

PBL: Newtonian Dynamics

活動單元：動力學 (牛頓定律)

By J Chen (陳衫豫), A Assefa, B Lin, J D White (白小明)

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0. Introduction 簡介 and Visualization

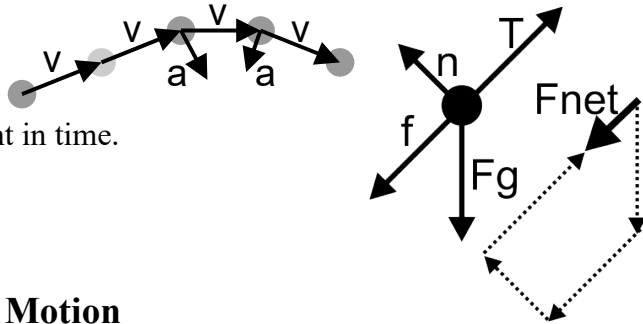
0.1 Preamble

在這個單元，你要使用三個有關力與運動的模擬實驗，在你開始作答問題前，玩玩看每個模擬實驗，熟悉每個模擬實驗的操作，並利用這些模擬來回答問題。

In this activity unit, you will perform virtual experiments with three different public domain physics simulations dealing with basic force and motion. Before you start answering the questions, play with each simulation. Get familiar with each of the different effects and buttons of the animations. Where there are tabs, utilize them.

0.2 Key Concepts

- Kinematics: Motion Diagram (MD, 運動圖)
- Dynamics: Free-body Diagram (FBD, 力圖): Shows all the forces on an object a given point in time.
- Graphs:
 - Kinematics: $\bar{s}(t)$, $\bar{v}(t)$, $\bar{a}(t)$
 - Dynamics: Forces vs time $\bar{F}(t)$



1. Visualizing and Graphing Forces and Motion

- 1.1 下載模擬器 Download, Run and Play with the PhET Simulation: "Forces in 1 Dimension"
- 1.2 Select: [Friction OFF] [All Graphs] Give the file cabinet a light push (impulse) and watch it slide. (a) Draw the graphs of horizontal components of $\bar{s}(t)$, $\bar{v}(t)$, $\bar{a}(t)$, and $\bar{F}(t)$ using different color pens. (b) Which parameter $\bar{s}(t)$, $\bar{v}(t)$, or $\bar{a}(t)$ is most closely related to $\bar{F}(t)$? (c) What happens after you stop pushing? 選擇[無摩擦力] 使用不同顏色的筆，並對櫃子施一固定力 F (a)畫出水平分量的 $\bar{s}(t)$, $\bar{v}(t)$, $\bar{a}(t)$, 和 $\bar{F}(t)$ (b) $\bar{s}(t)$, $\bar{v}(t)$, 和 $\bar{a}(t)$ 的關係 (c) 描述當你對櫃子停止施力後櫃子的狀態?

(a)		
(b)		

1.3 Use the replay feature to replay the motion in §1.2 (a) Draw the Free Body Diagram (FBD) (upper right) showing all forces for the file cabinet (i) before (ii) during and (iii) after the push. (b) What happens after you stop pushing the file cabinet? 選擇[無摩擦力]對櫃子施力(輕輕的, 未移動)後放手(a)畫出 3 張力圖分別是施力前、正在施力和放手後 (b)描述當你對櫃子停止施力後櫃子的狀態?

(i) FBD before	(ii) FBD during	(iii) FBD after	(b)

1.4 Select: [Friction ON] Give the File Cabinet a light push (impulse). (a) Draw the **Free Body Diagram** during the push. (b) Why doesn't the File Cabinet didn't move when you push it? 選擇物品:檔案櫃。(a)畫出力圖(b)解釋為什麼即使施力在櫃子上，但一開始卻未移動?

(a) FBD	(b) Why?

1.5 Select: [All Graphs] Strongly push the file cabinet until it starts moving. (a) Draw the graphs of horizontal components of $\vec{s}(t)$, $\vec{v}(t)$, $\vec{a}(t)$, and the various $\vec{F}(t)$ using different color pens. (b) Comment on the relationship between acceleration, velocity, position and force and how they differ from the previous simulation without friction 把加速度、速度、位置圖表打開。把你觀察到加速度、速度、位置跟力的關係記錄下來。選擇物品:檔案櫃。(a)紀錄當檔案櫃開始移動時作用力的圖表。(b)寫下你觀察到圖表之間的關聯 把加速度、速度、位置圖表打開。把你觀察到加速度、速度、位置跟力和 1.2 的圖表做比較寫出相同或相異處。

(a)	
F	
s,v,a	
	t
s	
v	
a	
F	

1.6 Change the object. e.g. to a refrigerator. What changes do you see with the force and the acceleration? (a) F is the same (b) a is the same 改變物品，並描述力和加速度有何不同(a)固定 F (b)固定 a。

(a)	
(b)	

2. Forces and Motion: Friction and Gravity

2.1 下載模擬器 Download, Run and Select: [Ramp Angle 0°]. Play with the PhET Simulation: “Ramp: Forces and Motion” 選擇角度為 0°

2.2 Tab: [introduction] Select: [ice (no friction)] Select: [Ramp Angle 0°] Give the object a short push and then stop. (a) Draw a **free body diagram (FBD)**. Identify the forces that are acting. (b) When you have stopped pushing, how is the object moving?. 在[介紹 分頁中] 選擇無摩擦力 (表面是冰)、角度為 0° 給物體一個力並釋放物體。(a) 畫出力圖分析，標出作用力。(b) 物體有怎樣的行為?在力作用之後物體會有什麼樣的運動狀態?

(a) FBD	(b) Why?
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2.3 Tab: [Introduction] Select: [Wood (friction)] [Ramp Angle 0°] Look at the different objects – Each type of object is defined by 3 parameters (m , μ_k , μ_s). 在[介紹 分頁中] 選擇木頭介面 (friction)、角度 0°。找到改變物體的選項。改變物體看看。參數: m , μ_k , μ_s

- a. By experimentation, try to understand qualitatively what affect each parameter has on the non-moving (static) object. (i) Draw the **free body diagrams** (ii) Explain which parameters affect the non-moving object. a.找出在未移動的物體上有什麼力是相對的 (i)畫出力圖 (ii)解釋影響未移動物體的力是什麼?
- b. By experimentation, try to understand qualitatively what affect each parameter has on the moving object. (i) Draw the **free body diagrams** (ii) Explain which parameters affect the moving object. b. 找出在移動中的物體上有什麼力是相對的 (i)畫出力圖 (ii)解釋影響移動物體的力是什麼?

a(i) FBD	a(ii) Why?
b(i) FBD	b(ii) Why?

2.4 Tab: [Friction] Select: [Ramp Angle 0°] Change the gravitational force. (a) Draw the **free body diagrams** for the object on earth, the moon and Jupiter. How do they differ? (b) Move the object on each planet, how much initial force did it require? (c) How does the gravitational force affect the friction force for the static and the moving objects? [摩擦力 分頁] 在此章節，改變重力跟，(a) 畫出當物體處在月跟木星上的力圖分析。(b) 試著在兩種情況下移動物體，要使物體移動的初始力要多大？(c) 在物體靜止時摩擦力是多少？當物體移動時摩擦力又是多少？

Earth	Moon	Jupiter
(a) FBDs		
(b)		
(c)		

2.5 Tab: [Friction] Select: [Walls Bouncy],[Ramp Angle 0°] Find a way to keep the object bouncing against the wall without slowing down in the process. What method you choose and explain? Show in **free body diagram**. [摩擦力 分頁](勾選彈簧) 找出方法使物體在兩彈簧間保持運動且過程中並不會使物體慢下來，寫下方法並說明，並畫下力圖？

(a) FBD	(b) Why?
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3. Systematic Experimentation: Connecting Force, Acceleration, Mass and Friction

3.1 Use the PhET simulation: "Forces in 1 Dimension". Select: [Graph Applied Force][Graph Acceleration]

3.2 Case 1: Select: [Friction: OFF]

- a. Choose an object. Push it by different forces and see how the acceleration changes. (a) Write down the results in the table. (b) Draw a graph. (c) Fit the data to an equation $\bar{a}=f(\bar{F})$. 使用同一種物品(ex: 櫃子、狗)，對此物品施不同的力得到不同的加速度。(a) 將數值紀錄在下列圖表 (b) 做數線圖 (c) 從數線圖中得出式子 $\bar{a}=f(\bar{F})$ (Hint: You might want to use a Spreadsheet program)

F	a	(b) Graph	(c) Equation

- b. Use different objects. Push it by the same force each time. Observe the change in acceleration. (a)

Write down the results in the table. (b) Draw a graph. (c) Fit the data to an equation $a_x=f(m)$. 使用不同物品，對此物品施相同的力得到不同的加速度。(a)將數值紀錄在下列圖表 (b)做出數線圖 (c)從數線圖中得出式子 $a_x=f(m)$ (Hint: You might want to use a Spreadsheet program)

m	a	(b) Graph	(c) Equation

c. Combine the two equations that you have found into one equation. 將你上述得到的兩個式子結合

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3.3 Case 2: Select: [Friction: ON]

a. Choose an object. Push it by different forces and see how the acceleration changes. (a) Write down the results in the table. (b) Draw a graph. (c) Fit the data to an equation $\bar{a}=f(\bar{F})$. 使用同一種物品(ex: 櫃子、狗)，對此物品施不同的力得到不同的加速度。(a)將數值紀錄在下列圖表 (b)做出數線圖 (c)從數線圖中得出式子 $\bar{a}=f(\bar{F})$

F	a	(b) Graph	(c) Equation

b. Use different objects. Push it by the same force each time. Observe the change in acceleration. (a) Write down the results in the table. (b) Draw a graph. (c) Fit the data to an equation $a_x=f(m)$. 使用不同物品，對此物品施相同的力得到不同的加速度。(a)將數值紀錄在下列圖表 (b)做出數線圖 (c)從數線圖中得出公式 $a_x=f(m)$

m	a	(b) Graph	(c) Equation

c. Combine the two equations that you have found into one equation. 將你上述得到的兩個式子結合

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3.4 Consider your results for the last two experiments. (a) How can you reconcile the two equations? (b) Write a general equation that takes into account the role of friction. 結合兩個實驗的結果 (a)你要如何整合兩個式子(friction, no friction) (b)寫下包含摩擦力的式子

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4. Playing with Ramps

4.1 Continue to use the simulation Ramps: Forces and Motion. Select: [Ramp Angle 30°]

4.2 Tab: [Introduction] Select: [Ramp Angle 30°] Push the box up the ramp and then move out of the way. Draw the **motion diagram**. 讓箱子滑上斜坡，並畫下運動圖。

4.3 Tab: [Introduction] With the box on the ramp, increase the angle. Why does the moving distance of the box on the ramp become shorter when the angle increases? Draw the **free body diagram** after you finish pushing. 增加角度。為什麼當角度增加時，箱子在斜坡上的移動距離變短。並畫下力圖。

(a) FBD	(b) Why?
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4.4 Tab: [Friction] Find a method allow object to be increase the sliding force without changing the item. 找出方法在不改變物品的狀況下增加下滑力。

4.5 Tab: [Friction] Change the gravitational force. Which force will change when you change the gravity. 當在不同星球時，重力的改變會使什麼力也跟著一起改變。

4.6 Tab: [Force Graph] Observe the graph, and find two relationships between the graphs. 觀察五張圖表並寫下你觀察到這五張圖的關係。

4.7 Tab: [Robot Moving Company] (a) Deliver the objects using the robot (hint: use left and right arrows) What is your highest score? (b) Observe the free body diagram and summarize the your observations. [機器人搬家公司 分頁] 利用機器人分送貨物(提示用鍵盤左右鍵)你得的最高分是多少? 觀察力圖並總結你所觀察的現象。

Student ID:	(b)
Score:	
Student ID:	
Score:	

4.8 Change to the PhET Simulation: "Forces and Motion". Use Tab: [Robot moving company] Deliver the objects using the robot What is your highest score? Observe the free body diagram. Summarize your observations. [機器人搬家公司 分頁] 利用機器人分送貨物(提示用鍵盤左右鍵)你得的最高分是多少? 觀察力圖並總結你所觀察的現象。

Student ID:	(b)
Score:	
Student ID:	
Score:	

4.9 Compare the case with the ramp and without the ramp. Write down the difference. 將上述兩個遊戲過程中不同的現象寫下。

5. Lunar Lander

5.1 下載模擬器 Download, Run and Play with the PhET Simulation: "Lunar Lander"

5.2 Draw a **motion diagram** showing how the landing goes if there is no fuel is used. 把火箭(沒有燃料時)的運動圖畫下來。

5.3 Now we have to keep the lander from crashing. (a) How will you do it? Explain why you choose this method. (b) Draw a picture. 現在我們要防止太空梭墜毀。請問你會用什麼方式(畫圖)並解釋選擇此方式的原因。

(a)	(b)
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5.4 If you want the lander to approach the moon at constant speed. (a) How can we achieve this? Explain. (b) Draw the free body diagram (FBD) at constant speed. 如果我們想讓太空梭以等速降落，我們應該如何完成此目標。(a)解釋你的方法 (b)畫出力圖。

(a)	(b)
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5.5 (a)What is the source of the “thrust” force? (b) The simulation shows two vectors. What do the yellow/red and green vectors represent? 你覺得火箭的推力和什麼有關？並且寫下畫面上向量(黃向量、綠向量)的物理意義？

(a)	(b)
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5.6 Control rocket to maintain a soft landing using the minimum amount of fuel. (a) Record the amount of fuel used for a soft-landing for you and your partner. (b) Explain a strategy to minimize the amount fuel used while safely landing the lunar module.

(a) Stud ID: Fuel Remaining: Score:	(b)
(b) Stud ID: Fuel Remaining: Score:	

6. 您的意見 Student Comments

6.1 Did you enjoy the activity? 你喜歡這個活動嗎？ Choose one”

LOVED 喜愛 75% 馬馬虎虎 25% HATED 憎恨

Why? 為什麼？

6.2 提出 1 或 2 個問題 可以 添加到本題目簿 如果你的問題被使用，加 1 分！（最多加 5 分） Suggest one or two additional questions that could be asked concerning any of the simulations you played with. (If we add your question, you will get 1% bonus marks for the course!)

Activity	Suggested Question	Answer to suggested question

6.3 有沒有別的意見？ Any other suggestions to improve this activity?

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6.4 Please write your student ID here for bonus marks if you have made suggestions.

ID:	ID:
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