PBL: Energy & Momentum
活動單元：關力與動量

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0. Introduction 簡介

在這個單元，你要使用四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。

We will now look at an alternative approach to dynamics. While in Newton's viewpoint, we describe motion using forces and mass, in this viewpoint we work with energy and momentum. In this activity unit, you will perform virtual experiments with three different public domain physics simulations dealing with energy and momentum. Before you start answering the questions, play with each simulation. Get familiar with each of the different effects, buttons and tabs.

1. Energy Skate Park : Basics

1.1 下載模擬器 Download, Run & Play with the PhET Simulation: “Energy Skate Park : Basics”

1.2 Select:[Intro] [“u” shape trace] Tick all the options. Put the skater on one side. What is the relationship between the speed of the skater and his position (vertical and horizontal)? 選擇:[入門] [U 形軌道] 將溜滑板的人放在一端，勾選所有選項。他最初速度和最大速度與他水平高度的位置有何關係?

1.3 Select:[Intro] [“u” shape trace] [bar graph] There are four different energies, some will change and the other won’t write down and explain why? 選擇:[入門] [U 形軌道] [直條圖] 直條圖上有 4 種不同的能量，有些會改變，有些不會，寫下並解釋為什麼?

Change:	Why change?
No Change:	Why no change?

1.4 Select:[Intro] [“u” shape trace] [bar graph] Combine four energies into an equation. 選擇:[入門] [U 形軌道] [直條圖] 結合圖表上的 4 種力，並寫下式子。

1.5 Select:[Intro] We assume that this system is isolated and closed. What is happening to the total energy? How is a closed system and total energy related? 選擇:[入門] 在你所觀察的上述問題，我們認為他是獨立且封閉的，這個條件會使總能倆有何特性，總能量跟封閉系統間有何關係?

1.6 Select:[Intro] [the second one trace] Put the skater on top and let her slide down. (a)What is her motion when she leaves the track? (b)Comment the reason why the skater move in this way. 選擇:[入門] [第二個軌道] 將滑板者放置高處，(a)當他滑落脫離軌道時會呈現何種運動狀態? (b)並解釋為何滑板者會呈現此運動狀態。

(a)	(b)

1.7 Select:[Intro] ["u" shape trace] [bar graph] Change the mass and observe the bar graph. (a) What changes? (b) Explain why this happens. 選擇:[入門] [U 形軌道] [直條圖] 現在改變重量，(a)觀察長條圖發生的變化(b)解釋造成變化的原因。

(a)	(b)

1.8 Select:[Friction] ["u" shape trace] [bar graph] The bar graph has one extra enengy. (a)What is this energy? (b)Where does the energy from? (c) How does the motion differ from the no-friction case? 選擇:[摩擦] [U 形軌道] [直條圖] 觀察長條突有一個能量是在無摩擦時沒有的 (a)這是什麼能? (b)這個能量從哪裡來? (c)這個運動狀態有別於無摩擦力時，為什麼?

(a)	(b)	(c)

1.9 Select:[Friction] ["u" shape trace] [bar graph] In this setup system play with the skater. What can you conclude about this system? Can we build machines that can run forever with out losing energy? 選擇:[摩擦] [U 形軌道] [直條圖] 在此系統中，你能建立一個機器永遠不會損失任何能量嗎?為什麼所有的機器到最後都會停下來呢?

2. Hooke's Law for Springs

2.1 下載模擬器 Download, Run and Play with the PhET Simulation: "Hooke's Law"

2.2 Select:[Intro] [Force] When you pull the spring, there are two forces. (a)Write are their forces names?. (b) Explain the source of the forces. 選擇:[入門] [力] 如果對彈簧施一個力，畫面上出現兩個相對得力 (a)分別是什麼力 (b)解釋為什麼會產生這兩個相對的力?

(a)	(b)

2.3 Systematic Experimentation: Effect of Force on Displacement. Select:[Intro] [Displacement] [Value] Push the spring. Observe the displacement with different forces. (i) Write down the spring constant of the force you are using for this experiment (ii) Write down the results in the table. (iii) Draw a graph. (iv) Fit the data to an equation $\Delta\mathbf{x}=f(\mathbf{F})$. 選擇:[入門] [位移、數值] 施予彈簧一個力，並觀察彈簧的位移量。(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 $\Delta\mathbf{x}=f(\mathbf{F})$

(i) The value of spring constant is _____ N.

F [N]	x [m]	(iii) Graph	(iv) Equation

2.4 Systematic Experimentation: Effect of Spring Constant on Displacement. Select:[Intro] [Displacement][Value] Push the spring and keep the applied force constant. Change the spring constant. What happens to the displacement?. (i) Write down the value of the force you are using for this experiment (ii) Write down the results in a table. (iii) Graph. (iv) Fit the data to an equation **x**=f(**k**). 選擇:[入門] [位移、數值] 施予彈簧一個定力，並觀察彈簧的位移量。(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 **x**=f(**k**)

(i) The value of the applied force is _____ N.

(ii) k [N/m]	x [m]	(iii) Graph	(iv) Equation

2.5 Systematic Experimentation: Springs in parallel. Select:[Systems][parallel] 選擇:[系統][並聯] Perform a series of experiments to see how forces are distributed between springs. For each case, apply a force of $\mathbf{F}_{app}$=100 N. 觀察彈簧受的分力，每個實驗都使用 100N。

a. Use the **same** spring constant for both springs. (i)Write down the results in a table. (ii) Graph your results (iii) Summarize the results with an equation, i.e. $\mathbf{F}_{top}$.= f(k) 上下彈性係數相同 (i)將實驗結果記錄在表格裡 (ii)將實驗數據寫成一個式子

k_{top} [N/m]	k_{bot} [N/m]	F_{top} [N]	F_{bot} [N]	Graph	Equation
200	200				
300	300				

b. Use **different** spring constants for both springs. (i)Write down the results in a table. (ii) Graph (iii) Summarize the results with an equation, i.e. $\mathbf{F}_{top}$.= f(k_{top}, k_{bot}) , $\mathbf{F}_{bot}$.= f(k_{top}, k_{bot}) ,. 上下彈性係數不同 (i)將實驗結果記錄在表格裡 (ii)將實驗數據寫成一個式子

k_{top} [N/m]	k_{bot} [N/m]	F_{top} [N]	F_{bot} [N]	Graph	Equation
200	200				
200	300				

2.6 Systematic Experimentation: Springs in series. Select:[Systems] [series] 選擇:[系統][串聯] Perform a series of experiments to see how forces are distributed between springs. For each case, apply a force of $\overline{\mathbf{F}}_{app}$=100 N. 觀察彈簧受的分力，每個實驗都使用 100N。

a. The spring constant is the same at left and right spring. (i)Write down the results in a table. (ii) Graph (iii) Summarize the results with an equation,i.e., i.e. $\mathbf{F}_{right}$.= f(k) 左右彈性係數相同 (i)將實驗結果記錄在表格裡 (ii)將實驗數據寫成一個式子

k_{left} [N/m]	k_{right} [N/m]	F_{left} [N]	F_{right} [N]	Graph	Equation
200	200				
300	300				

b. The spring constant is different at left and right spring. (i)Write down the results in a table. (ii) Graph (iii) Summarize the results with an equation, i.e. $\mathbf{F}_{left}$.= f(k_{left}, k_{right}) , $\mathbf{F}_{right}$.= f(k_{left}, k_{right}) . 左右彈性係數不同 (i)將實驗結果記錄在表格裡 (ii)將實驗數據寫成一個式子

k_{left} [N/m]	k_{right} [N/m]	F_{left} [N]	F_{right} [N]	Graph	Equation
200	200				
200	300				

3. Springs and Energy

3.1 Continue to use the PhET Simulation: “Hooke’s Law”. Select:[Energy]

3.2 Select: [Bar Graph] When is the potential energy maximum? Why? 選擇:[能量][能量圖] 為什麼能量圖的左右兩側皆為最大值?

3.3 Select: [Energy Graph] Why is the potential energy graph symmetical? (What is the energy dependent upon? 選擇:[能量][力圖] 為什麼位能忽大又忽小何什麼有關呢?

3.4 Systematic Experimentation: Find the relationships between this new quantity Potential Energy (U) with Force (F) and Displacement (x), i.e. (c) $\overline{\mathbf{F}}$(x)=f(x), (d) U(x)=f(x). (e) Can you write an equation relating the quantity U to F, i.e. eliminate k to get U(x) = f($\overline{\mathbf{F}}$(x))?

(a) Data			(b) Graph		Equations	
x	F	U		U F	(c) F(Δx)=	(d) U(x)=
				x	(e)	

4. Masses and Springs

4.1 下載模擬器 Download, Run and Play with the PhET Simulation: “Masses and Springs”

4.2 Select:[Energy][Damping None] Change the mass. What happens to total energy? 選擇:[能量] 如果改變重量會使總能發生什麼改變?

4.3 Select:[Energy] Why isn’t the maximum kinetic energy equal to the maximum elastic potential energy? 選擇:[能量] 為什麼彈力位能不等於動能?

4.4 Select:[Energy] [Gravity] Change the gravity (eg. use Moon, Earth,and Jupiter). Observe the energy bar graph. Comment the difference between Moon, Earth,and Jupiter. 選擇:[能量] [重力] 改變重力，比較能量圖在月亮、地球、木星的差異。

4.5 Select:[Energy] [Damping: Middle] (a)How does the motion change with damping? (b) What is damping? What is the cause of damping? 選擇:[能量][阻尼] (a)你知道阻尼是什麼嗎? 簡單解釋一下。 (b)當阻尼變大時對運動產生什麼影響?

(a)	(b)

4.6 Select:[Energy] [Damping None] [Spring constant] Change the spring constant. (a)What energies change together? (b) Why? 選擇:[能量][阻尼歸零] 改變彈性常數 (a)能量圖中的能量何者也跟著改變 (b)為什麼?

(a)	(b)

5. Collision Lab

5.1 Select:[Introduction][Show Value] Play with the Sim speed.Draw a picture of the situation for the two balls (a) before and (b) after the collision (b) At what point in time does the collision occure. Summarize what changes at this point in time. (hint : observe with sim speed low) 選擇:[介紹][數值] 調整 Sim speed。(a)畫出在物體碰撞前的狀態，(b)並說明兩物體在何時碰撞

(a) before	(b) after	(b)

5.2 Select:[Introduction] The product of a particle's mass and velocity is called momentum ($\bar{\mathbf{p}}=m\bar{\mathbf{v}}$). Momentum has the same as velocity. Draw the momentum of both objects in vector form and show their value. 選擇:[介紹] 質量與速度的乘積稱為動量，動量是以速度的方向為方向，劃出兩物體的動量包含大小及方向。

Before	After

5.3 Select:[Introduction][Momenta diagram] (a) One vector is the same both before and after the collision. What is the vector? (b) Why? (c) Draw this vector of before collision and after collision (hint:notice the length) X 選擇:[介紹][動量圖](a)在碰撞之後有一向量皆不變，是什麼? (b)為什麼? (c)畫出碰撞前後的向量圖(hint:注意長度)

(a)	(b)	(c)

5.4 Play with the simulation and try to find a condition that causes the total momentum vector to be different before and after the collision. What condition did you use? 使用模擬器，找出可以使前後總動量發生改變的情況，描述你的方法。

5.5 The fact that total momentum is the same before and after a collision is called the "Law of Conservation of Momentum"

5.6 Select:[Introduction] Set the mass of Particle 1 to 1 Kg. Set the mass of particle 2 to 0.5 Kg. Set the initial speed of particle 1 to1m/s. Start the simulation and observe closely. (a)Draw the motion diagram and calculate the initial momentum (p) of the particles. (b)Record the momentum (p) after collusion of the particles.(c) What did you observe?(hint : law of conservation applies here) 選擇:[介紹] 將 Particle 1 的質量改為 1Kg 速度改為 1 m/s，Particle 2 的質量改為 0.5 kg。開始模擬並仔細觀察。(a)畫出運動圖並計算初始系統(兩個粒子)的動量 (b)記錄碰撞後系統的動量 (c)你觀察到什麼?(提示此處可用動量守恆定律)

(a)	(b)	(c)

5.7 Select:[Introduction] Set the mass of Particle 1 to 1 Kg. Set the mass of particle 2 to 1Kg.Set the initial speed of particle 1 to1m/s. Start the simulation and observe closely. (a)Draw the motion diagram and calculate the initial momentum (p) of the particles. (b)Record the momentum (p) after collusion of the particles. (c)Compare with the previous question.Comment on the difference. 選擇:[介紹] 將 Particle 1 的質量改為 1Kg 速度改為 1 m/s，Particle 2 的質量改為 1kg。開始模擬並仔細觀察。(a)畫出運動圖並計算初始系統(兩個粒子)的動量 (b)記錄碰撞後系統的動量 (c)和上一題做比較有什麼差異

(a)	(b)	(c)

6. 您的意見 Student Comments

6.1 Did you enjoy the activity? 你喜歡這個活動馬？ Choose one"

□ LOVED 喜爱 □ 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?

7. SUGGESTED QUESTIONS

7.1 **Systematic Experimentation: Springs in parallel. Select:[Systems] [parallel]** 選擇:**[系統][並聯] Perform a series of experiments the displacements are distributed between springs. For each case, apply a force of Fapp=100 N.**