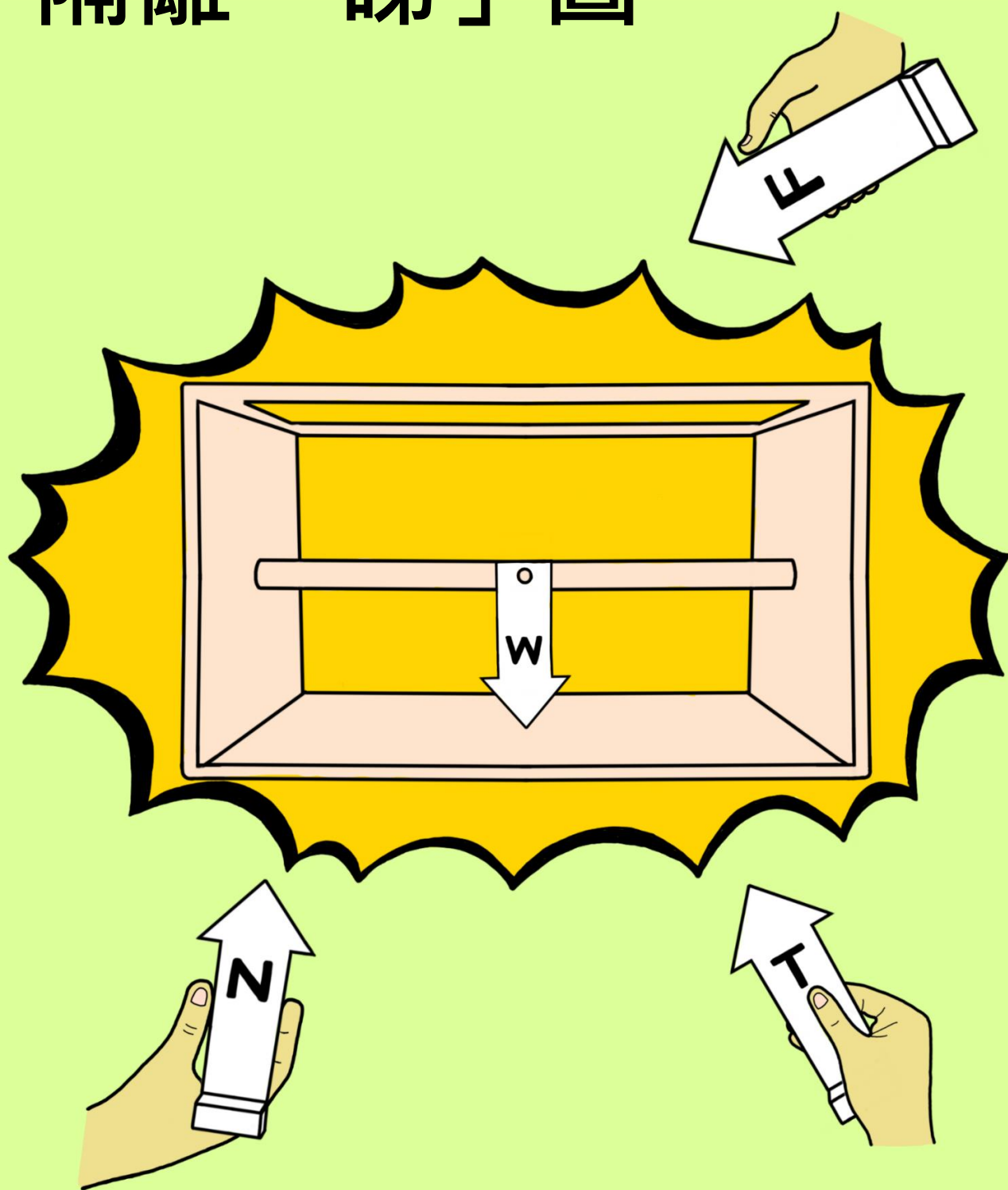


Free-D Set

隔離「睇」圖



優質教育基金
Quality Education Fund



Faculty of **Education**
The University of Hong Kong
香港大學教育學院

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Teacher's manual

Free-D Set

Introduction

A 3D-printed free-body box with arrows is used to help students visualize the free body diagram for different simple mechanical systems.

Related Concepts

Vectors, Forces, Free-body diagram

Objectives

- To manipulate a physical, tangible 3D teaching aid in learning abstract concepts
- To visualize the free-body diagrams in different simple systems in mechanics
- To clarify the directions and magnitude of forces and the points of application of different forces acting on an object

Materials

Item	Quantity
Free-body box set	2
Ramp	2
Pulley System	1
String/rope	adequate



Preparation

Materials needed

<u>Item</u>	<u>Quantity</u>
3D printer and printing material (see below)	1
Colour Marker	1
String	adequate
Reusable Adhesive (e.g. Blu-tack, Hoop & Loop fastening tape)	adequate

3D printed materials

<u>Item</u>	<u>Quantity</u>
3D-printed block	1
Arrows	1 set
- Force	
- Friction	
- Normal force	
- Tension	
- Weight	

Procedure

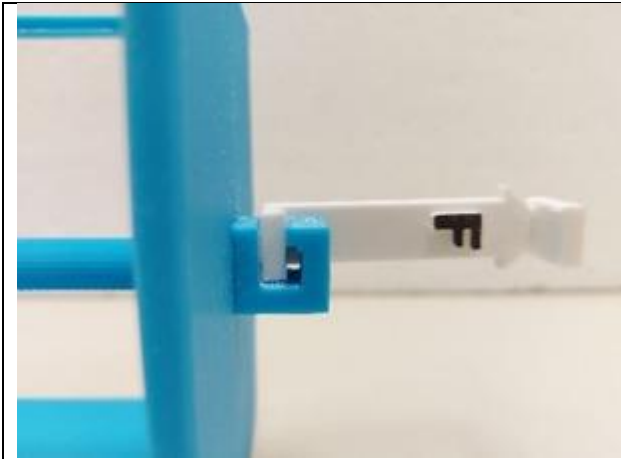
3D printing

1. Download the [NAME].stl file..
2. Import the .stl file to the 3D printer for printing.
3. Select the parameters of 3D printing based on the printer availability.
4. Print all the materials.

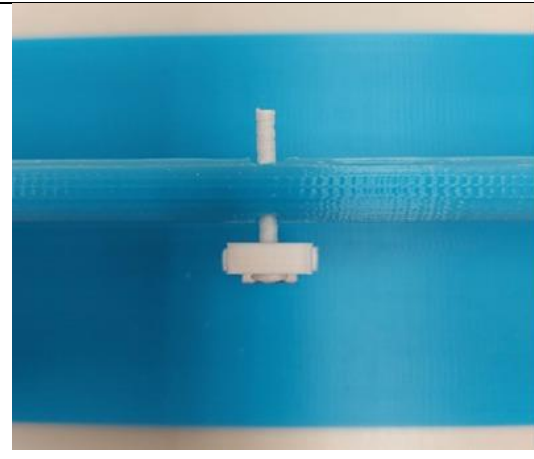
(The quality of the 3D printing models depends on the quality and settings of the 3D printer)

Making the arrows

- “External force”: attach the reusable adhesive to both ends of the arrow.
- “Friction”: attach the reusable adhesive to the end of the arrow.
- “Normal force”: attach the reusable adhesive to the end of the arrow.
- “Weight”: Use a small string to tie the arrow loosely through the hole at the centre of the block.



“External force” arrows



“Weight” arrows

Suggested Demonstration

1. Give a brief summary of different types of force, how and when the force occurs.
2. Check students’ prior knowledge about free-body diagrams and scaffold their ideas with the worksheet guidelines on how to draw the diagram (Worksheet P.1).
3. Allow students to discuss with others and attempt the “Prediction” section of the worksheet (Worksheet P.2).
4. Carry on the session depending on the teacher’s choice

Teacher performs the demonstration

- a. Set up as the cases shown in the worksheet on a table.
- b. Demonstrate or ask students to put all the force arrows on the block appropriately.
- c. Tackling any misconceptions, e.g. misplacement of arrows, missed or excess arrows.
- d. Ask students to observe and draw the free-body diagram on the worksheet (Worksheet P.3).
- e. Repeat step a-d for the next case.

Students are provided with one set-up per group

- a. Allow students to work on different cases as shown in the worksheet.
 - b. Provide necessary guidance to the students in need.
 - c. Encourage students to record their observations in the worksheet (Worksheet P.3).
5. Ask students to generalize the characteristics of common forces, draw and explain the examples on the worksheet (Worksheet P.4).
 6. Resolve students’ inquiries through discussion, explanation and consolidation of the ideas.

物理 – 力和運動

工作紙 – 隔離體圖

姓名: _____ () 班別: _____ 日期: _____

目的

1. 認識隔離體圖的重要性和如何使用隔離體圖
2. 利用隔離體圖表示作用於物體的力
3. 概括作用於物體的力的特徵

簡介

平常作用於物體 X 的力	力如何出現	甚麼時候需要畫圖
重量	地球作用於 X 的引力	當 X 的重量／質量不等於零
法向力	X 放置於一表面上時，表面作用於 X 的力	當 X 放置於平面或斜面上
張力	以繩子或彈簧拉扯著 X	當連接著 X 的繩子或彈簧被拉緊
摩擦力	X 在另一個物體的表面上滑動或放置在斜面上，妨礙 X 運動或對抗 X 運動的趨勢	當 X 在非平滑的表面上滑動，或放置在斜面
外力 - 推力 - 拉力	X 被外力推動／拉扯	當 X 被外力推動／拉扯

隔離體圖

自由體圖是用於顯示在給定情況下作用在物體上的所有力的相對大小和方向的圖。隔離體圖可以方便了解物體所受的力或力矩之間的關係，也有助於求解物體運動方程中待解的力。



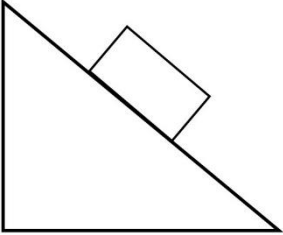
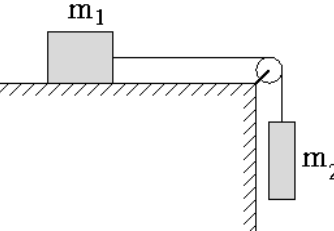
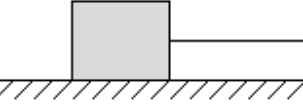
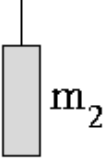
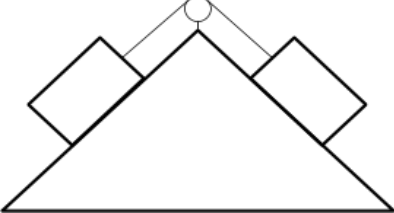
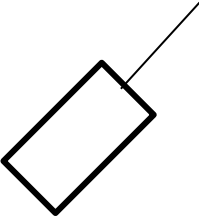
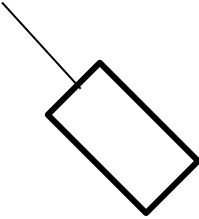
繪畫隔離體圖的指引

圖中每一種力會以**箭頭**表示該力作用於物體的方向及位置。

- ⇒ 箭號的**尾部**表示該力作用於物體上的位置。
- ⇒ 箭號的**長度**表示該力的量值。
- ⇒ 如整個系統有多個物體需要繪畫隔離體圖，應個別地繪畫各個物體的隔離體圖。



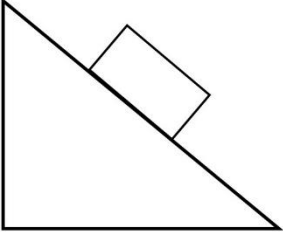
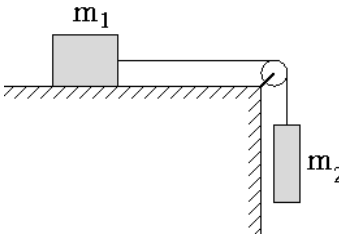
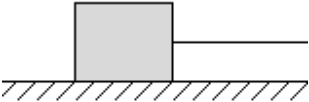
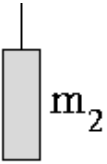
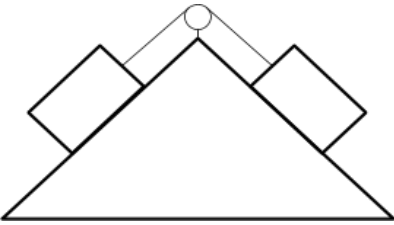
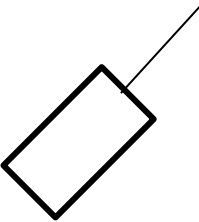
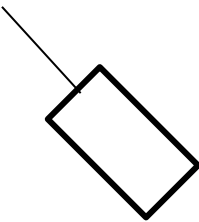
I- 預計 (PREDICT)

- a) 在右欄寫出所有作用在物體上的力。
 b) 在左欄的圖形上繪畫出所有作用於物體上的力。

<p>物體從左方被外力推 (非平滑的表面)</p> 	<p>物體從左方被外力拉 (非平滑的表面)</p> 	<p>作用於物體上的力:</p>
<p>物體靜止在斜坡上 (非平滑的表面)</p> 		<p>作用於物體上的力:</p>
<p>滑輪系統 (一) (非平滑的表面)</p> 	<p>物體 1 m_1</p> 	<p>作用於物體 1 上的力:</p>
<p>物體 2</p> 		<p>作用於物體 2 上的力:</p>
<p>滑輪系統 (二) (非平滑的表面)</p> 		<p>作用於物體 1 上的力:</p>
<p>物體 1 (較重)</p> 	<p>物體 2 (較輕)</p> 	<p>作用於物體 2 上的力:</p>

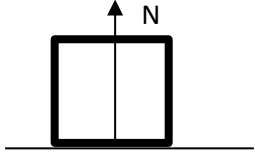
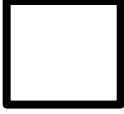
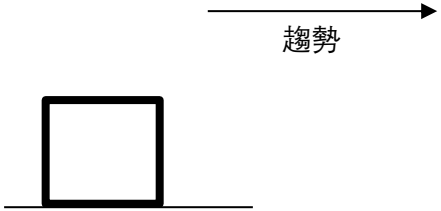
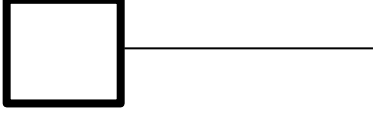


II – 觀察 (OBSERVE)

在以下各題目的隔離體圖空格上，繪畫相應的隔離體圖和指出各種作用於物體上的力。

<p>物體從左方被外力推 (非平滑的表面)</p> 	<p>物體從左方被外力拉 (非平滑的表面)</p> 	<p>作用於物體上的力:</p>
<p>物體靜止在斜坡上 (非平滑的表面)</p> 		<p>作用於物體上的力:</p>
<p>滑輪系統 (一) (非平滑的表面)</p> 	<p>物體 1 m_1</p> 	<p>作用於物體 1 上的力:</p>
<p>物體 2</p> 		<p>作用於物體 2 上的力:</p>
<p>滑輪系統 (二) (非平滑的表面)</p> 		<p>作用於物體 1 上的力:</p>
<p>物體 1 (較重)</p> 	<p>物體 2 (較輕)</p> 	<p>作用於物體 2 上的力:</p>

III – 解釋 (EXPLAIN)

填寫各種作用於物體上的力的特徵，並在隔離體圖繪畫這些力。

法向力 (Normal force)		例子	
標籤:		 <p>例: 從接觸面上</p>	
箭號的方向:			
重量 (Weight)		例子	
標籤:			
箭號的方向:			
摩擦力 (Friction)		例子	
標籤:			
箭號的方向:			
張力 (Tension)		例子	
標籤:			
箭號的方向:			
外力 – 推/拉 (External force – push /pull)		例子	
標籤:		推	拉
箭號的方向:			

Physics – Force and Motion

Worksheet – Free Body Diagram

Name: _____() Class: _____ Date: _____

OBJECTIVES

1. Recognize the importance of Free-body diagrams and their use
2. The Free-body diagram is used to represent the forces acting on an object
3. Summarize the characteristics of the forces acting on an object

INTRODUCTION

The force that acts on object X	Existence of the force	When you need to draw
Weight	The gravitational pull acting on X by Earth	When the weight/mass of X is not equal to zero
Normal Force	When X is placed on a surface, the force which the surface acts on X	When X is placed on a flat or inclined plane
Tension	When X is pulled with a rope or spring	When the rope or spring attached to X is tightened
Friction	When X slides on a surface or is placed on a slope, the force which hinders or counters the tendency of X's movement	When X slides on a rough surface or is placed on a level
External force - Push - Pull	When X is being pushed or pulled by an external force	When X is pushed/pulled by an external force

Free-body diagram

Free-body diagrams are diagrams used to show the relative magnitude and direction of all forces acting upon an object in a given situation.



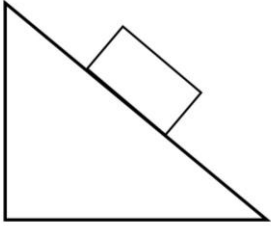
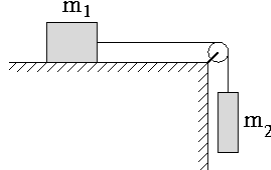
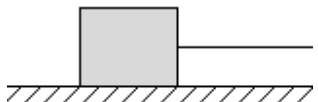
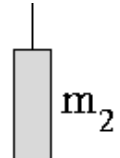
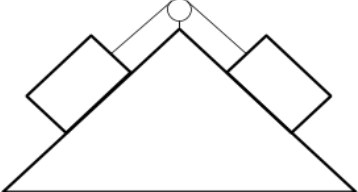
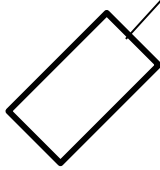
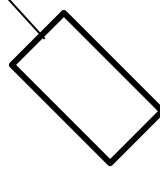
Guidelines for drawing a free body diagram

Each force in the Free-body diagram uses an **arrow** to indicate the direction and location of the force acting on the object.

- ⇒ The **tail** of the arrow indicates where the force acts on the object.
- ⇒ The **length** of the arrow represents the magnitude of the force.
- ⇒ If the system consists of multiple objects that need to be presented with a Free-body diagram, they should be drawn individually.



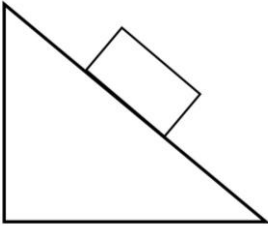
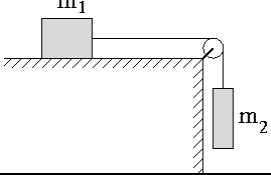
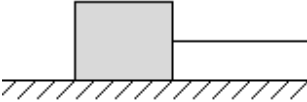
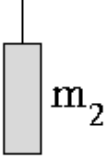
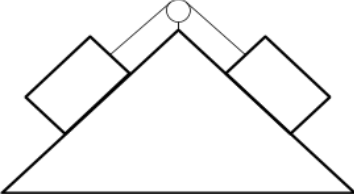
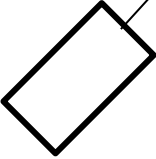
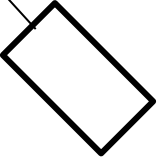
I - Predict

- a) Write all the forces acting on the object in the right column.
 b) Draw all the forces acting on the object on the figure in the left column.

<p>Block being pushed from the left (rough surface)</p> 	<p>Block being pulled from the left (rough surface)</p> 	<p>Forces acting on the block:</p>
<p>Block resting on an inclined surface (rough surface)</p> 		<p>Forces acting on the block:</p>
<p>Simple pulley system (1) (rough surface)</p> 		<p>Forces acting on block one:</p>
<p>block one m_1</p> 	<p>block two m_2</p> 	<p>Forces acting on block two:</p>
<p>Simple pulley system (2)** (rough surface)</p> 		<p>Forces acting on block one:</p>
<p>block one (heavier)</p> 	<p>block two (lighter)</p> 	<p>Forces acting on block two:</p>




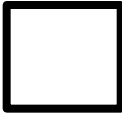


II - Observe

Draw the corresponding Free-body diagrams and indicate the various forces acting on the objects.

<p>Block being pushed from the left (rough surface)</p> 	<p>Block being pulled from the left (rough surface)</p> 	<p>Forces acting on the block:</p>
<p>block resting on an inclined surface (rough surface)</p> 		<p>Forces acting on the block:</p>
<p>Simple pulley system (1) (rough surface)</p> 		<p>Forces acting on block one:</p>
<p>block one m_1</p> 	<p>block two m_2</p> 	<p>Forces acting on block two:</p>
<p>Simple pulley system (2)** (rough surface)</p> 		<p>Forces acting on block one:</p>
<p>block one (heavier)</p> 	<p>block two (lighter)</p> 	<p>Forces acting on block two:</p>

III - Explain

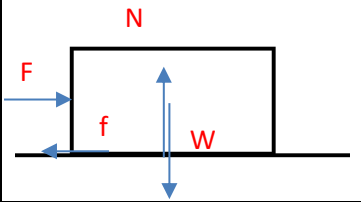
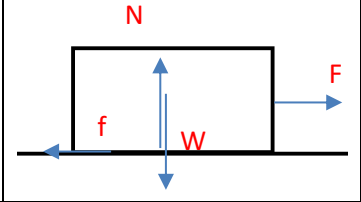
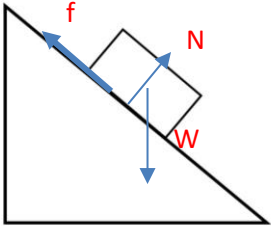
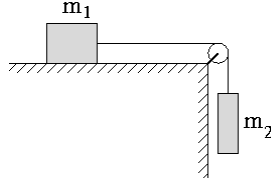
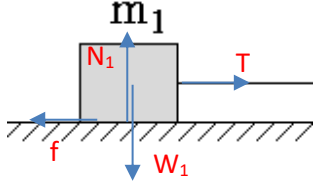
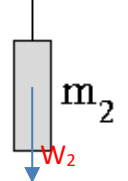
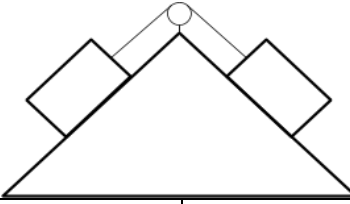
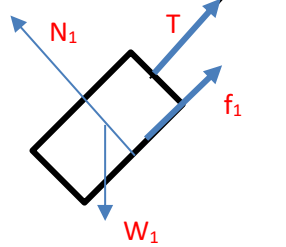
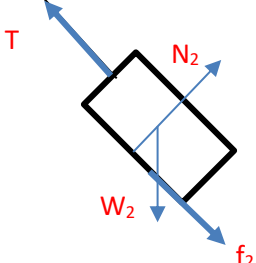
Write down the characteristics of forces and draw the forces in the Free-body diagrams.

Normal forces		Example	
Label:			
Direction:			
Weight		Example	
Label:			
Direction:			
Friction		Example	
Label:			
Direction:			
Tension		Example	
Label:			
Direction:			
External force – push /pull		Example	
Label:		Push 	Pull 
Direction:			

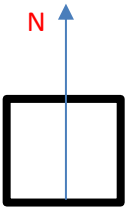
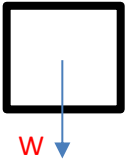


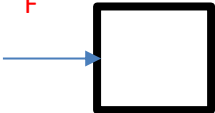

物理 – 力和運動
工作紙 – 隔離體圖

工作紙建議答案

II – 觀察

<p>物體從左方被外力推</p> 	<p>物體從左方被外力拉</p> 	<p>作用於物體上的力:</p> <p>外力 (F) 法向力 (N) 磨擦力 (f) 重量 (W)</p>
<p>物體靜止在斜坡上</p> 		<p>作用於物體上的力</p> <p>法向力 (N) 磨擦力 (f) 重量 (W)</p>
<p>滑輪系統 (一)</p> 		<p>作用於物體 1 上的力:</p> <p>張力 (T) 法向力 (N₁) 磨擦力 (f) 重量 (W₁)</p>
<p>物體 1</p> 	<p>物體 2</p> 	<p>作用於物體 2 上的力:</p> <p>張力 (T) 重量 (W₂)</p>
<p>滑輪系統 (二) (非平滑的表面)</p> 		<p>作用於物體 1 上的力:</p> <p>張力 (T) 法向力 (N₁) 磨擦力 (f₁) 重量 (W₁)</p>
<p>物體 1 (較重)</p> 	<p>物體 2 (較輕)</p> 	<p>作用於物體 2 上的力:</p> <p>張力 (T) 法向力 (N₂) 磨擦力 (f₂) 重量 (W₂)</p>

III – 解釋

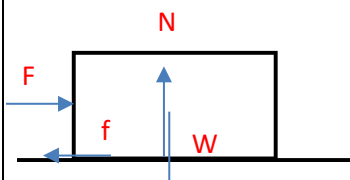
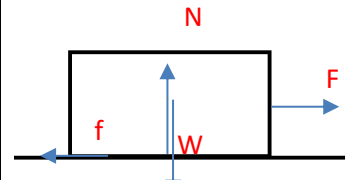
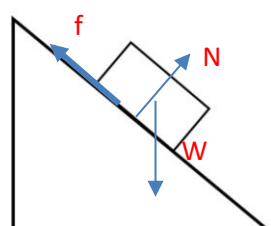
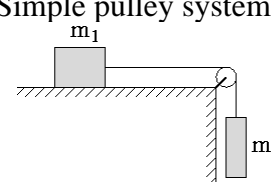
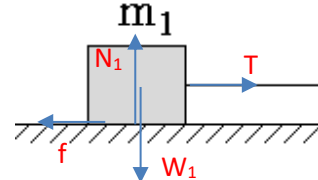
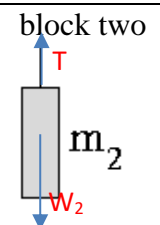
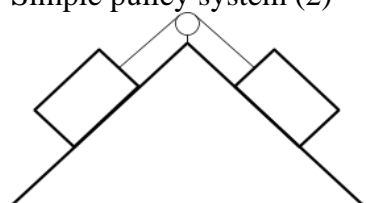
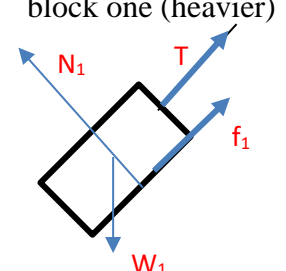
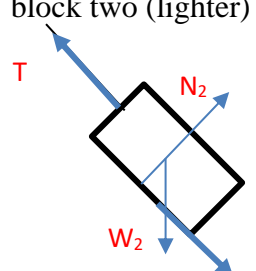
法向力 (Normal forces)	例子	
標籤: N	 <p style="text-align: center;">從接觸面上</p>	
箭號的方向: 垂直於接觸面		
重量 (Weight)	例子	
標籤: W	 <p style="text-align: center;">從物體的中心</p>	
箭號的方向: 指向地下		
摩擦力 (Friction)	例子	
標籤: f	 <p style="text-align: center;">從物體與粗糙面的接觸面</p>	
箭號的方向: 相反於物體的運動方向／趨勢		
張力 (Tension)	例子	
標籤: T	<p style="text-align: center;">從繩子連結物體的位置</p> 	
箭號的方向: 平行於繩子		
外力 – 推/拉 (External force – push /pull)	例子	
標籤: F	<p style="text-align: center;">根據題目所示</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>推</p>  </div> <div style="text-align: center;"> <p>拉</p>  </div> </div>	
箭號的方向: 根據題目所示		

PHYSICS – FORCE AND MOTION

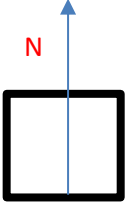
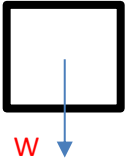

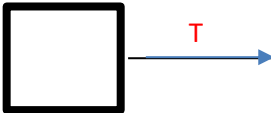
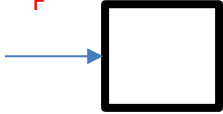

WORKSHEET – FREE BODY DIAGRAM

SUGGESTED ANSWERS

II - Observe

<p style="text-align: center;">Block being pushed</p> 	<p style="text-align: center;">Block being pulled</p> 	<p>Forces acting on the block:</p> <ul style="list-style-type: none"> External force (F) Normal Reaction (N) Friction (f) Weight (W)
<p style="text-align: center;">block resting on inclined surface</p> 		<p>Forces acting on the block:</p> <ul style="list-style-type: none"> Normal Reaction (N) Friction (f) Weight (W)
<p style="text-align: center;">Simple pulley system (1)</p> 		<p>Forces acting on block one:</p> <ul style="list-style-type: none"> Tension (T) Normal Reaction (N_1) Friction (f) Weight (W_1)
<p style="text-align: center;">block one m_1</p> 	<p style="text-align: center;">block two</p> 	<p>Forces acting on block two:</p> <ul style="list-style-type: none"> Tension (T) Weight (W_2)
<p style="text-align: center;">Simple pulley system (2)**</p> 		<p>Forces acting on block one:</p> <ul style="list-style-type: none"> Tension (T) Normal Reaction (N_1) Friction (f_1) Weight (W_1)
<p style="text-align: center;">block one (heavier)</p> 	<p style="text-align: center;">block two (lighter)</p> 	<p>Forces acting on block two:</p> <ul style="list-style-type: none"> Tension (T) Normal Reaction (N_2) Friction (f_2) Weight (W_1)

III - Explain

Normal force	Example	
Label: N	<div style="text-align: center;">  <p>Pointing from the contact surface</p> </div>	
Direction: Perpendicular to the contact surface		
Weight	Example	
Label: W	<div style="text-align: center;">  <p>Pointing from the centre of the object</p> </div>	
Direction: Towards the ground		
Friction	Example	
Label: f	<div style="text-align: center;">  <p>Along the contact surface</p> </div>	
Direction: Opposite to the intended motion		
Tension	Example	
Label: T	<div style="text-align: center;">  <p>Along the point of string/rope attachment</p> </div>	
Direction: along the string/rope		
External force – push /pull	Example	
Label: F	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>Push</p>  </div> <div style="text-align: center;"> <p>Pull</p>  </div> </div> <p style="text-align: center; color: red;">Subjected to the question</p>	
Direction: Subjected to the question		

Free-D Set

隔離「睇」圖

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