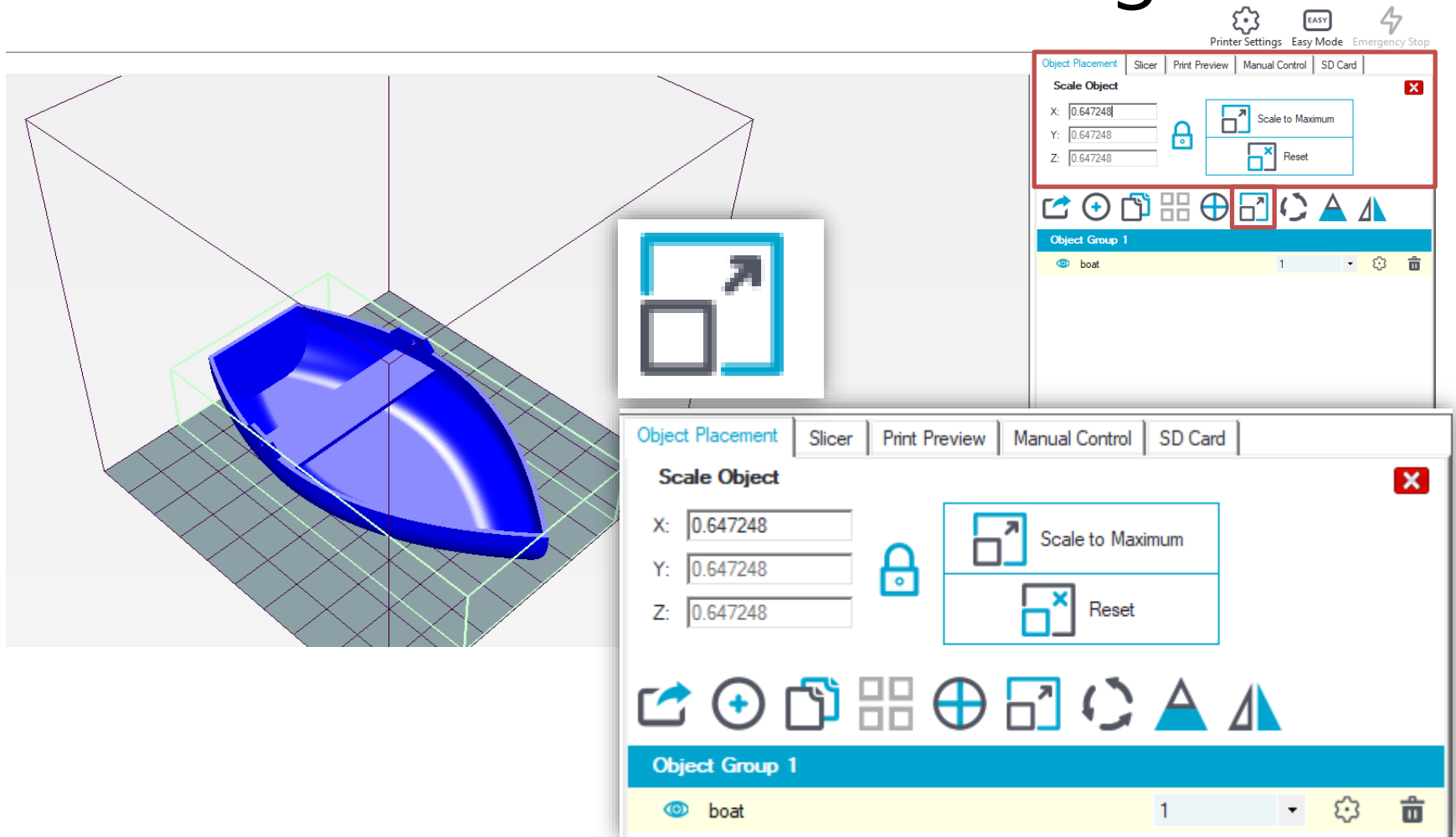
E

C

OK Apply Cancel

# Step 3: 比例Scaling

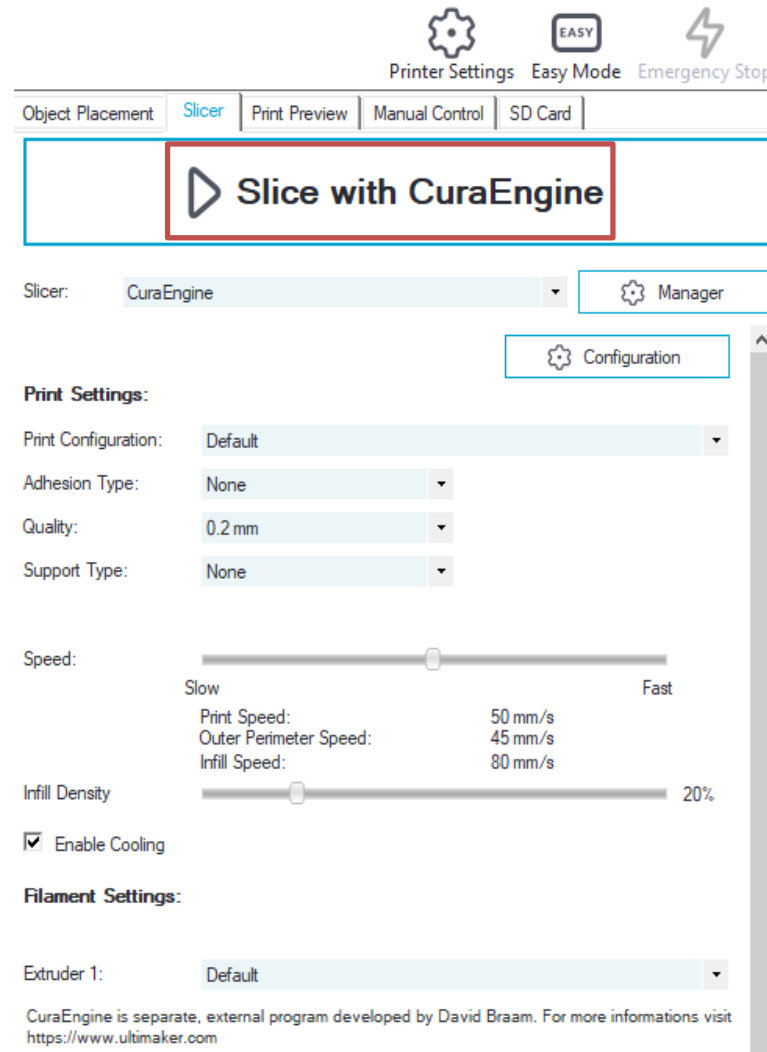
## 檢查比例 Check Scaling





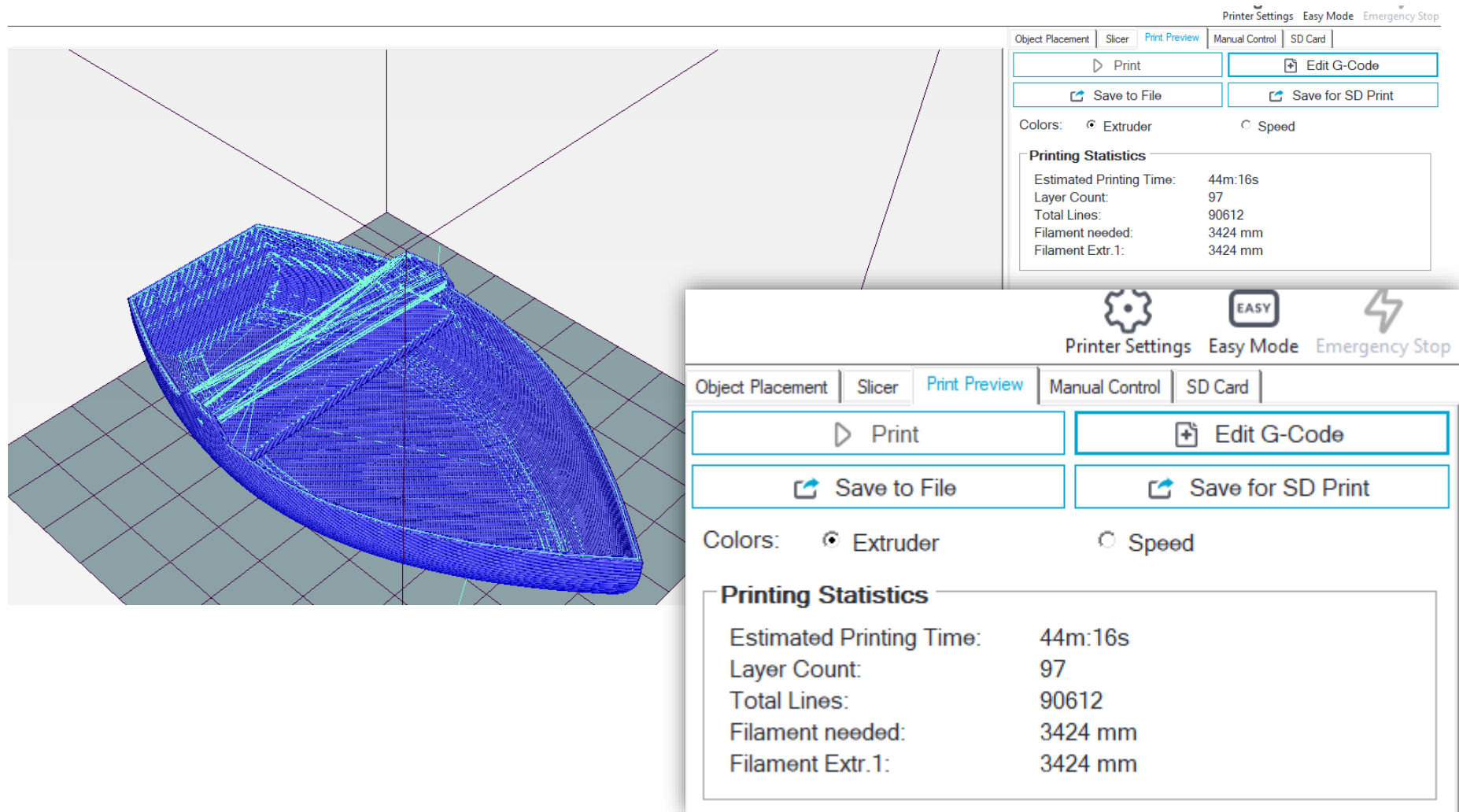
# Step 4: 切片機Slicer

Click “Slice with CuraEngine” under tab “Slicer”



# Step 5: 匯出 Export G-code file

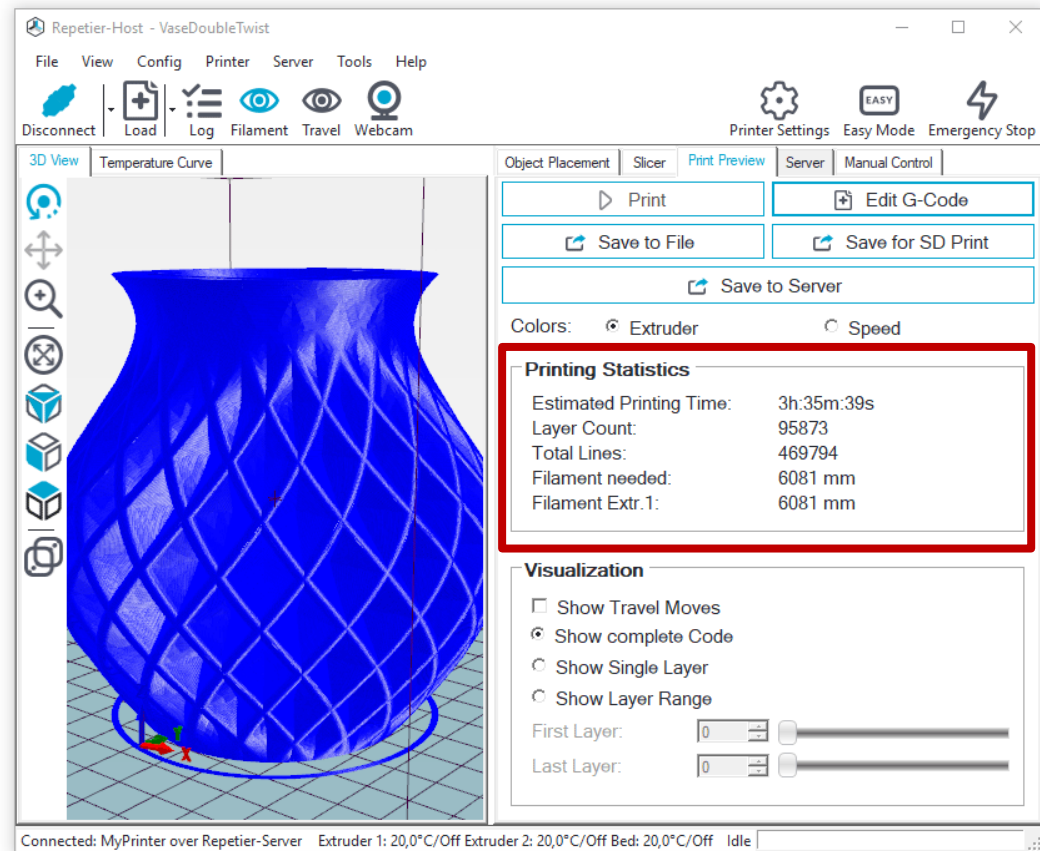
## Click "Save to File"



# Step 6: 檢查打印統計數據

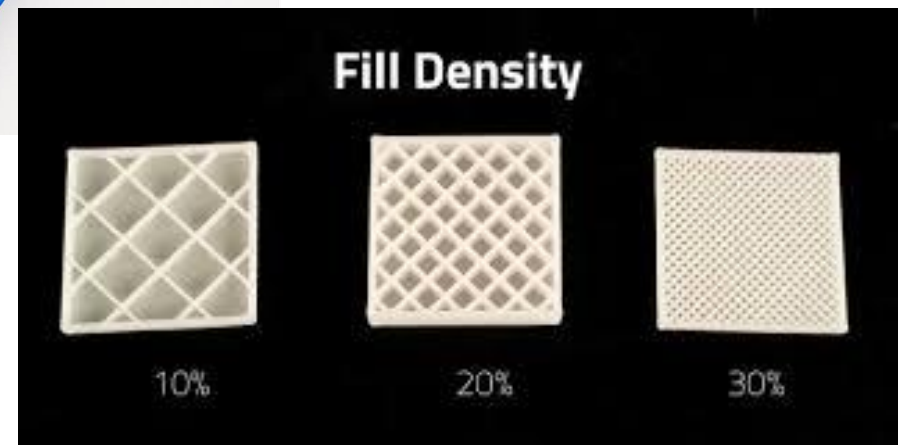
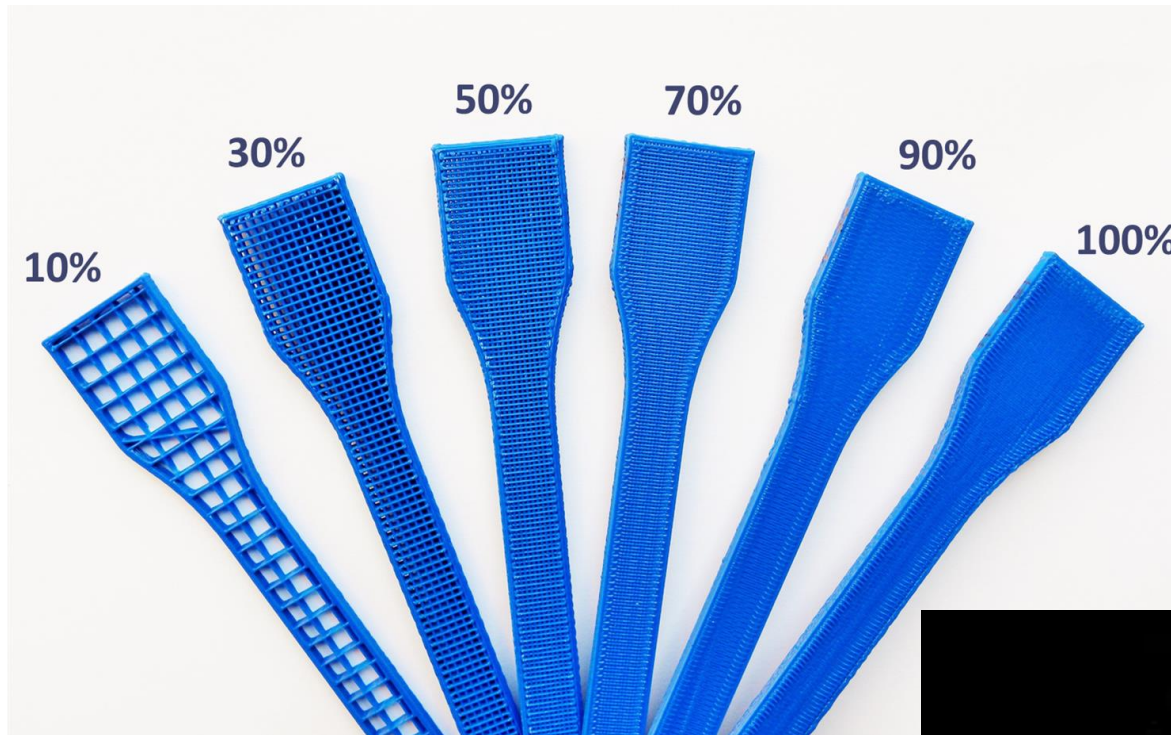
## Check the print statistics

- 檢查打印所需的時間和材料
- 確保有足夠的材料
- 保存文件和SD卡



# Step 7: 儲存 store in SD Card

# 填充圖層 Infill Layer



# 認識填充百分比、層高和填充圖案的影響

## Influence of infill %, layer height and infill pattern

| Strength                |      | Infill % |    |    |    |    |    |     |
|-------------------------|------|----------|----|----|----|----|----|-----|
| [MPa]                   |      | 10       | 30 | 50 | 70 | 80 | 90 | 100 |
| Layer<br>Height<br>[mm] | 0.1  | 8        | 12 | 17 | 25 | 29 | 33 | 39  |
|                         | 0.15 | 9        | 14 | 20 | 28 | 33 | 38 | 44  |
|                         | 0.2  | 10       | 15 | 21 | 30 | 35 | 40 | 46  |
|                         | 0.25 | 10       | 15 | 22 | 31 | 37 | 42 | 49  |
|                         | 0.3  | 10       | 15 | 22 | 31 | 36 | 42 | 48  |

| Speed                   |      | Infill % |    |    |    |    |    |     |
|-------------------------|------|----------|----|----|----|----|----|-----|
| [mins]                  |      | 10       | 30 | 50 | 70 | 80 | 90 | 100 |
| Layer<br>Height<br>[mm] | 0.1  | 21       | 35 | 47 | 61 | 68 | 74 | 80  |
|                         | 0.15 | 14       | 23 | 32 | 41 | 46 | 50 | 54  |
|                         | 0.2  | 10       | 18 | 24 | 31 | 35 | 38 | 41  |
|                         | 0.25 | 8        | 14 | 20 | 25 | 28 | 31 | 33  |
|                         | 0.3  | 7        | 12 | 16 | 21 | 24 | 26 | 28  |

| Cost                    |      | Infill % |    |    |    |    |    |     |
|-------------------------|------|----------|----|----|----|----|----|-----|
| [cents]                 |      | 10       | 30 | 50 | 70 | 80 | 90 | 100 |
| Layer<br>Height<br>[mm] | 0.1  | 6        | 9  | 13 | 17 | 18 | 21 | 22  |
|                         | 0.15 | 6        | 10 | 14 | 18 | 19 | 21 | 23  |
|                         | 0.2  | 6        | 10 | 14 | 18 | 20 | 22 | 23  |
|                         | 0.25 | 6        | 10 | 14 | 18 | 20 | 22 | 23  |
|                         | 0.3  | 6        | 10 | 14 | 18 | 20 | 22 | 23  |

| Quality                 |      | Infill %  |    |    |    |    |    |     |
|-------------------------|------|-----------|----|----|----|----|----|-----|
|                         |      | 10        | 30 | 50 | 70 | 80 | 90 | 100 |
| Layer<br>Height<br>[mm] | 0.1  | very high |    |    |    |    |    | low |
|                         | 0.15 | high      |    |    |    |    |    |     |
|                         | 0.2  | medium    |    |    |    |    |    |     |
|                         | 0.25 | low       |    |    |    |    |    |     |
|                         | 0.3  | very low  |    |    |    |    |    |     |

BEST    WORST

**Infill increases → cost/quality/printing time/strength increases**

## E. 如何設置3D打印機How to set the 3D Printer

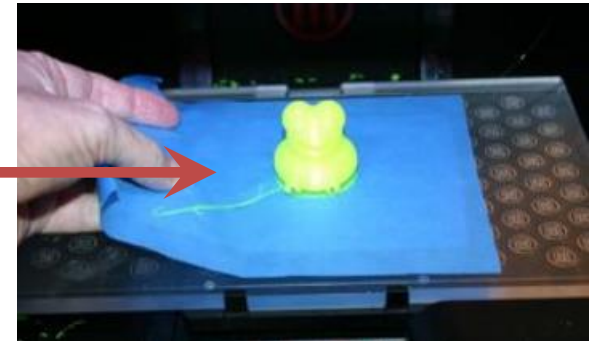
- 打印機設置Printer Setting
  - 隨打印機包提供的規格specifications provided with the package of printer
- 預熱打印機Pre-heat the printer



# 打印示範

## Demonstration of printing

- Step 1: 在打印台上粘上膠帶Stick a sticky tape on the print table



- Step 2: 插入Insert the SD Card
- Step 3: 選擇Select “Print from SD Card” from the menu

SD Card





# 打印3D物件的一些提示和常見錯誤

## Some tips and common pitfalls for printing 3D objects

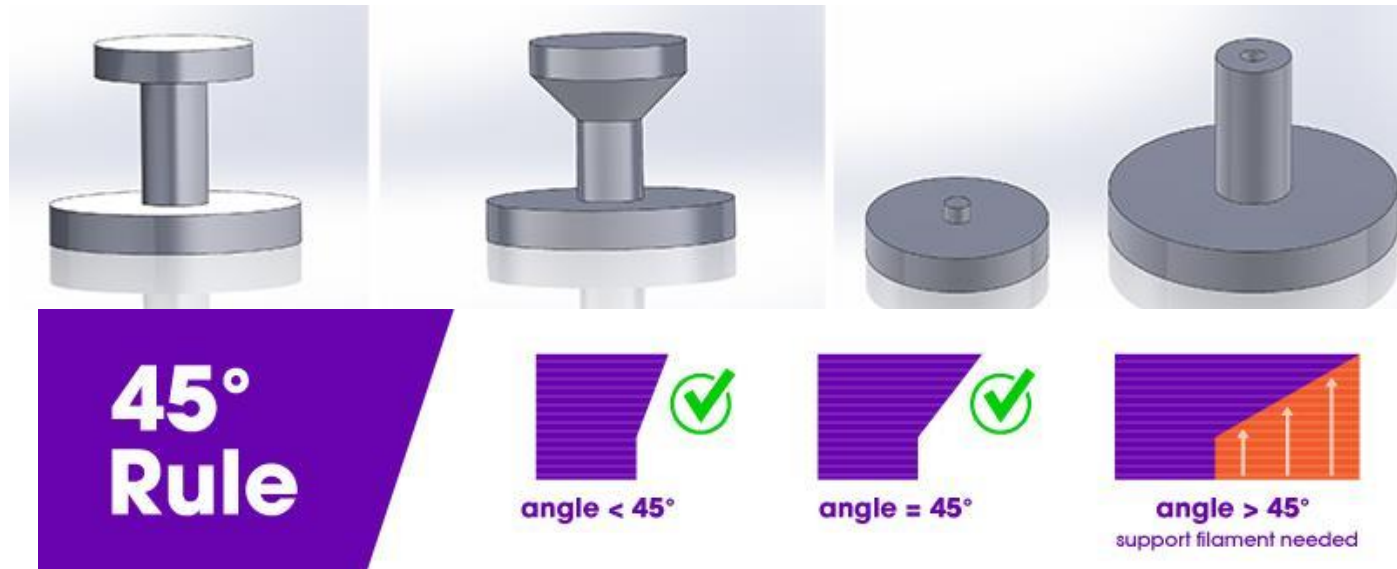
- **系數調較:**
  - 橫向擴展Horizontal expansion
  - 填充密度Infill Density (參考reference: 20%, 不能太低cannot be too low)
  - 壁厚度Wall thickness
  - 速度Speed
- **溫度要求:** 實驗遇到的溫度Temperature encountered in the experiment; 環境the environment (不能高;取決於材料的類型cannot be high; depending on the types of materials)
- **膨脹問題**
- **支撐:** 調整在地板上放置的軸 (X、Y 或 Z)Adjust which axis (X,Y or Z) lay on the floor
  - 支撐材料supporting materials
- 如何在使用 ABS 材料時創造合適的環境How to create a suitable environment when using ABS materials

# 排除故障

## Troubleshooting for successful printing

1. 不夠絲 Out of Filament
2. 噴嘴太靠近印刷床 Nozzle Too Close to Print Bed
3. 噴嘴阻塞 Blocked Nozzle
4. 打印頭錯過了床 Print Head Misses the Bed
5. 擠出中期停止打印 Extrusion Stopped Mid-Print
6. 打印不粘到打印床 Print Doesn't Stick to Print Bed
7. 支撐倒下 Supports Fell Apart

# 支持材料 Supporting Materials (如需要)



## The 45 degree rule (45 度法則)

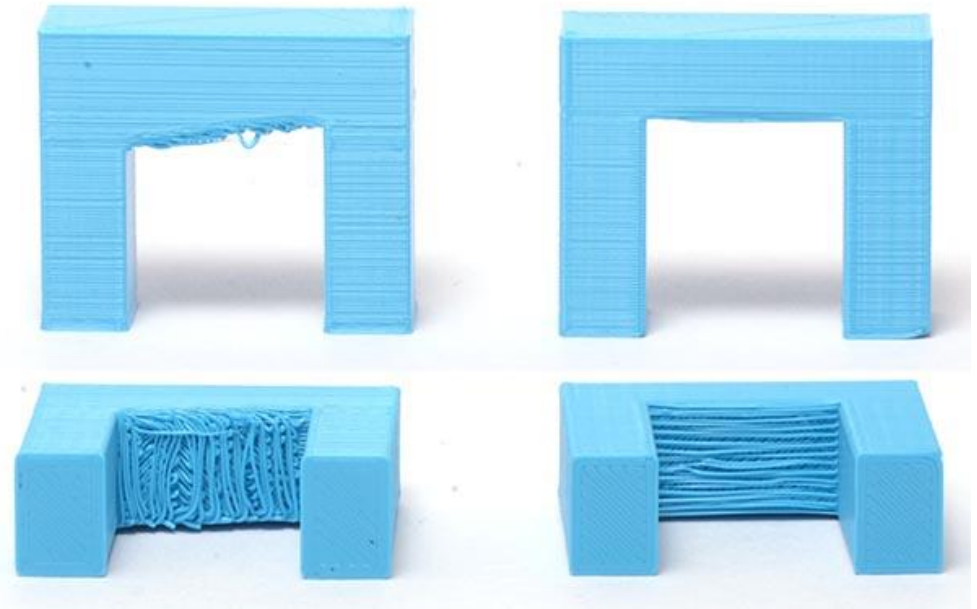
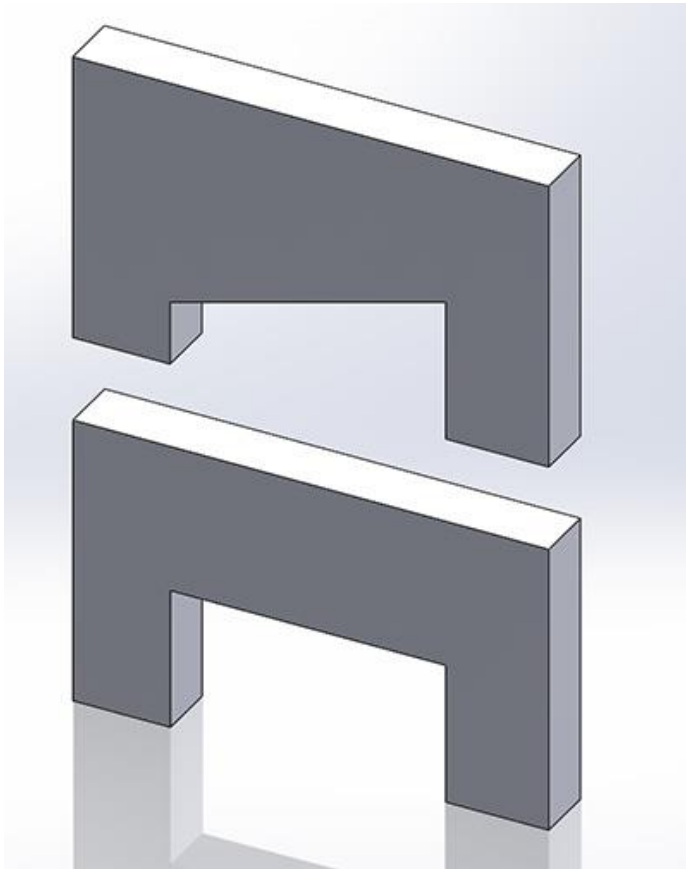
圖像的中間部分顯示了我們如何將懸垂角度改變到45度，使該部分易於列印。這並不總是可能的。在上面的部分，應該有一個皮帶沒有硬邊在中間運行，以保持它的位置防止滑出。

進階:

創建一個跨度，而不是一個陡峭的懸垂 (如適用)

Create a span instead of a steep overhang if possible

三維打印機的噴嘴在兩邊距離越大，  
乾度越快，  
三維打印機效能越佳。



# 進階:可溶長絲 Dissolvable Filament

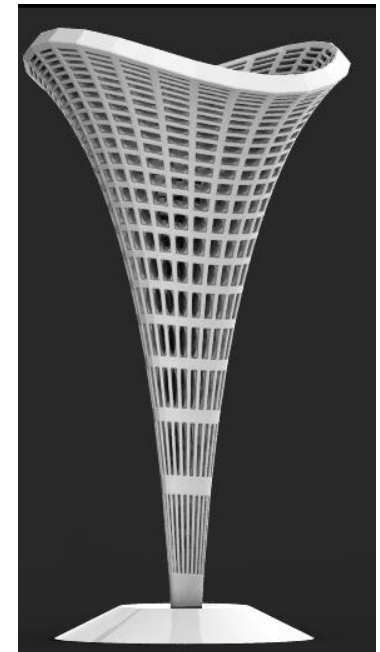
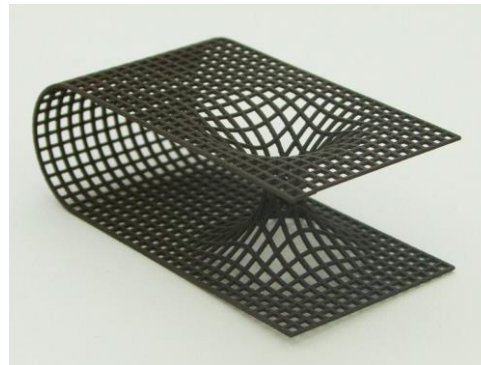
如你想製作複雜的形狀，你可參考:

Ultimaker PVA Explained - Water-soluble support material:

<https://www.youtube.com/watch?v=0ENgGkPP94w>



進階實驗: 黑洞製作  
Black Hole / Worm Hole



## F. 第一節 總結 Summary

- 不同類型的3D打印機Different types of 3D printer
  - Delta type 3D-printer
  - 笛卡爾Cartesian (xyz-axis type) 3D-printer
- 不同類型的打印材料Different types of printing materials
  - ABS, PLA...
- 學到的工具：Tools we've learnt:
  - 設計3D對象Design 3D object: TinkerCAD

# iClass 互動學習系統的 登入方法

- Step 1: 開啟 Chrome
- Step 2: 使用電腦登入帳戶  
(帳戶資料已於開課前派發；如有問題，請向實驗室同工索取)
  - URL: <http://portal.iclass.hk/index.php>

iClass 互動學習

繁體中文

登入名稱

密碼

登錄

或經以下平台登入

Google Office 365

NEWS



# iClass 互動學習系統的 登入方法 (續)

The screenshot displays the iClass system interface. At the top, there's a header with the university logo and the text '3dprint'. Below this, a sidebar on the left contains icons for user profile, settings, and a lock. The main content area is divided into two sections: '課程' (Course) and '動態' (Dynamic). The '課程' section lists a course titled '資訊科技教育與學科有關系列: 運用3D打印機和資訊科技工具促進物理科的學與教' (Information Technology Education and Discipline Related Series: Using 3D Printers and Information Technology Tools to Promote Learning and Teaching in Physics). The '動態' section shows recent activities, including a group discussion and a Google Form assignment. Below these sections, a navigation bar includes '教師模式' (Teacher Mode), '課程代碼: WP7170', and '新增課題' (Add Topic). The '課程簡介' (Course Introduction) tab is selected, showing a list of topics. The '第一節' (First Lesson) topic is highlighted. Below the topics, a '課題資料夾' (Topic Folder) section is visible, containing a list of topics and their descriptions. The topics listed are: 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. Below the topics, there are links for '小組討論- 課題分享' (Group Discussion - Topic Sharing) and 'Google Form活動作業: 提交Tinkercad 設計作品連結' (Google Form Assignment: Submit Tinkercad Design Work Link).

Step 3:

按課程名稱

Click the course name to access

Step 4:

按所屬課程主題

Click the respective topic to access related course materials

課程的相關文件及資源分享可以於「課程資料夾」中下載。

Course documents including PPT slides and assignment can be downloaded from "Topic Folder".