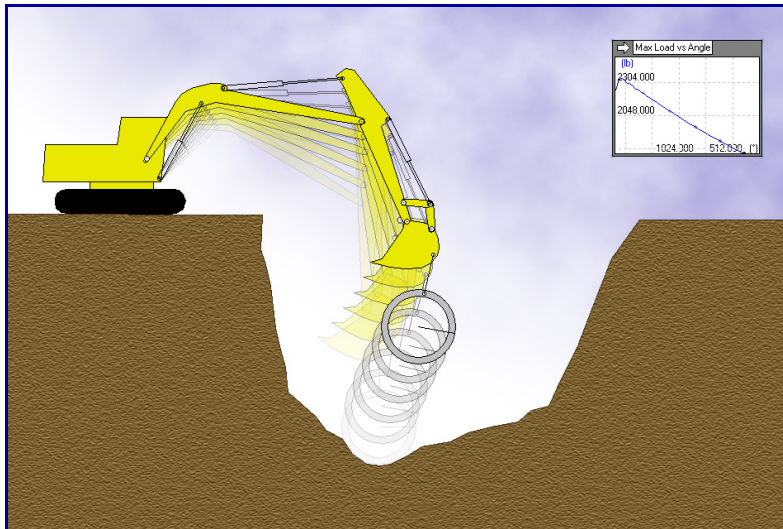


Welcome to Working Model

Working Model is the result of a 20-year collaborative effort between professional engineers and software specialists. We are committed to providing you **easy-to-use**, engineering software that makes you more productive, and saves time and money on hardware prototyping, testing, and virtual product development.

To begin, install Working Model and go through each step of the demonstration described below.

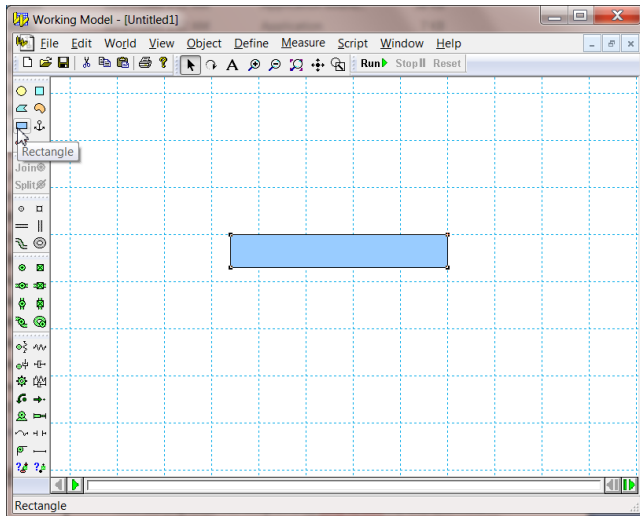


Starting Working Model

1. Ensure that Working Model is installed on your computer.
2. From the Windows Menu, click on Programs, then **Working Model 2D**, and then **Working Model 2D**. This opens a simulation.

1 Creating a Falling Block

1. The first simulation is Newton's first experiment, dropping a block.
2. To draw a rectangle, click on the Rectangle tool, then click in the workspace and draw a long thin rectangular block.
3. To run the simulation and see the block fall due to gravity, click **Run**.
4. Click **Reset** to reset the simulation.



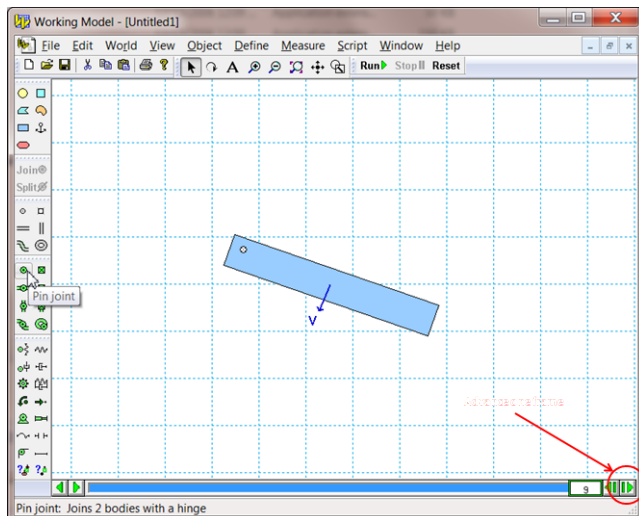
2 Adding a Velocity Vector

1. To add a velocity vector, right-click on the rectangle to display the pop-up menu.
2. From the menu, choose Vectors the choose Velocity.
3. Click **Run** and observe that the vector changes magnitude as the block falls.
4. Click **Reset**.

Optional: To show the velocity vector's x and/or y component, click on the Define menu, select Vector Display, and check the X and/or Y box.

3 Making a Pendulum

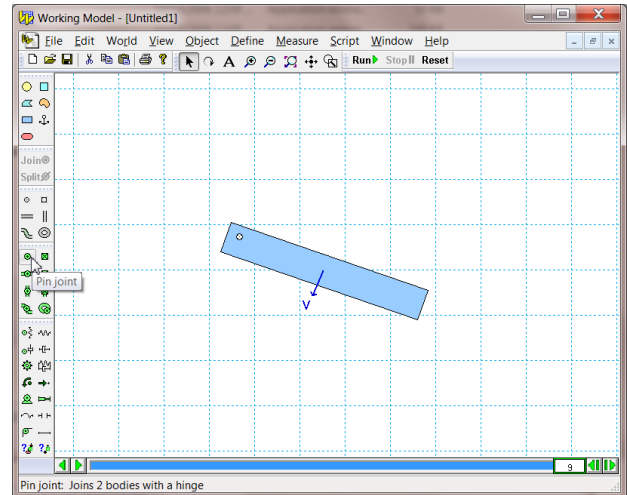
1. To make a pendulum, click on the Pin joint tool and then click on the upper left-hand corner of the rectangle.
2. Click **Run** and observe that the vector changes magnitude and direction as the pendulum moves. Click **Reset**.



Optional: Each click on  at the bottom of the screen advances one frame.

4 Graphing the Pendulum's Motion

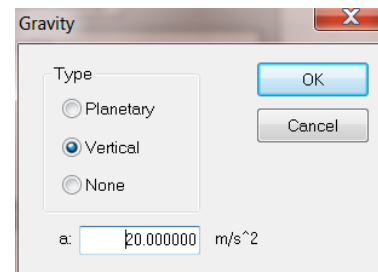
1. To graph the pendulum's motion, right-click on the rectangle. From the pop-up menu choose **Measure->Position->Rotation Graph**.
2. To collect data, click **Run**. Note: Data can be displayed as a graph, bar chart, or number, and can be changed while running the simulation by clicking the  on the top left-hand corner of the graph. Click **Reset**.
3. The graph shows the pendulum's amplitude and frequency. To make the graph larger, click on the graph and drag its lower right-hand corner to the right.



5 Changing Gravity

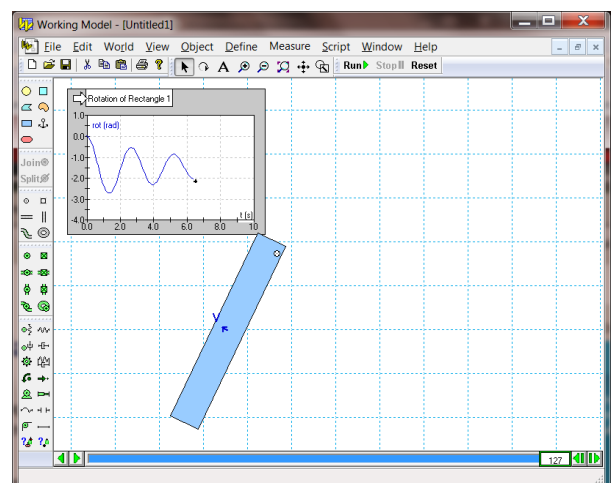
1. To change gravity, click on the World menu, select Gravity, type the value 20 m/sec² in the input box, and click [OK].
2. Click **Run** and observe that, in agreement with theoretical and experimental predictions, the pendulum has a higher natural frequency. Click **Reset**.

*Note: Working Model was designed to be **easy-to-use**. For example, in this exercise, the only time you need to touch the keyboard is to enter the value 20.*



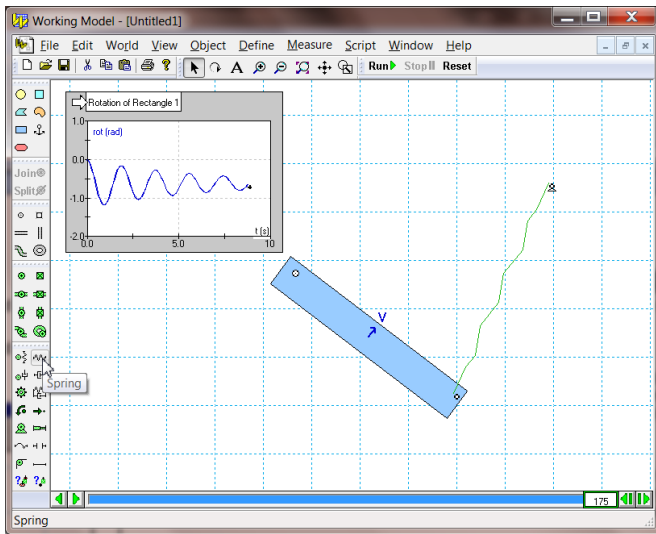
6 Adding Air Resistance

1. Under the World menu, select Air Resistance, click on Low Speed, and accept the default air resistance value of 0.3 kg/(m*s) by clicking [OK].
2. Click **Run** and observe the exponentially decaying oscillations. Click **Reset**.



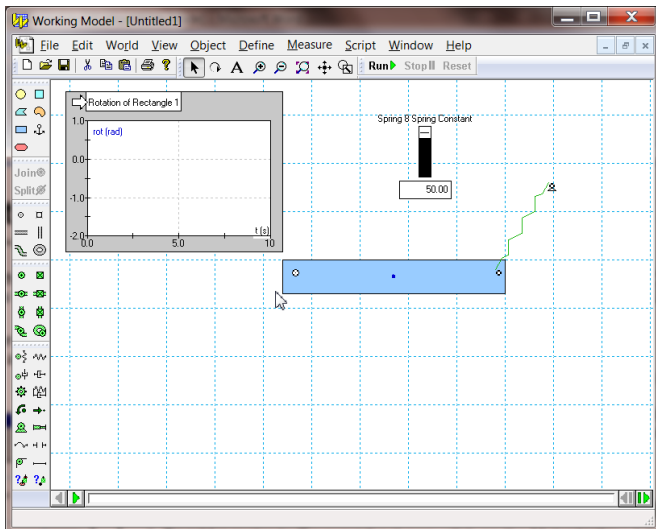
7 Adding a Spring

1. To add a spring, click on the Spring tool. Click on the upper right-hand corner of the block and stretch the spring up and to the right.
2. Click **Run** and observe the pendulum's higher natural frequency and new equilibrium position. Click **Reset**.



8 Controlling the Spring Constant

1. To control the spring constant, right-click on the spring. From the pop-up menu choose **Measure->New Control->Spring Constant**.
2. The slider that controls the spring will appear in the left-hand side of the workspace. To move the slider's location closer to the spring, click on its **title** and drag it next to the spring.
3. To see the effect of varying the spring constant, click **Run** and observe that the pendulum angle is a function of the spring-constant (move the slider up and down while the simulation is running). Click **Reset**.

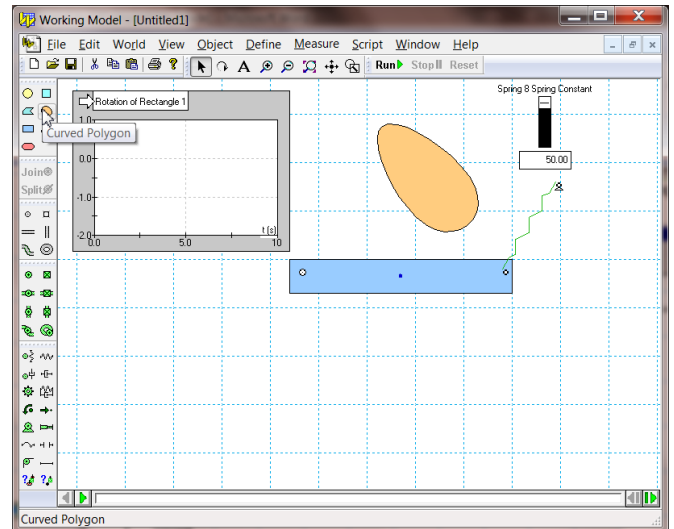


Optional: The properties of any object can be modified by either double-clicking on the object (e.g., the rectangle, pin point, graph, spring, spring-constant control) or right clicking on it and choosing **Properties** from the pop-up menu. The appearance or geometry of an object can be modified by right clicking on the object, and selecting **Appearance** or **Geometry** from the pop-up menu..

9 Collisions with a Smooth Polygon

1. To create a smooth polygon, click on the Curved Polygon tool, click in the workspace in a few locations. Double-click to close the polygon.
- (If your rectangle is high on the screen, click  to zoom to extents.)
2. Click **Run** to start the simulation and observe that the curved polygon bounces and rolls on top of the rectangle. Automatic collision and contact is a very useful feature in Working Model (even the elastic and frictional properties of objects may be varied). Click **Reset**.

Note: Collision sound/motion sound can be added to a simulation. To add a collision sound, click on the curved polygon, select the Measure menu, and choose Hear the Collision. (computer speakers required)

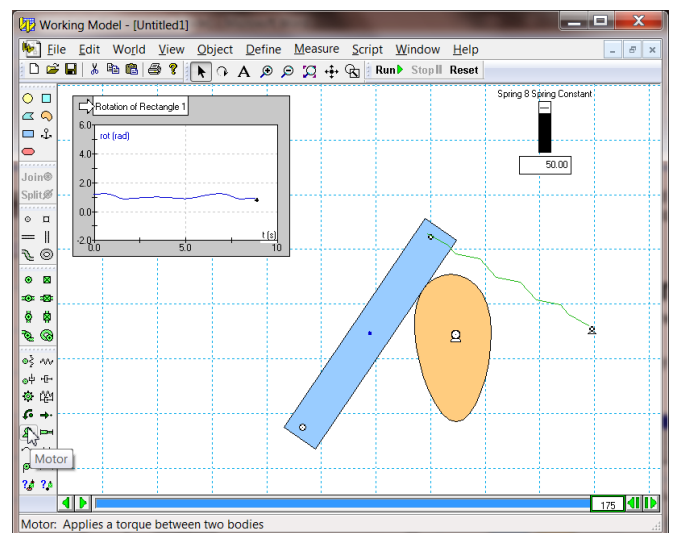


10 Smart Editor

1. Working Model's Smart Editor allows the user to change an object's position and orientation while keeping constraints intact.
2. To change the orientation of the rectangle, click on the rectangle and drag the mouse to rotate the rectangle counterclockwise so that it is nearly vertical as shown below. (If necessary, click  to view to extents.)

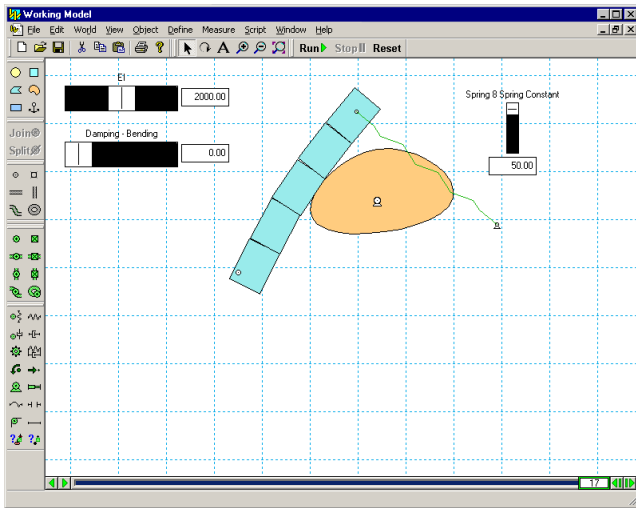
11 Creating a Cam-Follower Mechanism

1. To add a motor to the curved polygon, click on the Motor tool, and then click on the curved polygon.
2. Click **Run** and observe that the rectangle's motion is determined by the shape of the curved polygon and the motor's speed. Click **Reset**.



12 Creating a Flexible Beam

1. To convert the rectangle into a flexible beam (Flexbeam), click on the rectangle.
2. Under the Script menu, select Flexbeam.
3. In the "Flexible Body Information" dialog box, accept the default values and click [OK]. Click [OK] in the "No Flexbeam Undo" dialog Box.
4. Click **Run** to start the simulation and observe that the formerly rigid rectangle is now acting as a Flexbeam. Change the values of the "EI" and "Damping - Bending" sliders to change the Flexbeam's stiffness and damping. Click **Reset**.



13 Animation Step and Integrator Error

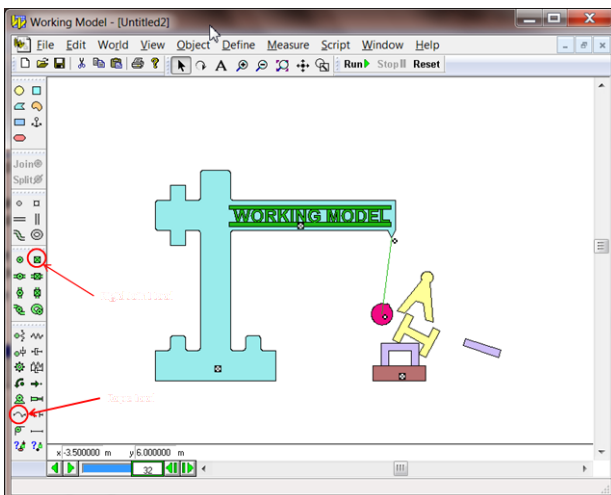
1. To change accuracy, select the World menu and then Accuracy...
2. Select an Integrator Error small enough to meet your accuracy requirements.
3. Select an Animation Step that produces smooth visual results.

14 Importing DXF Files

1. Open a new simulation by selecting the File menu and clicking on New.
2. To import a DXF file, select the File menu and click on Import.
3. In the Import window, navigate to the directory where Working Model is installed, for example, C:\Program Files\Working Model 2D and then select the sub-directory WM\Introduction.
4. Select the file WMDXFDemo.dxf and click [Import]. This imports the DXF objects (a crane, wrecking ball, a Working Model logo, and an abandoned building).
5. Click **Run** and watch all the objects fall due to gravity. Click **Reset**.

15 Simulating a Building Demolition

1. To anchor the base of the building, click on the Rigid Joint tool, then click on the base of the building.
2. To anchor the crane, click on the Rigid Joint tool, then click on the crane.
3. To fix the Working Model logo to the crane, click on the Rigid Joint tool, then click on the Working Model logo.
4. To attach the wrecking ball to the crane with a rope, click on the Rope tool, then single-click on the ball, and then single-click on the crane to create a rope.
5. Click **Run** and observe that Working Model detects the shape of the imported DXF objects and automatically calculates how they collide. Click **Reset**.

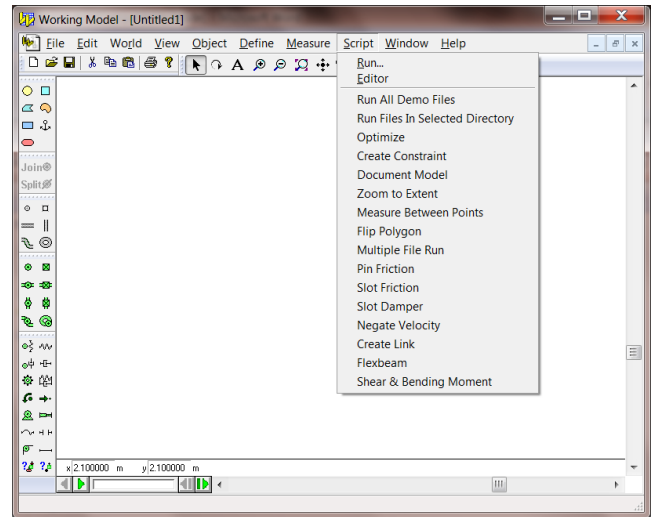


16 Adding Colors to DXF Objects

1. Objects that are imported from a DXF file are treated the same as objects created within Working Model. You can change their appearance, measure their velocity, acceleration, etc.
2. To add color to the crane, right-click on the crane.
3. Choose **Appearance** from the pop-up menu.
4. In the Appearance window, note that the fill pattern is currently set as "no." Click on the drop-down menu and change it to another pattern.
5. Click on the fill color drop-down menu and change the fill color to blue.
6. Close the Appearance window.
7. To change the color of the other objects, repeat steps 2 to 6.
8. Click **Run** to start the simulation. Click **Reset**.

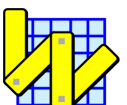
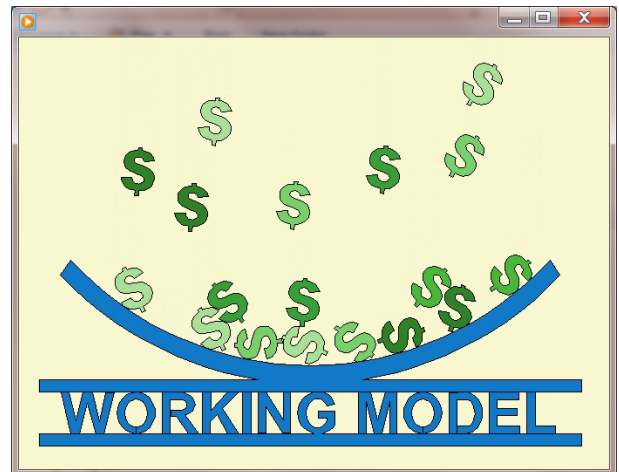
17 Running Demo Files

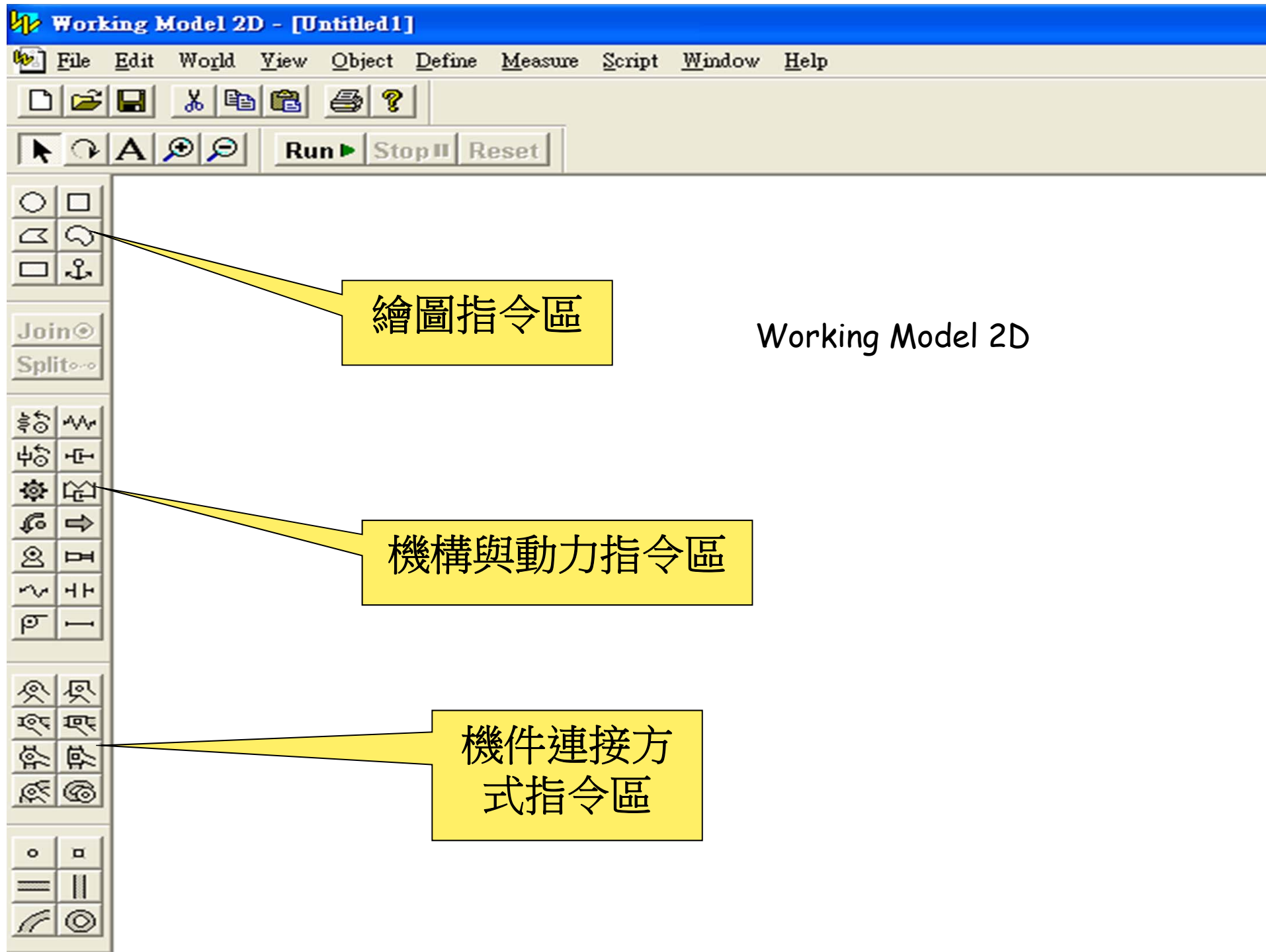
1. Under the Script menu, click on "Run All Demo Files".
2. Sit back and enjoy a series of demos on a variety of engineering topics.



18 Creating a Movie

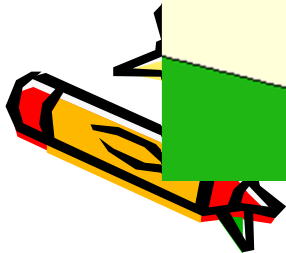
1. You can create a movie from any Working Model simulation.
2. To see an example, select **File** menu, then **All Programs**, then **Working Model 2D**, then **Working Model 2D Files**, then **Introduction** and then double-click on WorkingModelMoneyBowl.avi.



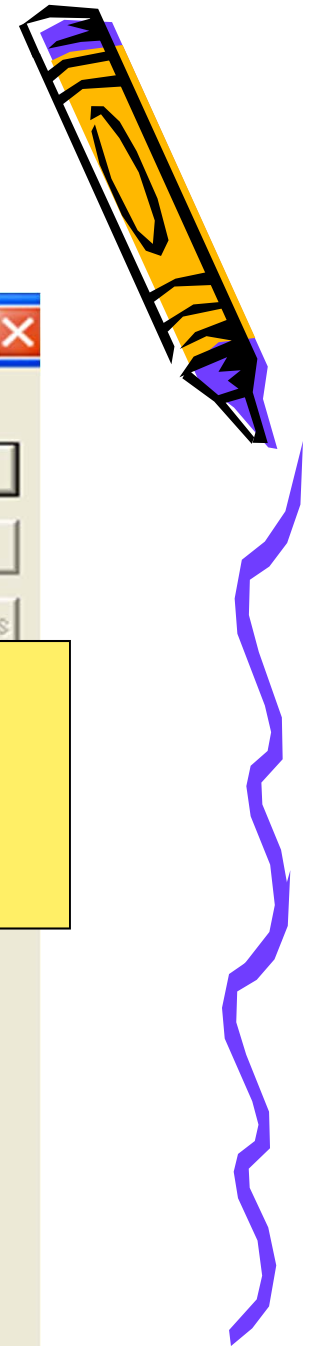


A yellow pencil with a purple eraser and a purple band is shown drawing a wavy purple line on a white background. The pencil is positioned diagonally, with the eraser at the top and the lead tip at the bottom. The line it has drawn is a simple, wavy, horizontal stroke.

Pause control, under the World menu, is used to stop the simulation when a specific condition is met. This allows you to leave your computer as you run long simulations.



模擬速度快慢的 調整設定方法



Simulation Accuracy

☐ Fast
☐ Accurate
☒ Custom

Animation Step
☐ Automatic
☒ 0.050 sec
20.000 /sec

Integrator Error
☒ Automatic
☐ 0.502 in

Integrator
☐ Euler (approximate, fast)
☒ Runge-Kutta (accurate)

Integration Step
☐ Fixed
☒ Variable

Overlap Error:
☐ Automatic
☐ 0.502 in

Assembly Error:
☒ Automatic
☐ 0.050 in

Significant Digits:
☒ Automatic
☐ 7

Warnings:
☐ Inaccurate integration
☒ Initial body overlap
☐ Redundant constraints
☒ Inconsistent constraints

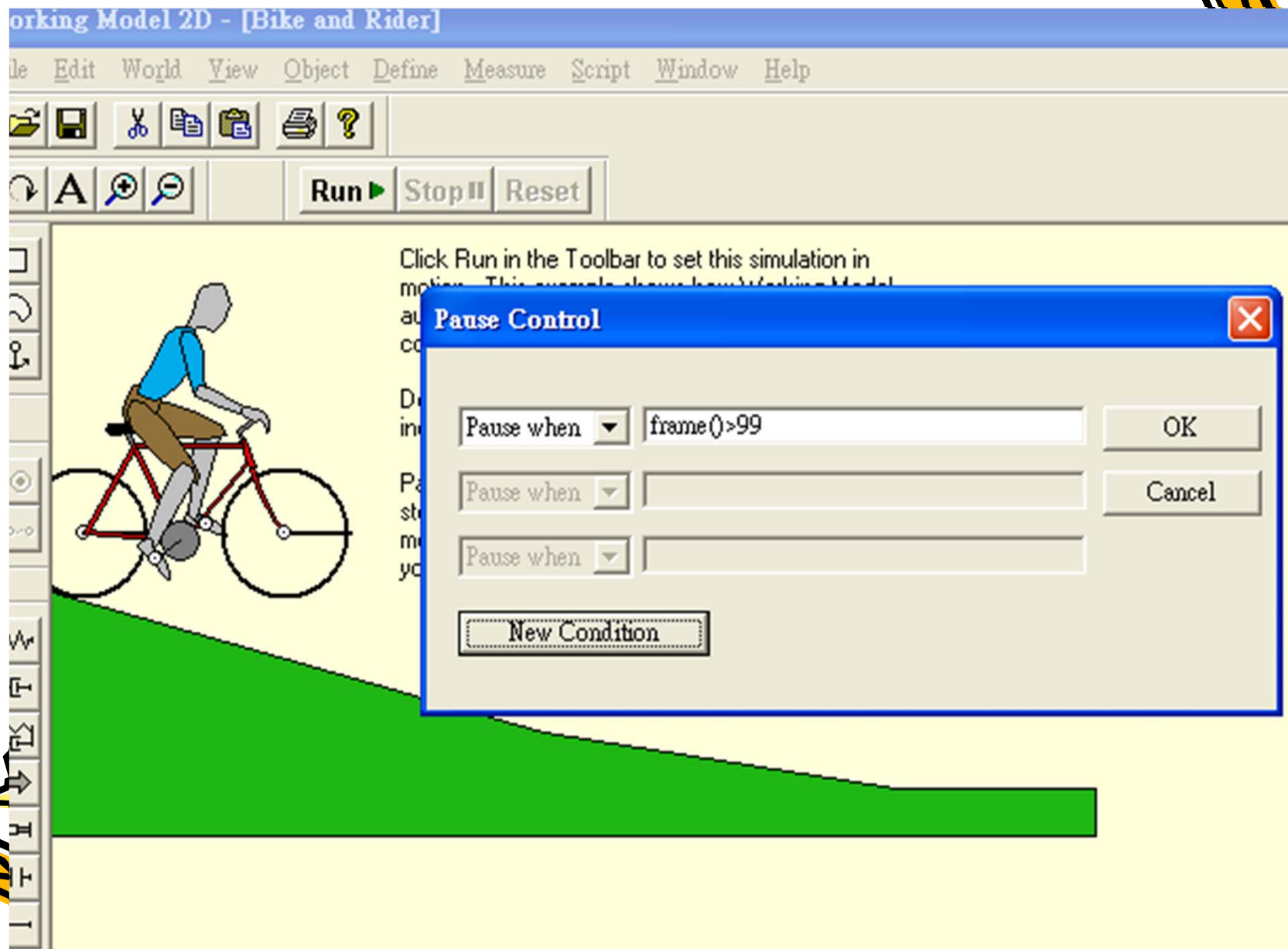
OK
Cancel
Fewer Choices

軟體設定為”自動”

一步驟 0.05秒，
秒數設定越小，
模擬速度越慢

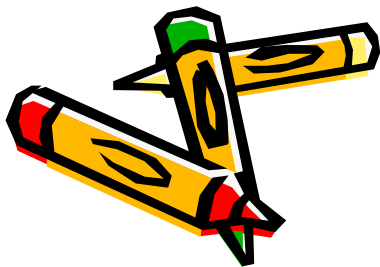
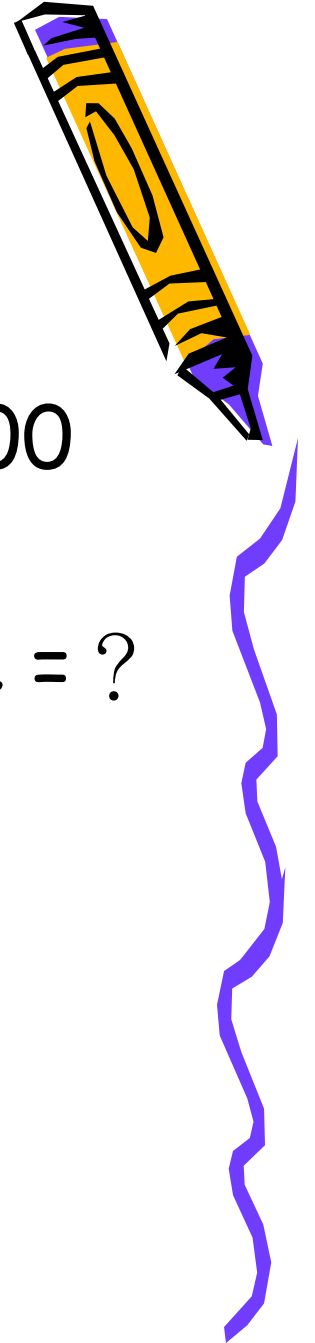


Pause Control



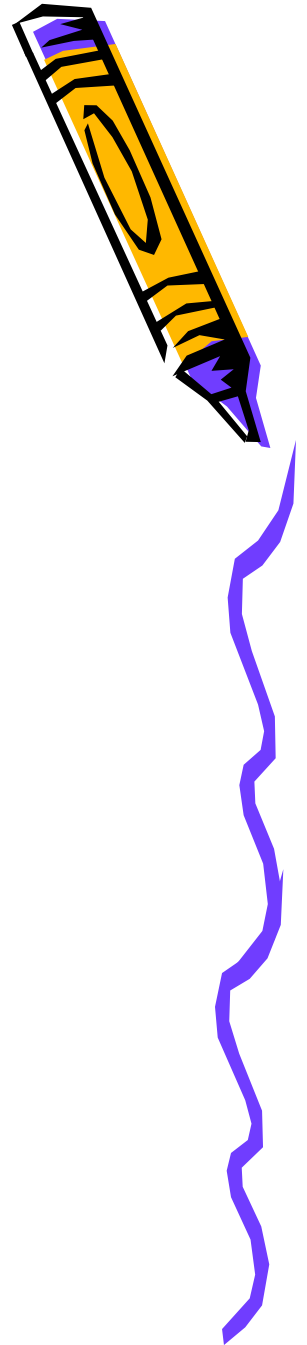
Time setting method

- Set frame() >99 , means frame=100 will begin action.
- Set frame=100 , it means set time = ?
- $100 \text{ frame} \times 0.02 \text{ sec} = 2 \text{ sec}$
- Set time= 3 sec, frame will be 150

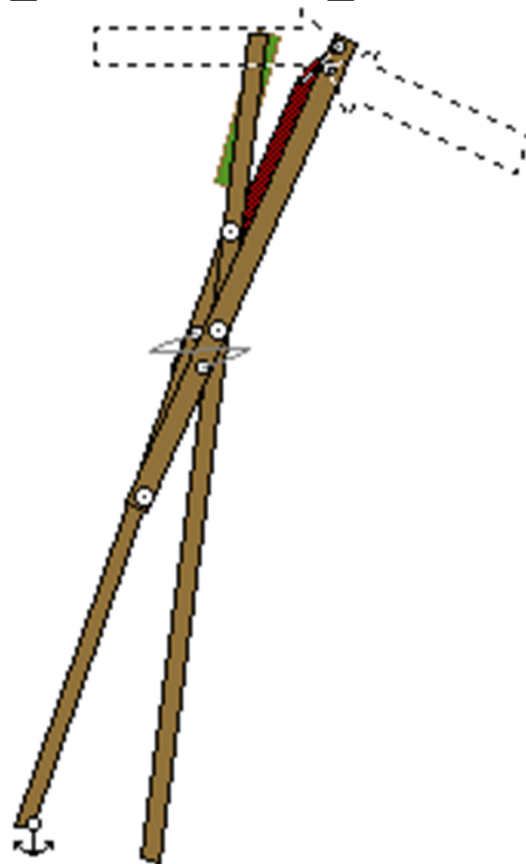


Pause control

- Reset
- Loop
- Stop



Working model 2D/SAMPLE/ Engineering/Mechanism/chair

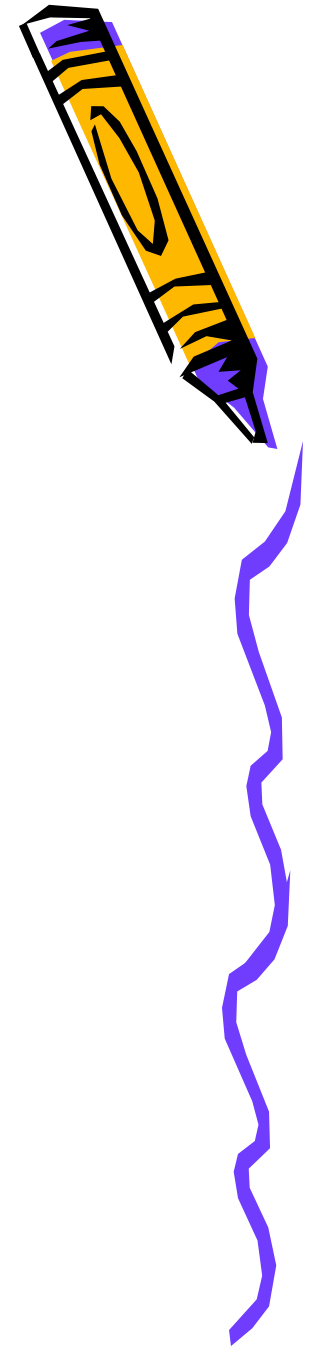


Click the RUN button, and press and hold the "Open" button to open up this chair, and the "Close" button to close it back up. This simulation shows how events can easily be controlled by a user. In this case, a two forces are being interactively turned on and off as the simulation is running.

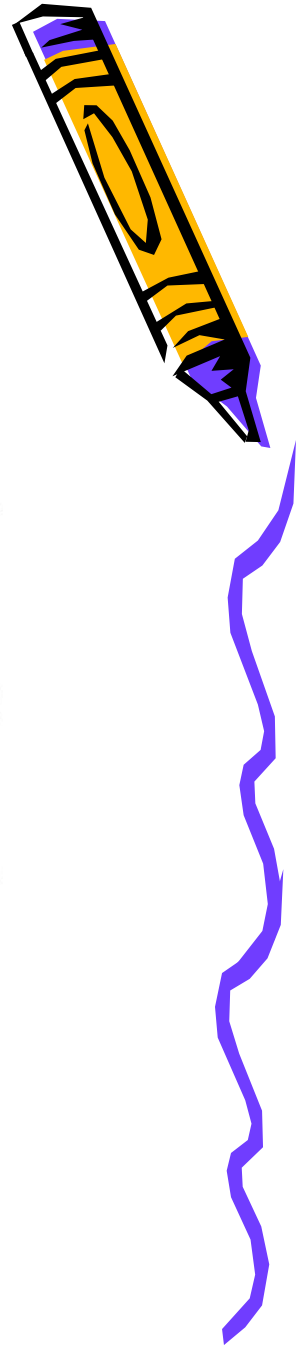
This simulation also shows some of the power of the Smart Editor. Click on the red cushion and, holding the mouse button down, drag to the right. The mechanism is exercised, and the chair opens. This feature, called inverse kinematics, is a very powerful tool that can be used during the layout and design of a mechanism.

Open Chair

Close Chair

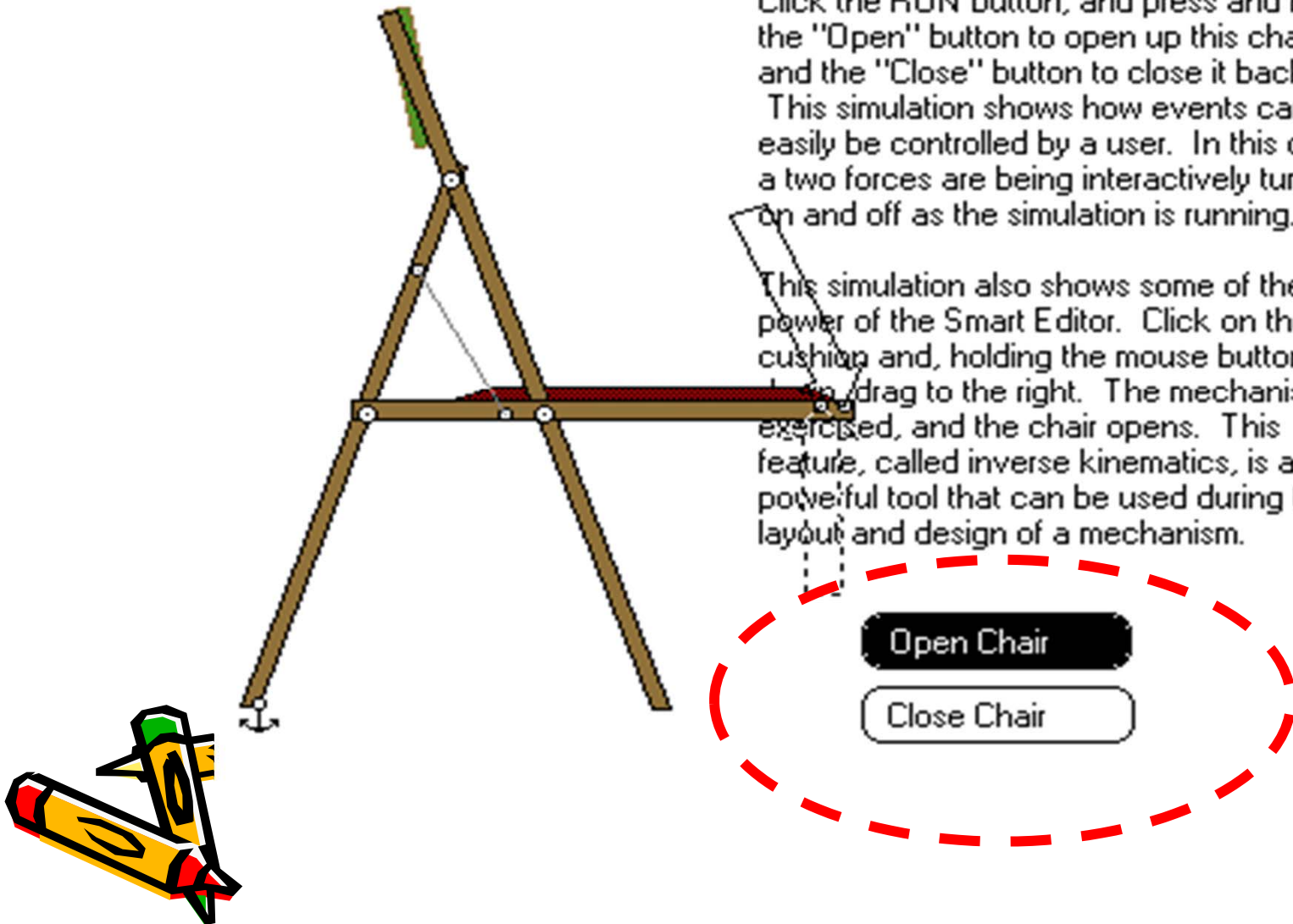


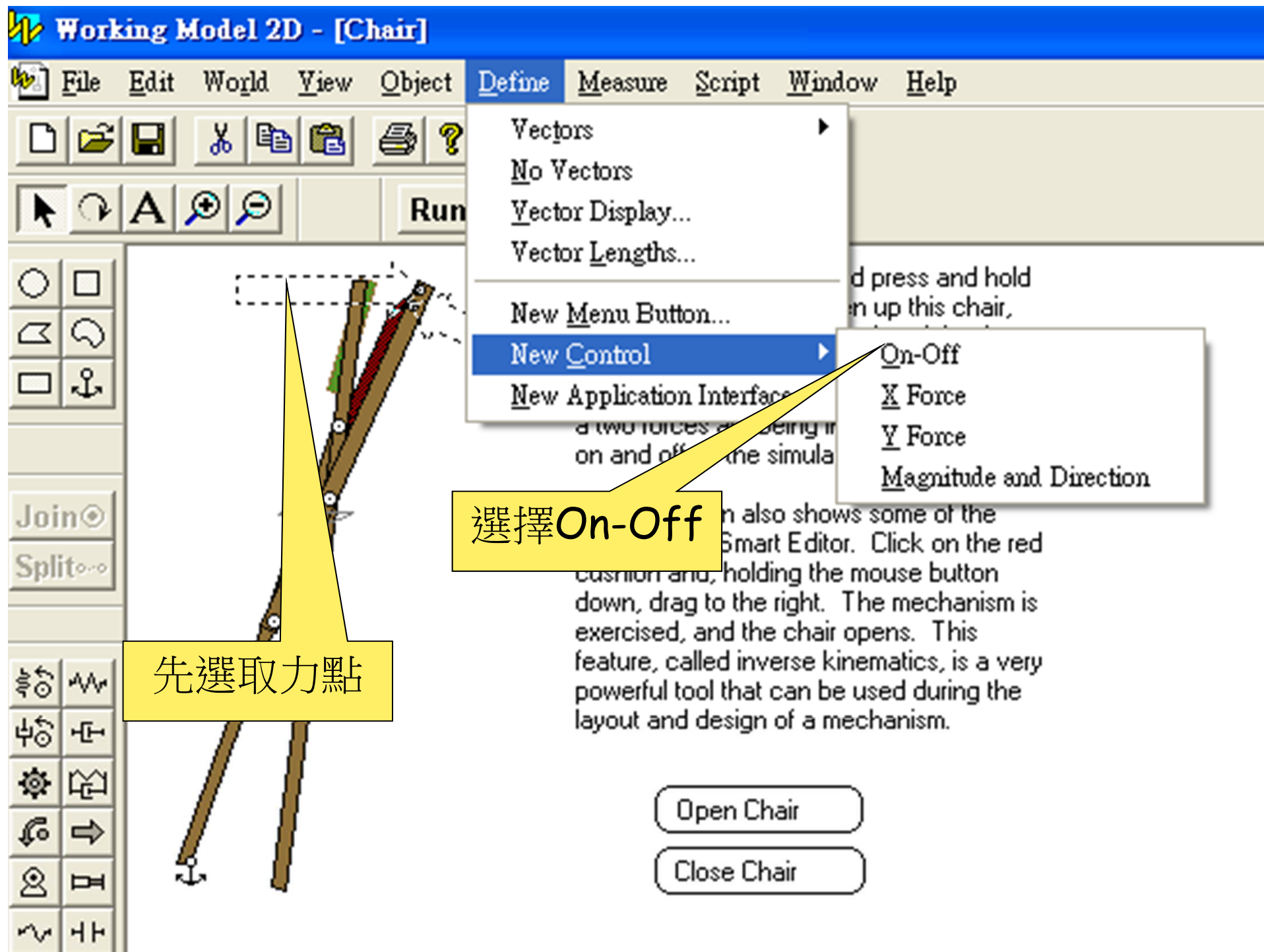
如何產生控制按鈕？



Click the RUN button, and press and hold the "Open" button to open up this chair, and the "Close" button to close it back up. This simulation shows how events can easily be controlled by a user. In this case, a two forces are being interactively turned on and off as the simulation is running.

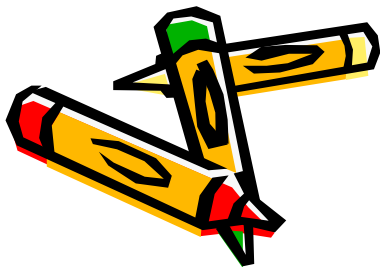
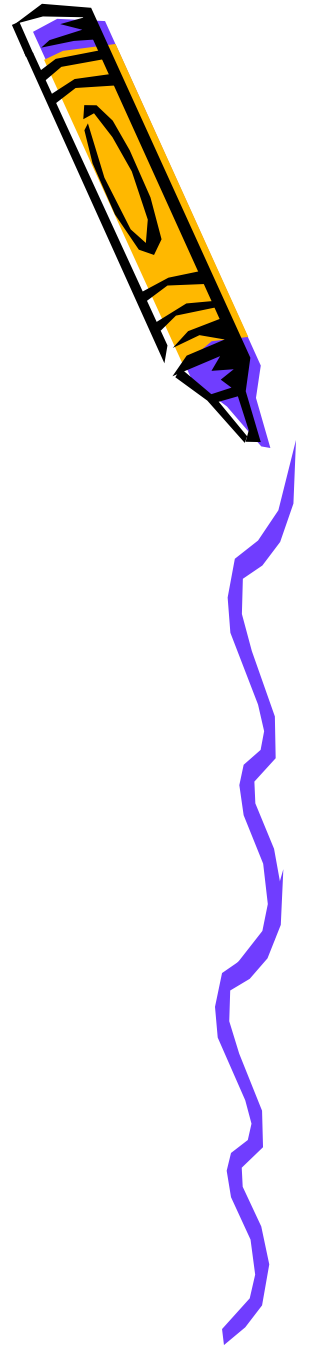
This simulation also shows some of the power of the Smart Editor. Click on the red cushion and, holding the mouse button down, drag to the right. The mechanism is exercised, and the chair opens. This feature, called inverse kinematics, is a very powerful tool that can be used during the layout and design of a mechanism.

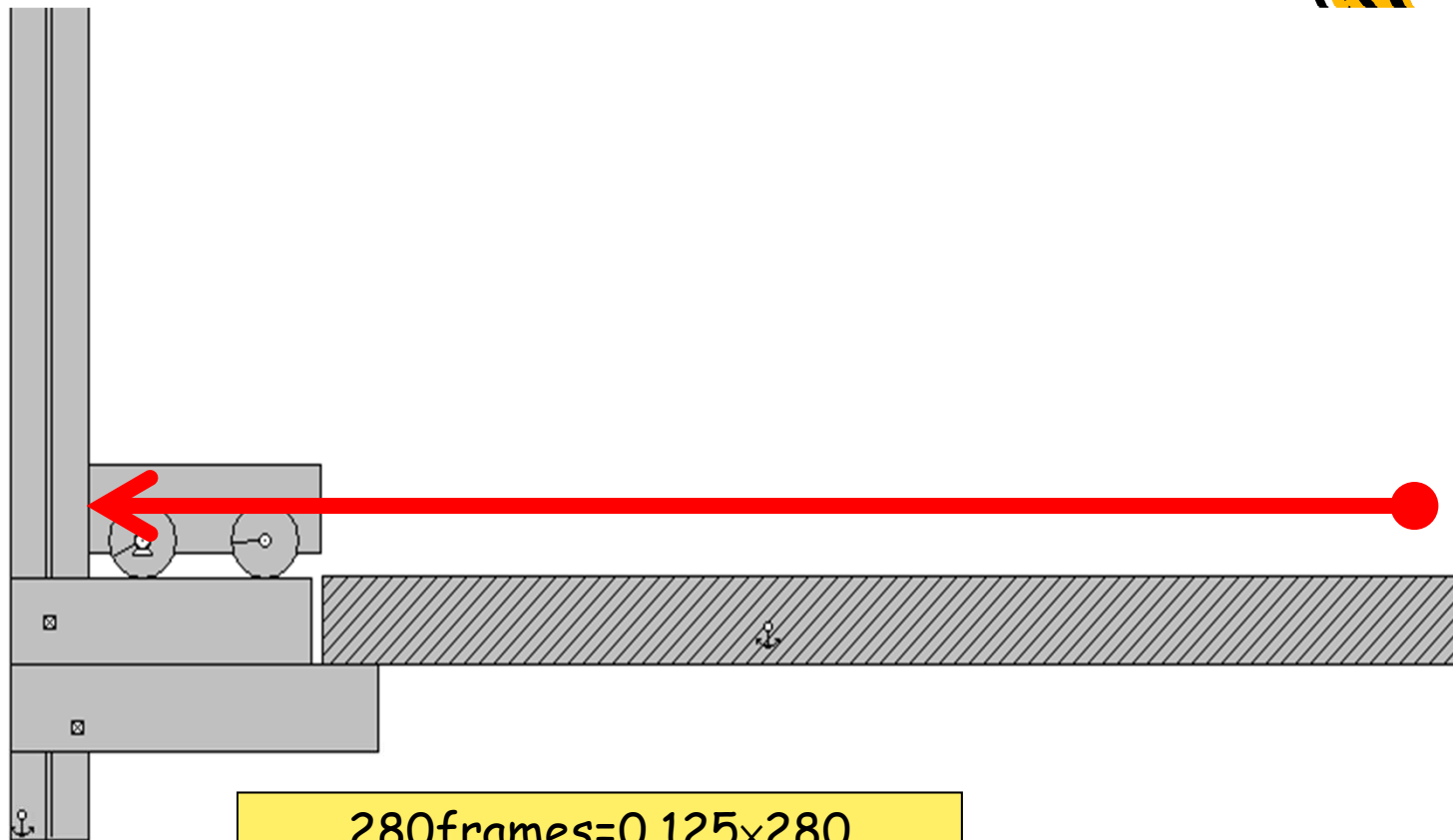




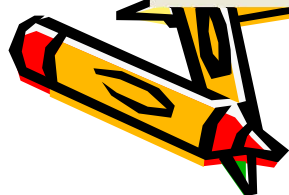
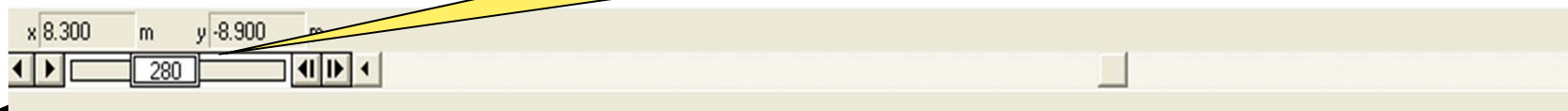
時序控制之方法

- 時間參數之設定：
- World > > Accuracy > > Animation Step > > 0.125 sec





$280\text{frames} = 0.125 \times 280$
 $= 35 \text{ sec}$ 到達



Properties

* Constraint[14] - Motor

Motor

Type Velocity

value 57.296 ?s

Base Point

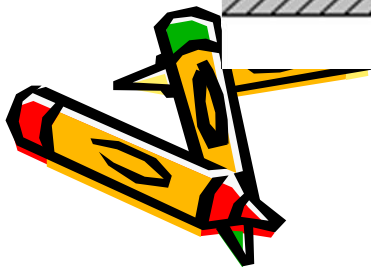
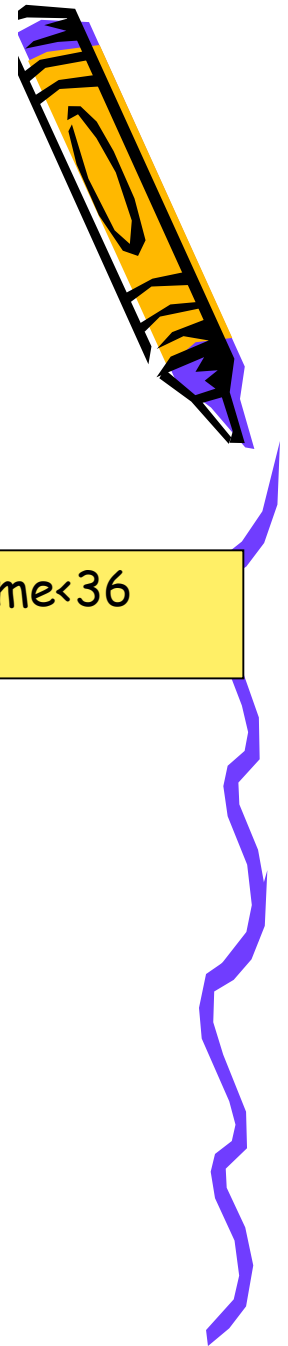
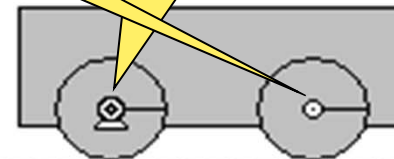
Active when

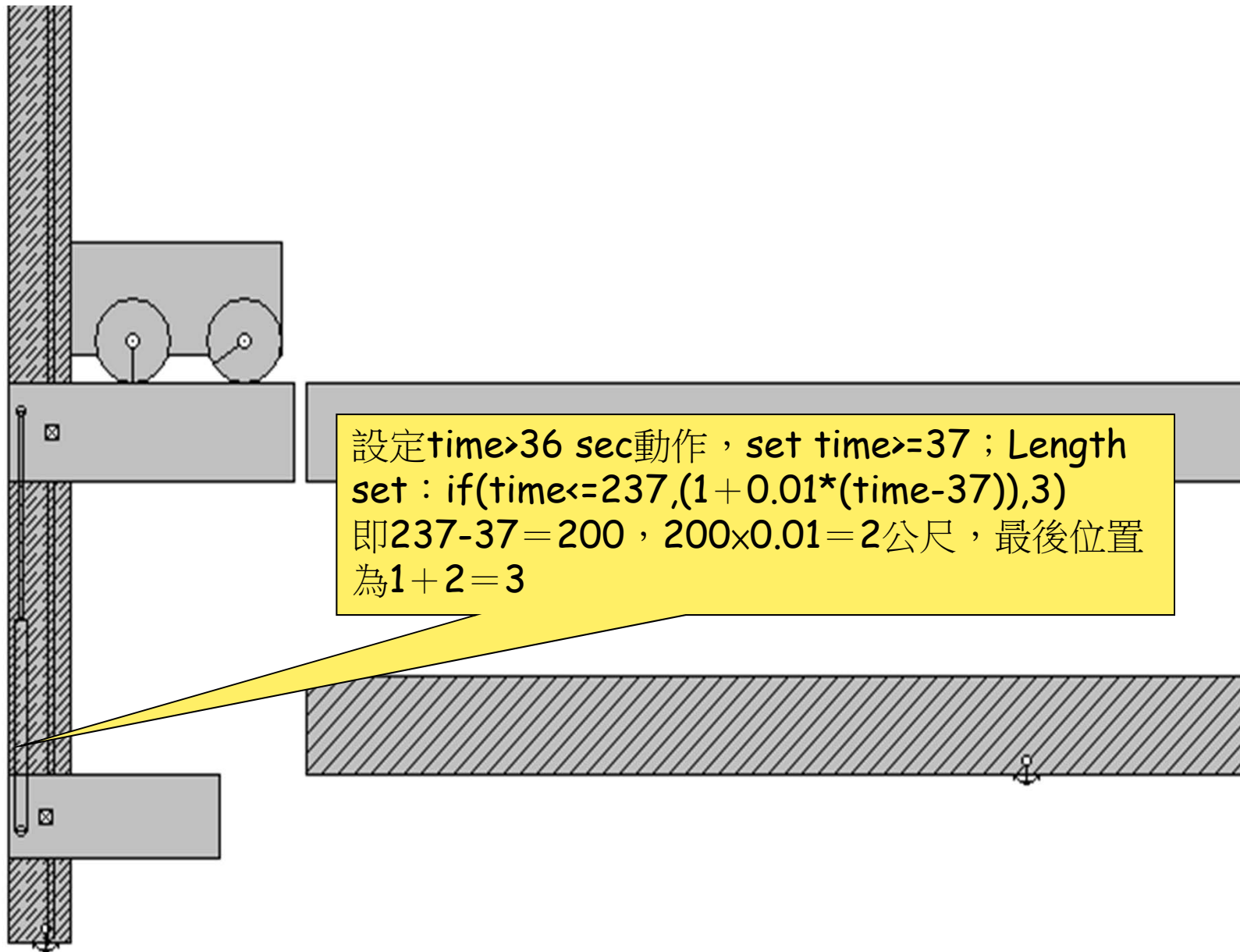
☐ Always

time < 35

馬達設定 time>237以後
動作；set time>=240

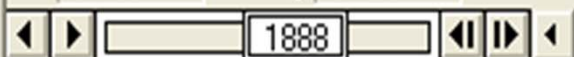
馬達時間設定 Time<36



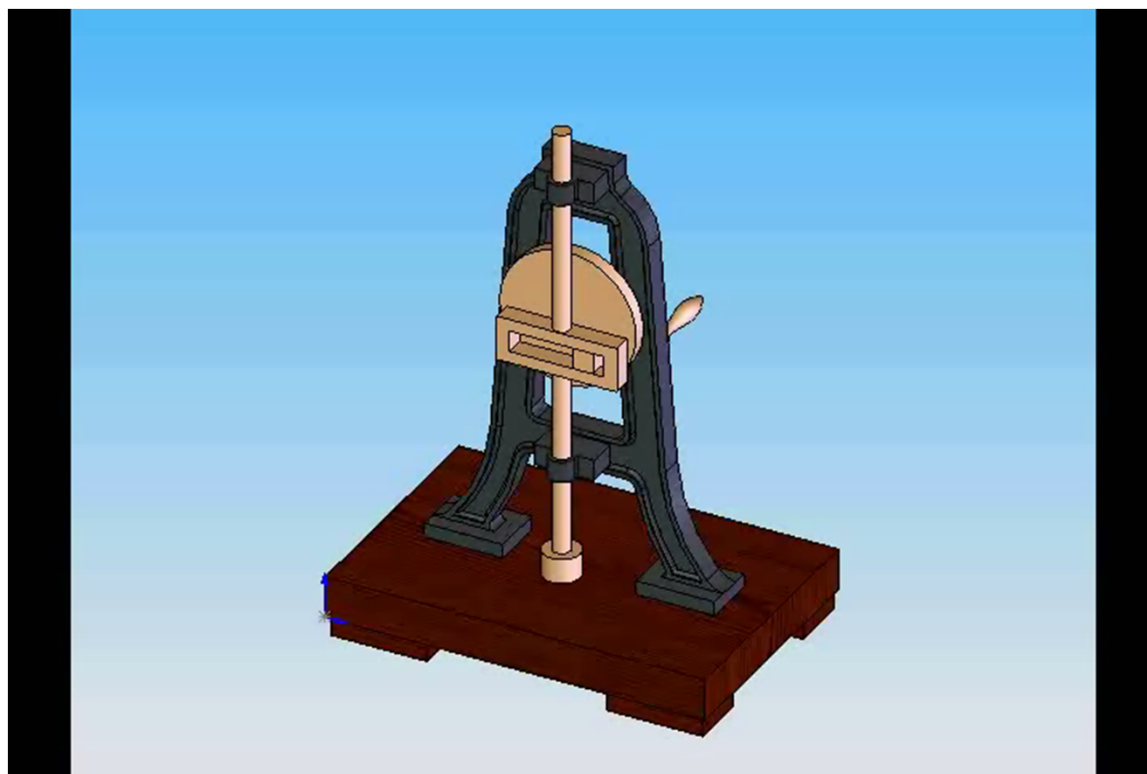
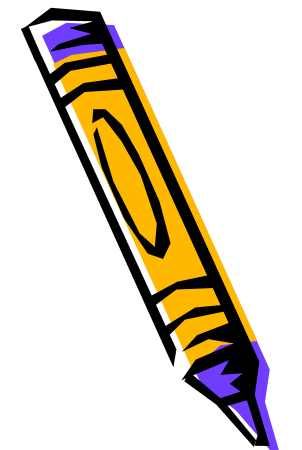


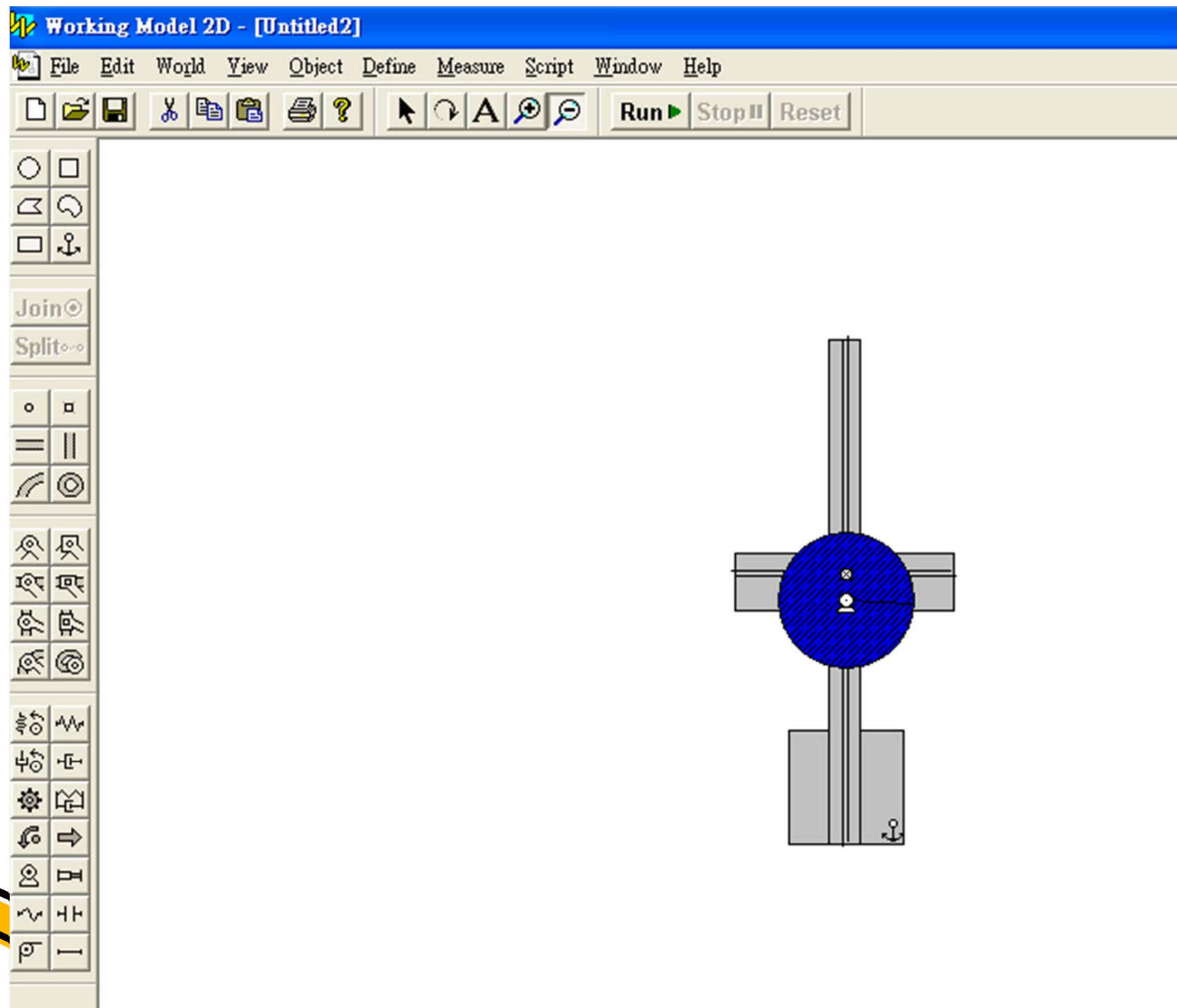
設定time>36 sec動作，set time>=37；Length
set：if(time<=237,(1+0.01*(time-37)),3)
即 $237-37=200$ ， $200 \times 0.01=2$ 公尺，最後位置
為 $1+2=3$

x -0.750 m y -0.100 m



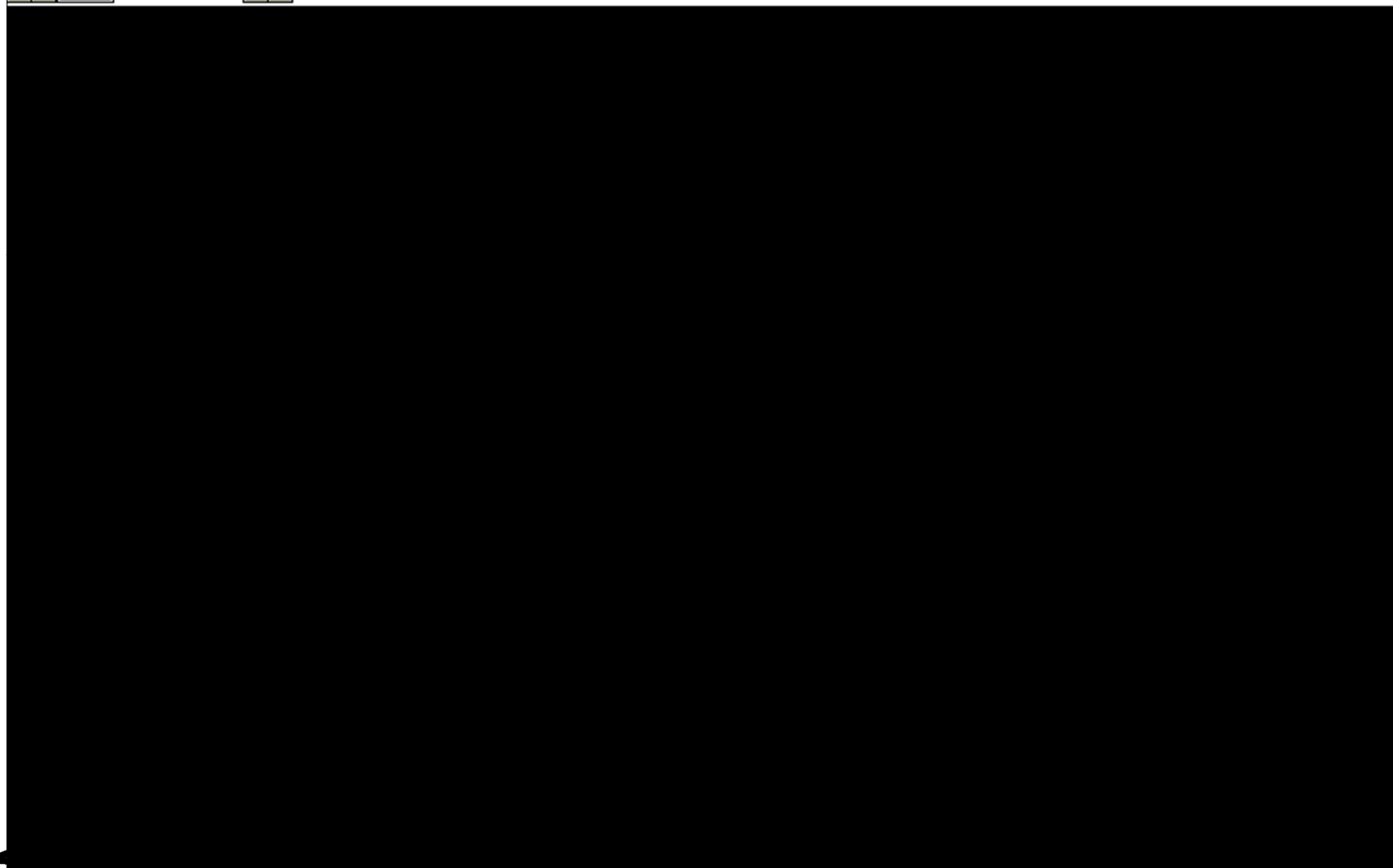
Ready



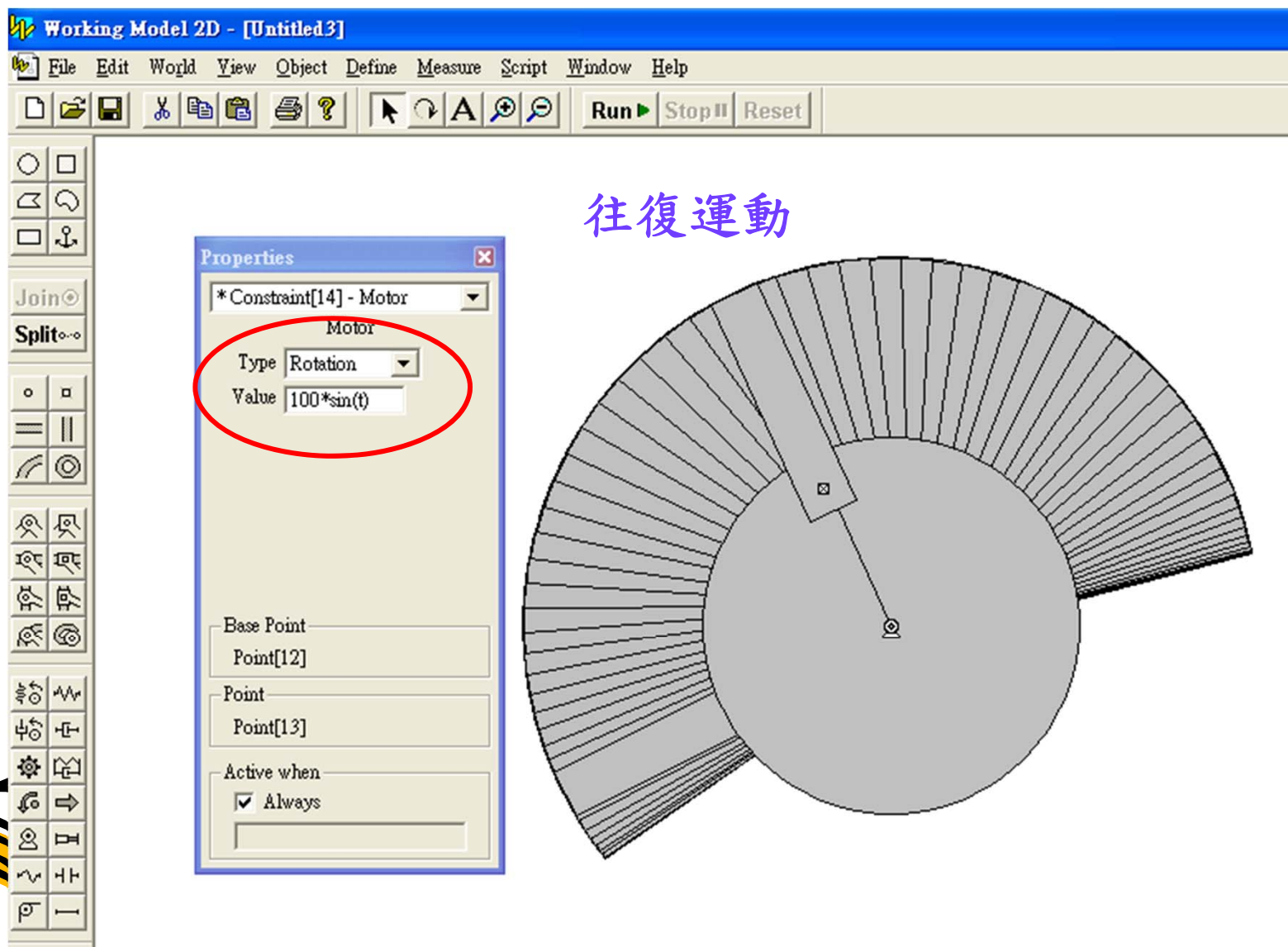




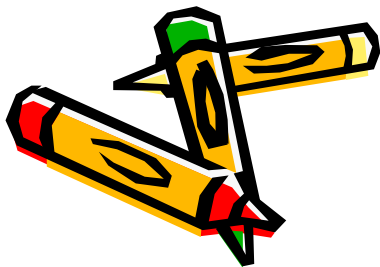
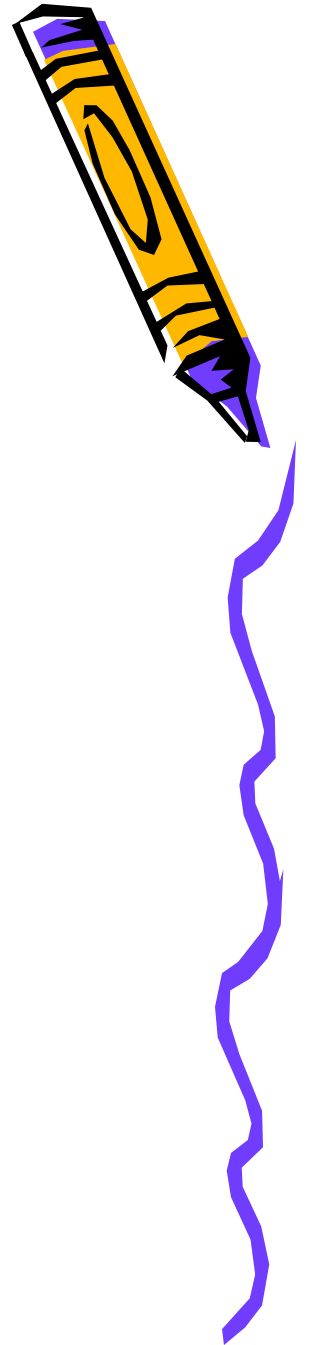
x 7.000 m y 0.200 m
◀ ▶ 0 ◀ ▶



馬達的控制設定方法



- $\sin(t)=0\sim 1$ 之間作變化
- $10*\sin(t)$ 將於 $0\sim 10$ 間作變化
- $\cos(t)=-1\sim +1$ 之間作變化



Time
t 0.000 s

Properties

*Constraint[19] - Motor

Motor

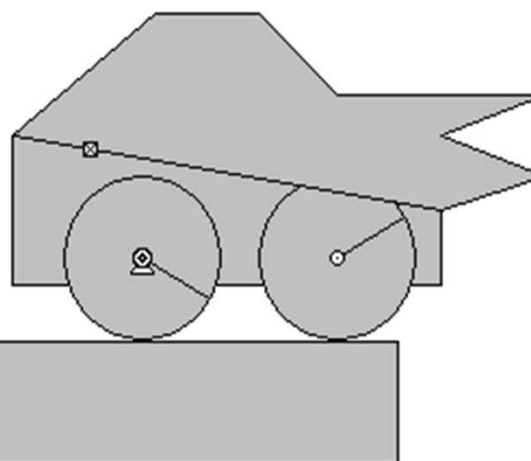
Type Velocity

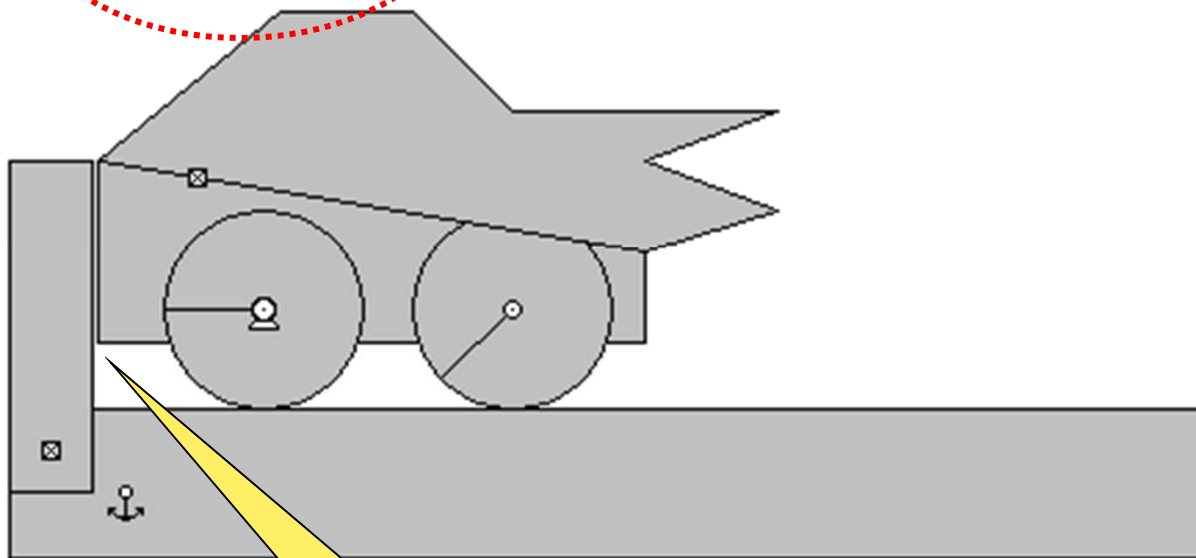
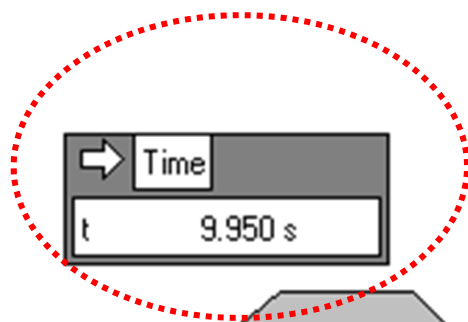
Value 1.000 rad/s

Base Point
Point[17]

Point
Point[18]

Active when
☒ Always

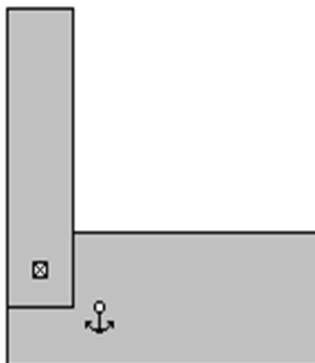




找到終點位置時的
時間



Time
t 0.000 s



Properties

*Constraint[19] - Motor

Motor

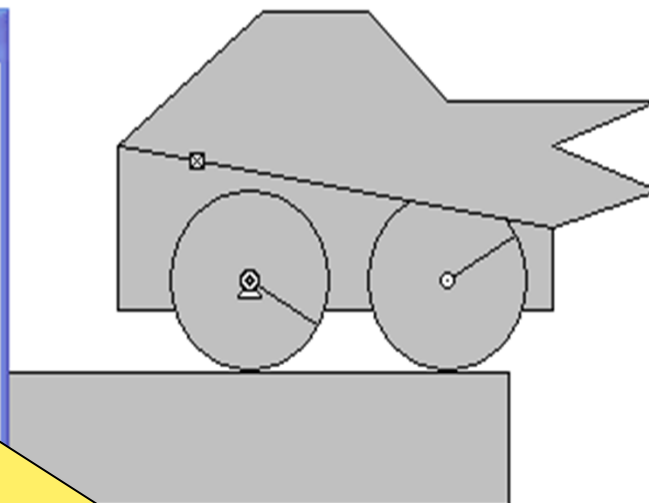
Type Velocity

Value $\text{if}(t < 10, 1.000, 0)$

Base Point
Point[17]

Point
Point[18]

Active when
☒ Always



$\text{If}(t < 10, 1, 0)$
在10之前馬達速度=1
超過10後馬達速度=0





南榮科技大學102學年度第二學期教師教學媒體觀摩及數位教材製作

理論與實務之教學結合應用：

以連桿機構之研究為例

報告人：工程科技研究所 副教授
蔡錦山

大綱

- § 摘要
- § 緒言
- § 連桿機構之簡介
- § 連桿機構之製作
- § 連桿機構之運動分析
- § 結論

摘要

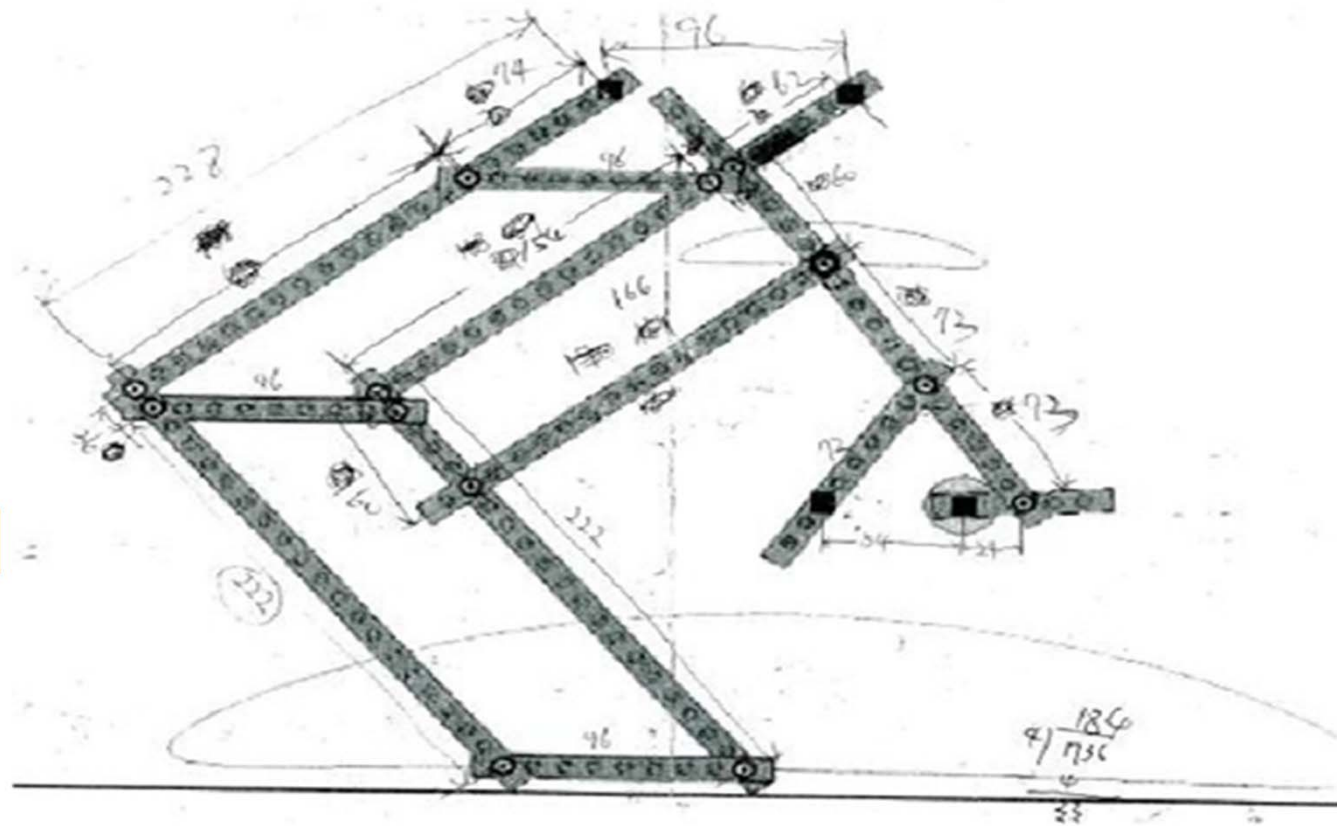
先利用 **Working Model 2D** 軟體將各連桿機構，依所設定之尺寸等比例繪圖、輸入動力源參數後進行動作模擬及分析，並藉由軟體針對連桿機構之特定位置進行速度、加速度及作用力之計算；再將所模擬之連桿機構加工、組裝及測試、模組化後，與 **Working Model 2D** 軟體所模擬之結果進行比較。

緒言

- 研究動機
- 研究目的

研究動機

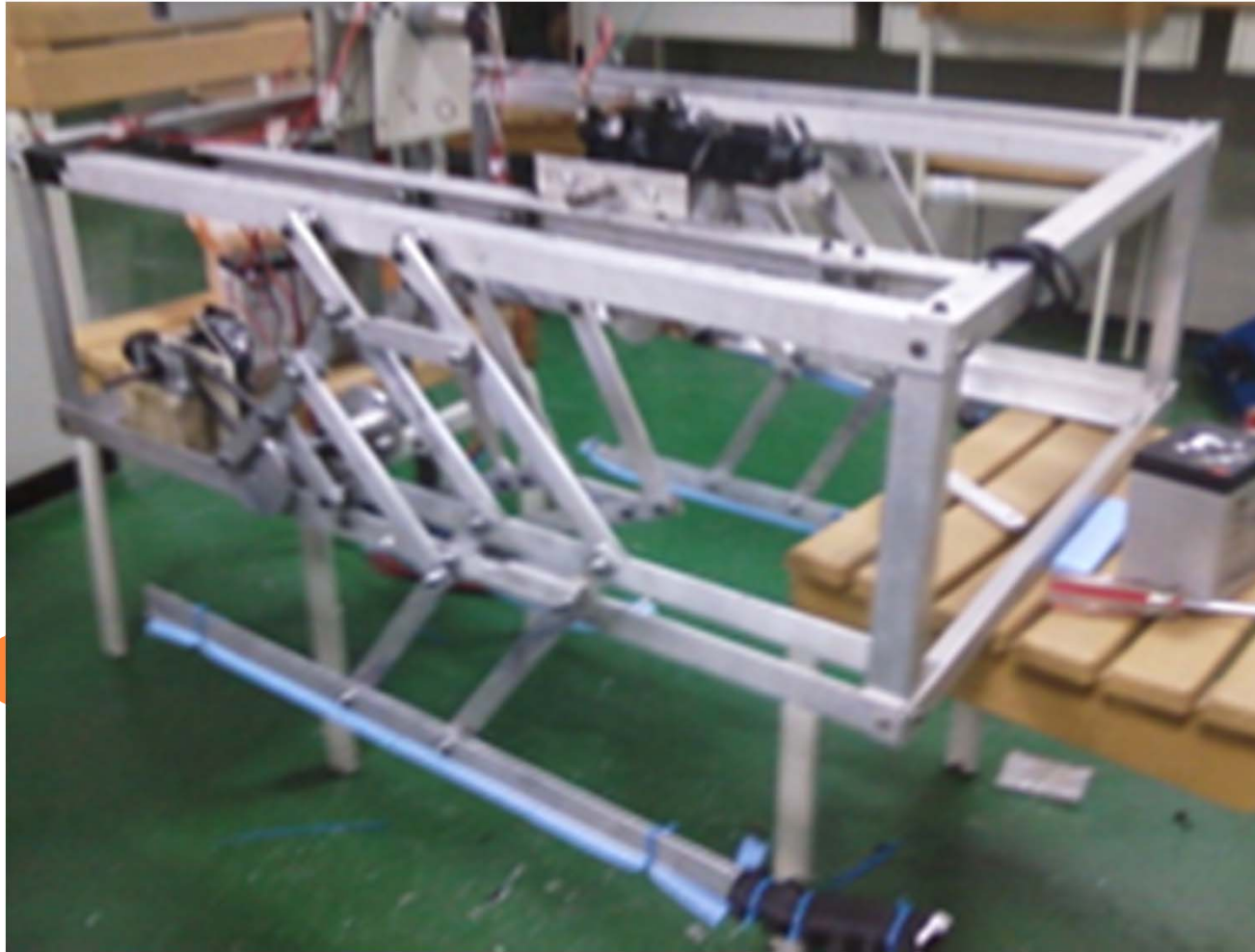
雙Chebyshev足部機構設計圖



雙Chebyshev足部機構模擬圖



雙Chebyshev足部機構完成圖



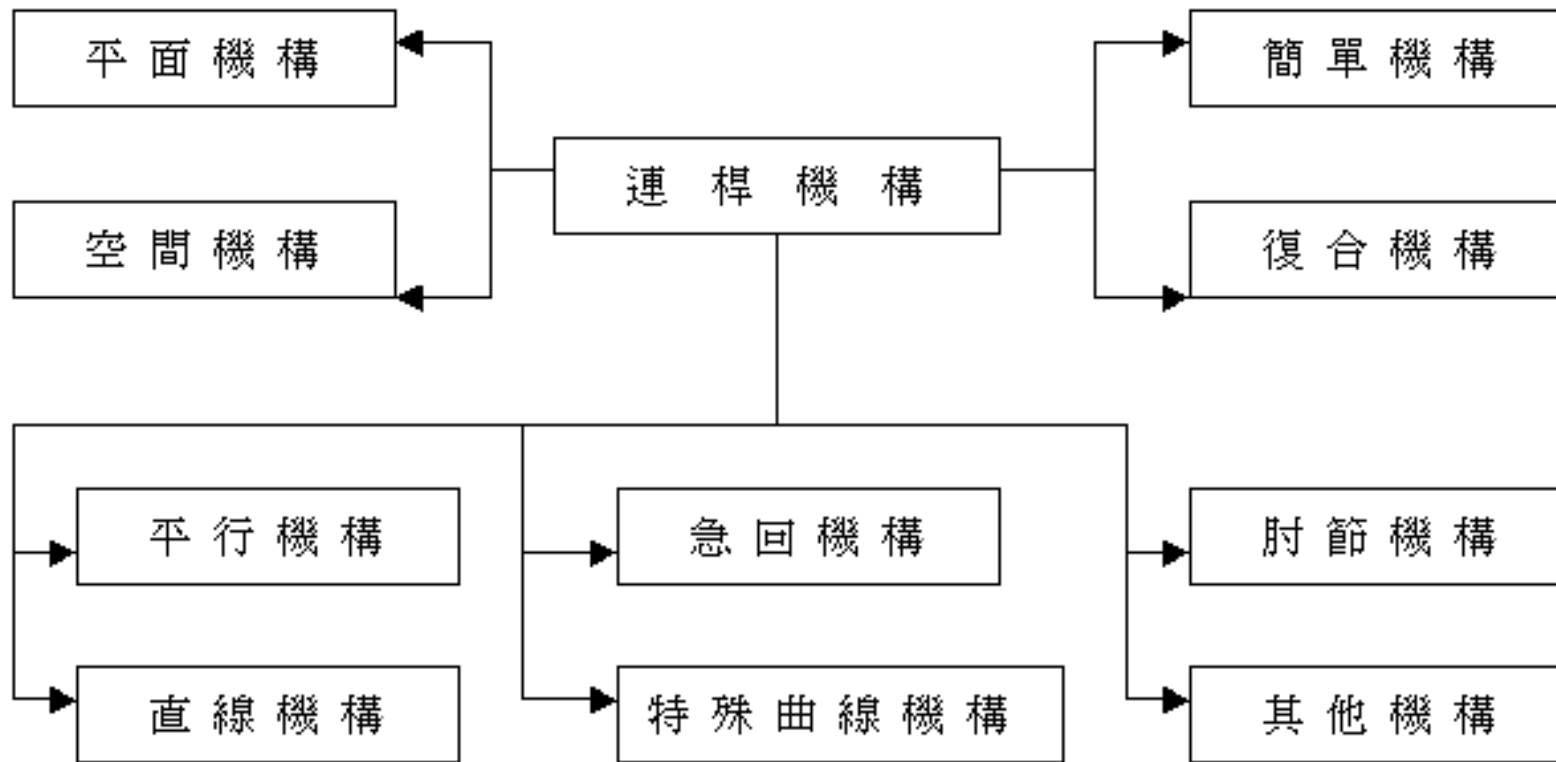
研究目的

- 為了簡化連桿機構之設計流程、時間、製作及測試成本。

連桿機構

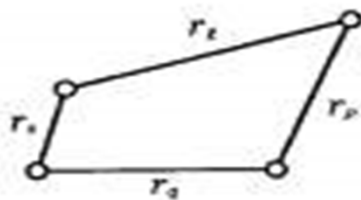
- 所謂連桿機構乃是指由連桿元件組成的機構，其主要之功能為運動型態與方向的轉換、運動狀態（位移、速度、加速度）的對等、剛體位置的導引及運動路徑的產生。

連桿機構分類方塊圖

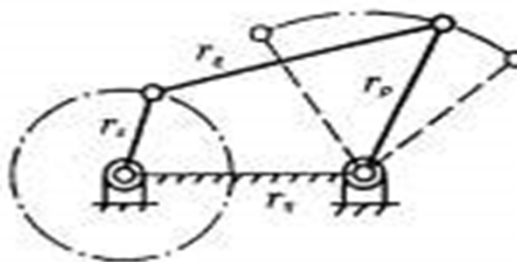


資料取自：[http://sparc.nfu.edu.tw/~cml/meeting\(20070323\)/5.htm](http://sparc.nfu.edu.tw/~cml/meeting(20070323)/5.htm)

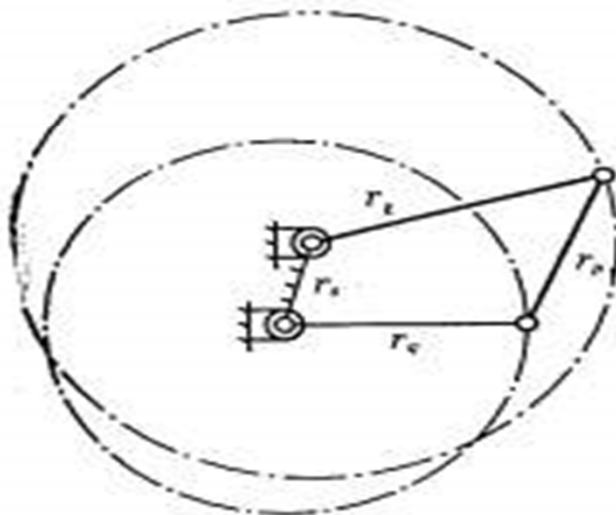
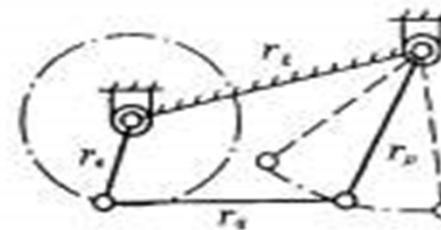
葛氏運動鏈及其倒置機構



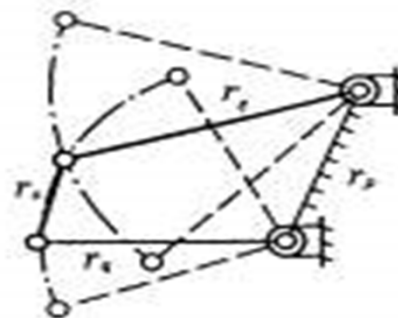
(a) 葛式運動鏈



(b) 曲柄搖桿機構



(c) 雙曲柄機構

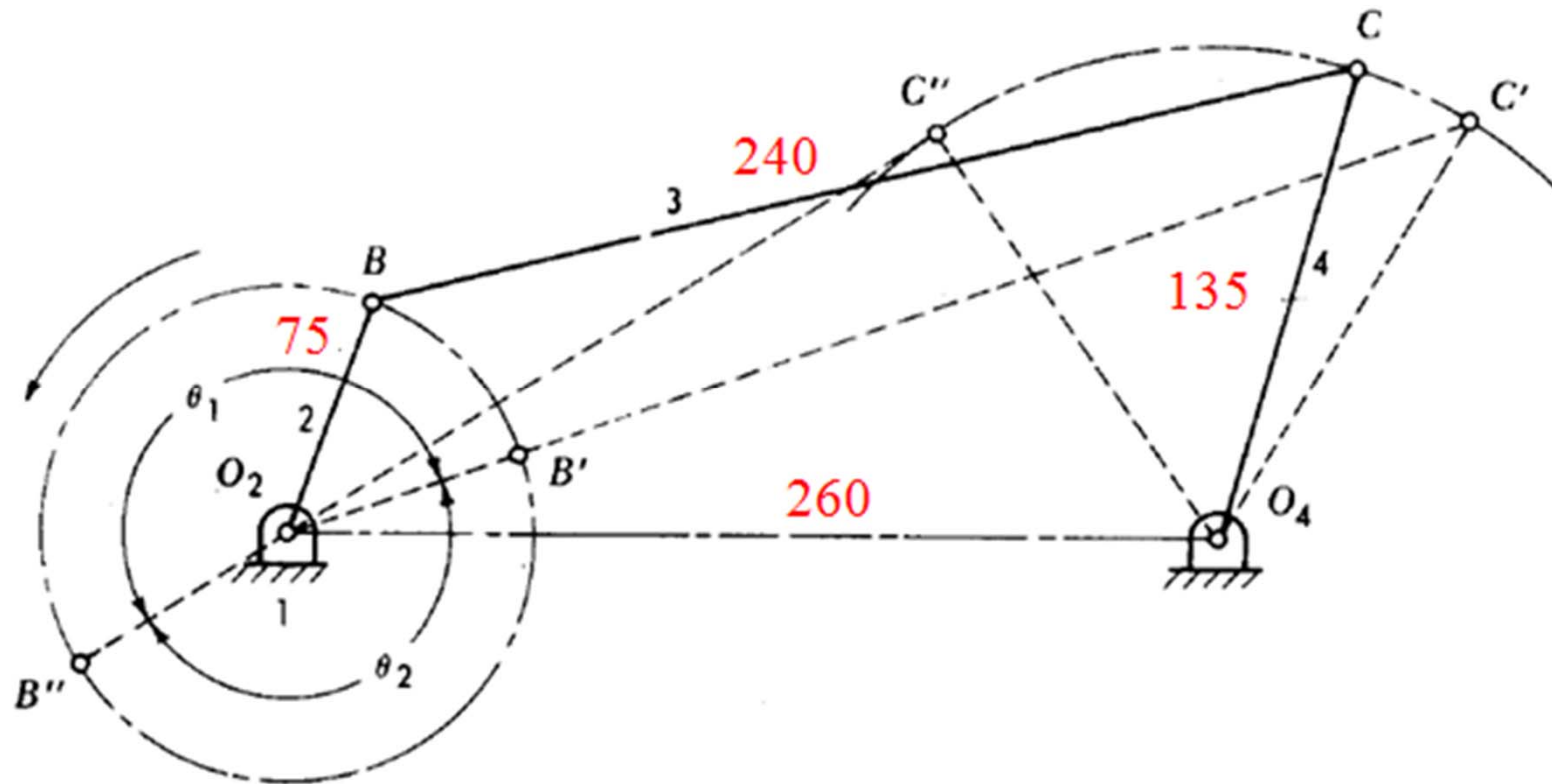


(d) 雙搖桿機構

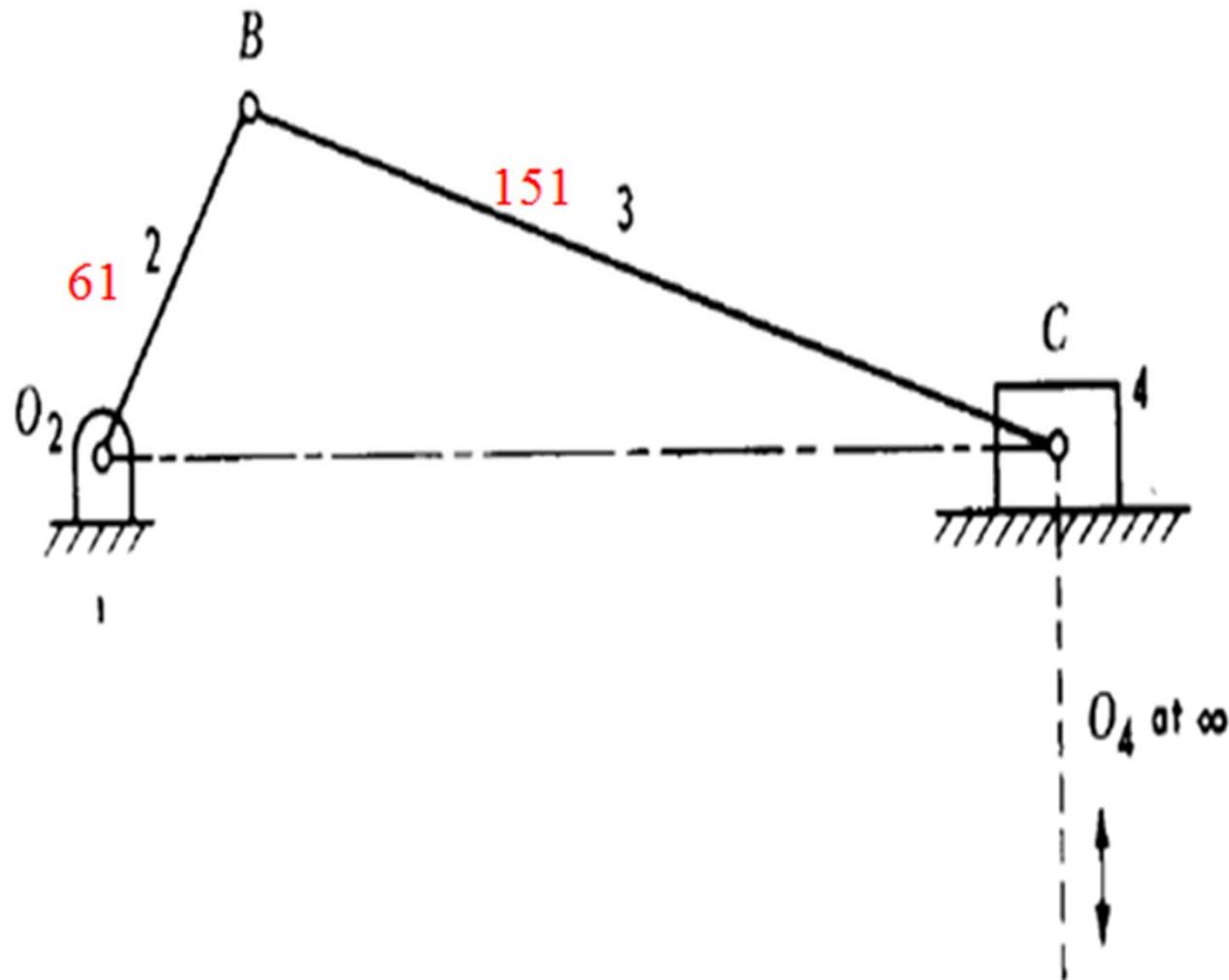
<http://mmrl.cgu.edu.tw/rehab/mme/rehab/organize/chap2/mechanism/no4.htm>

連桿機構之簡介

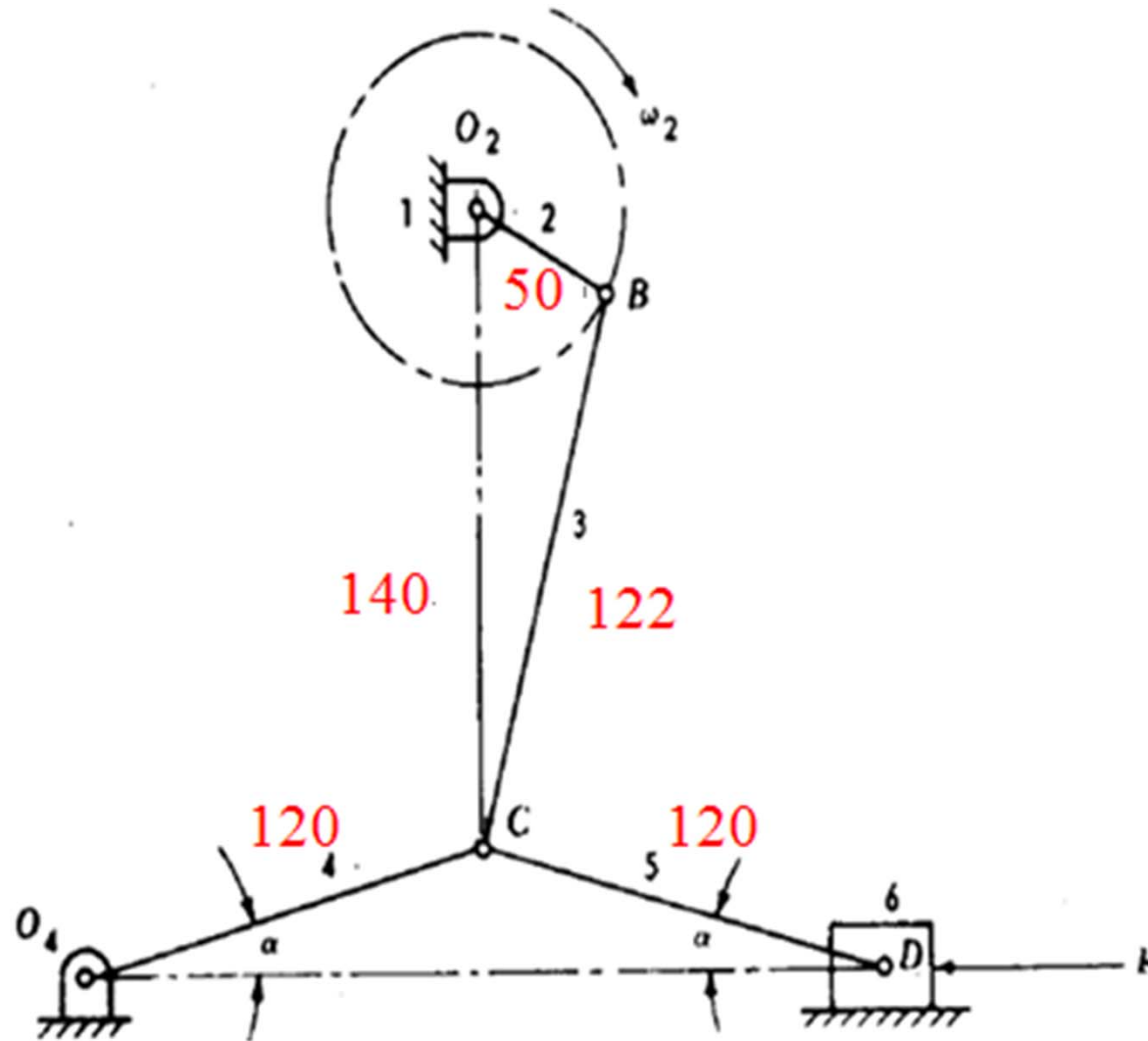
曲柄搖桿機構示意圖



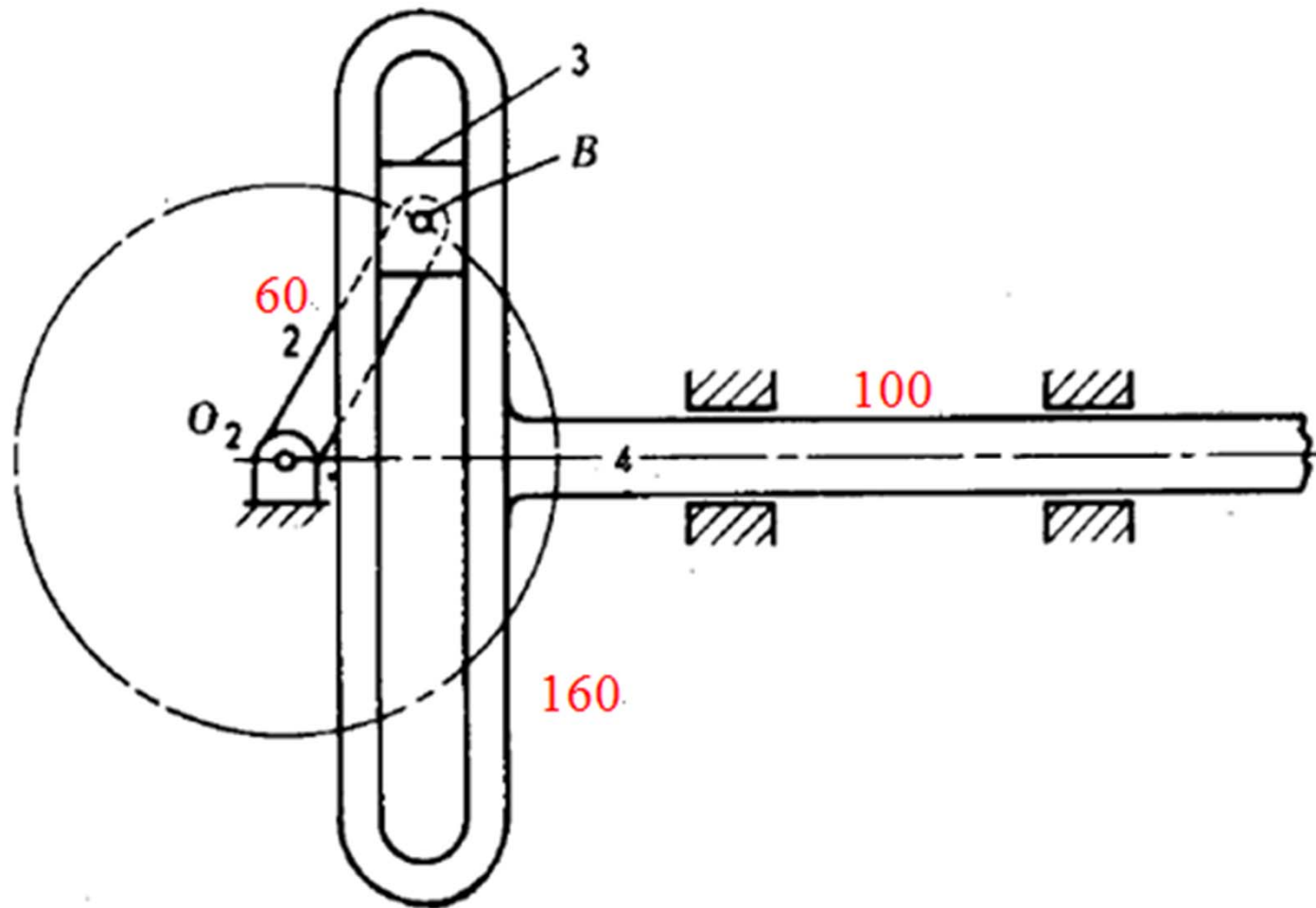
滑塊曲柄機構示意圖



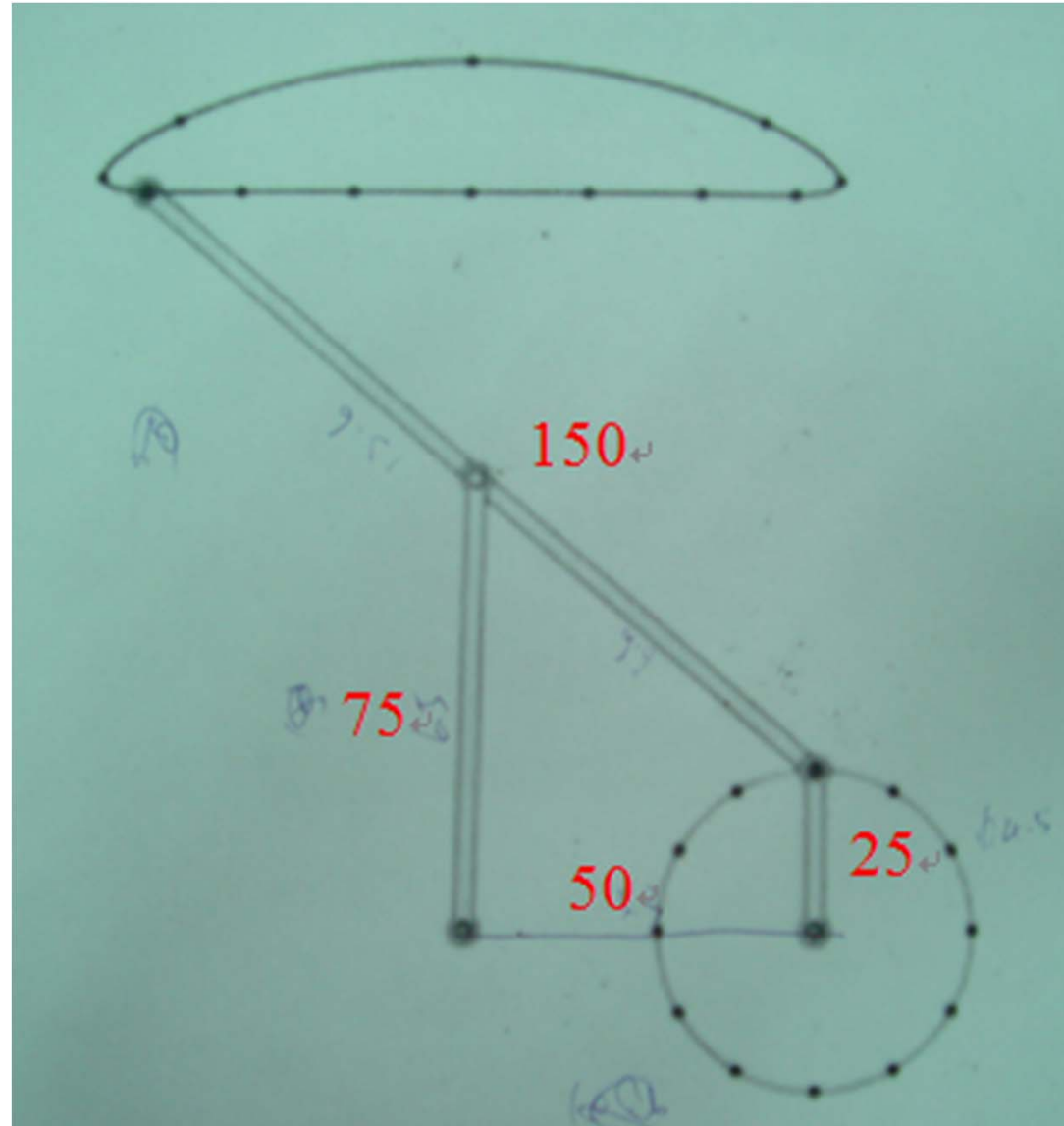
肘節機構示意圖



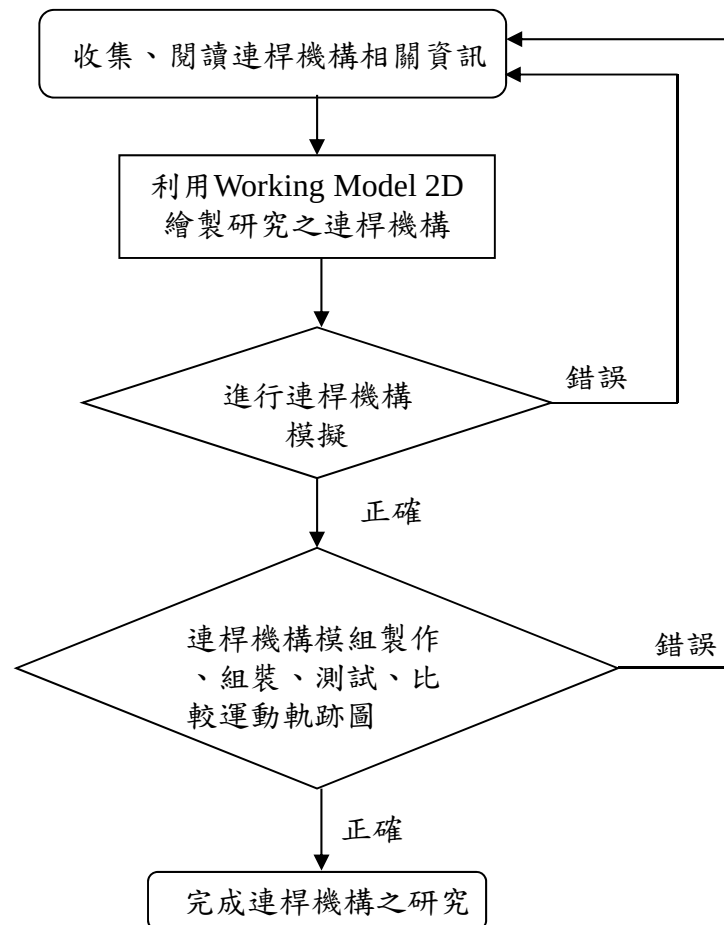
蘇格蘭軛示意圖



Chebyshev連桿機構示意圖

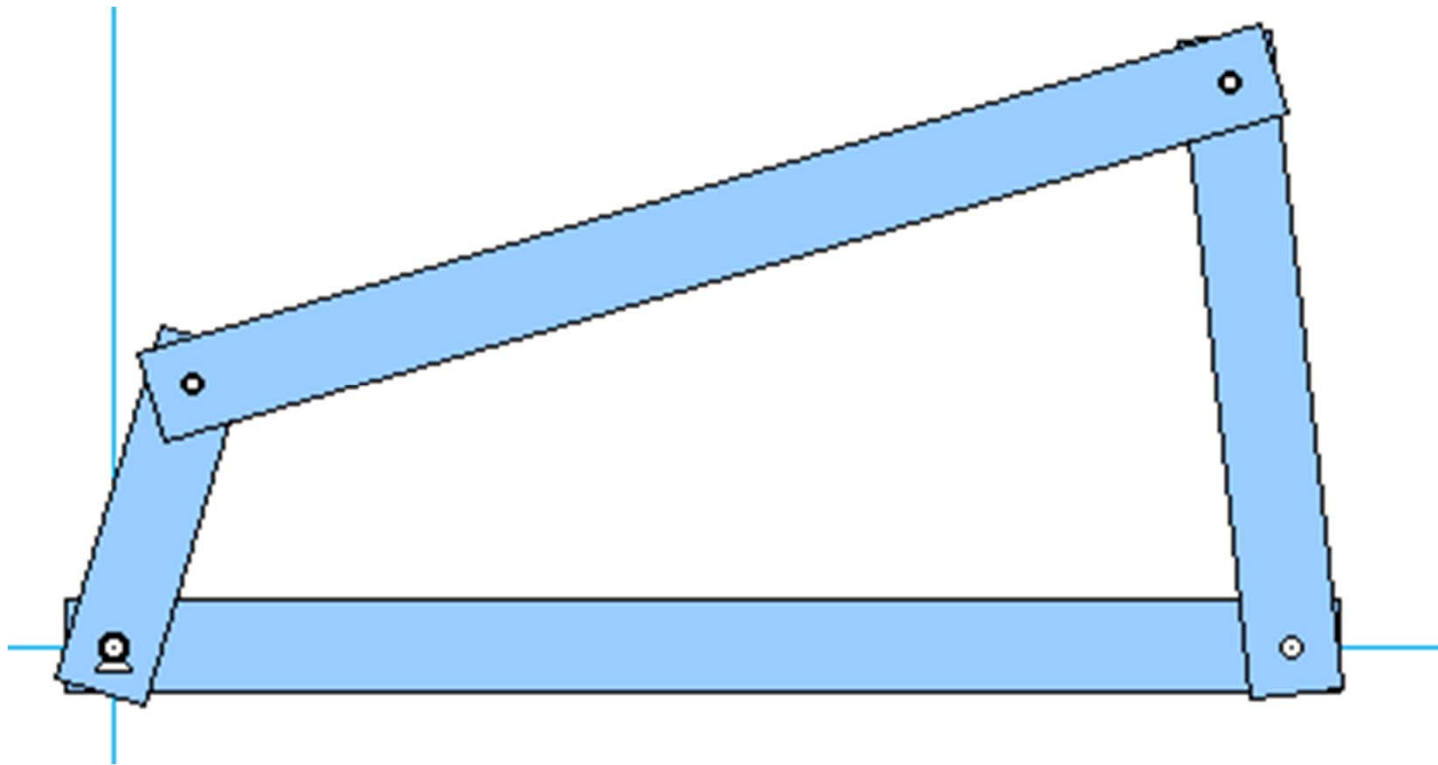


連桿機構研究流程

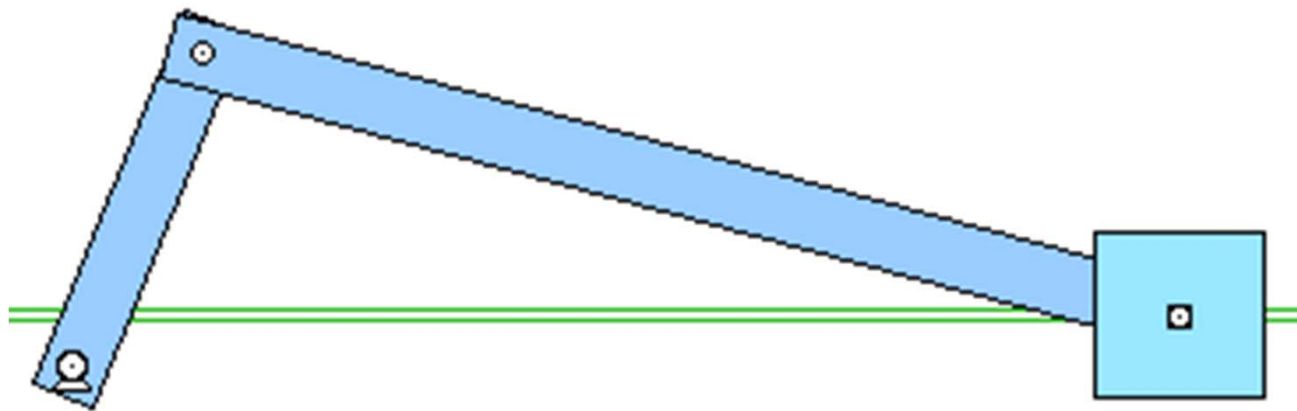


連桿機構之Working Model 2D圖

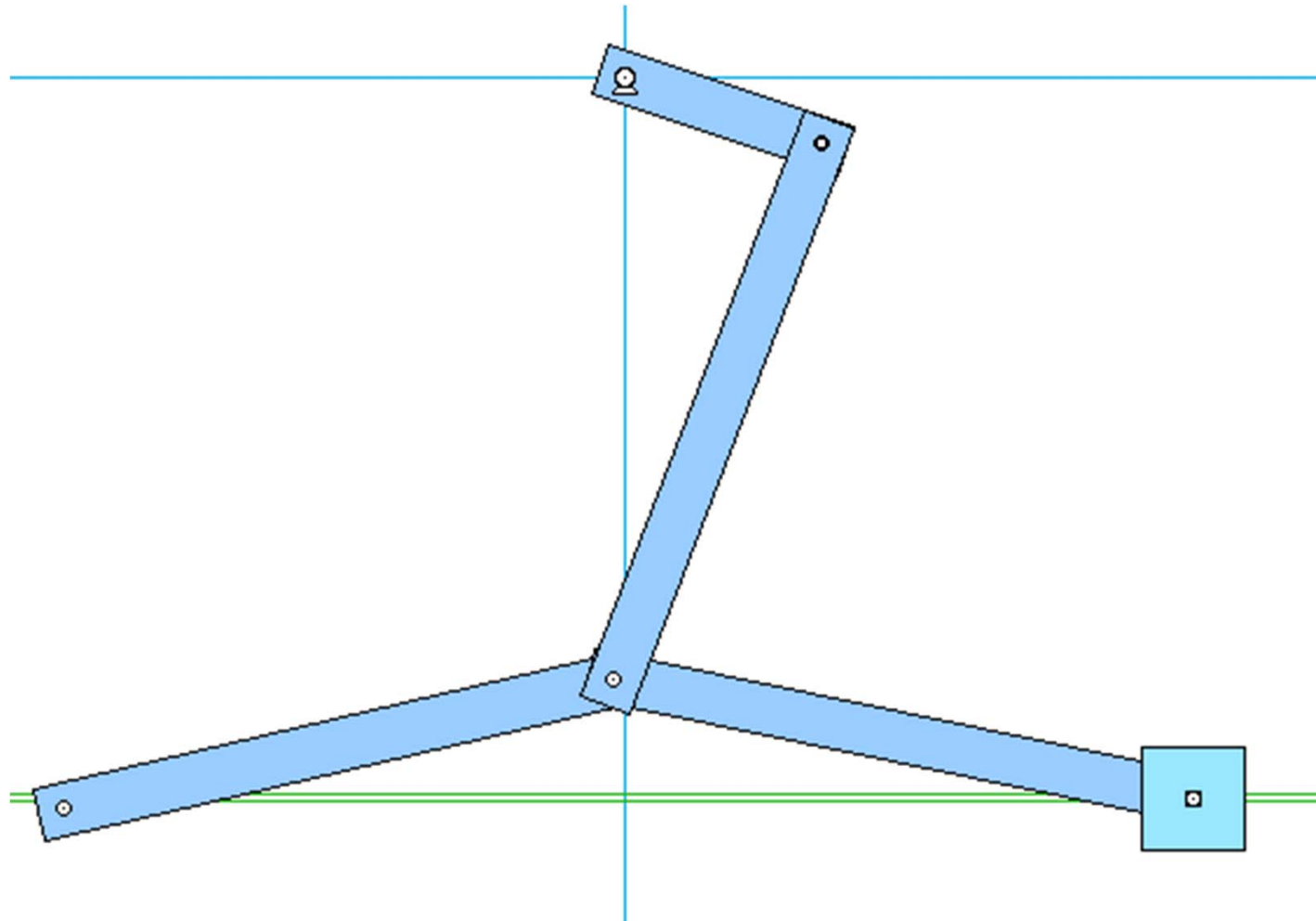
曲柄搖桿機構Working Model 2D圖



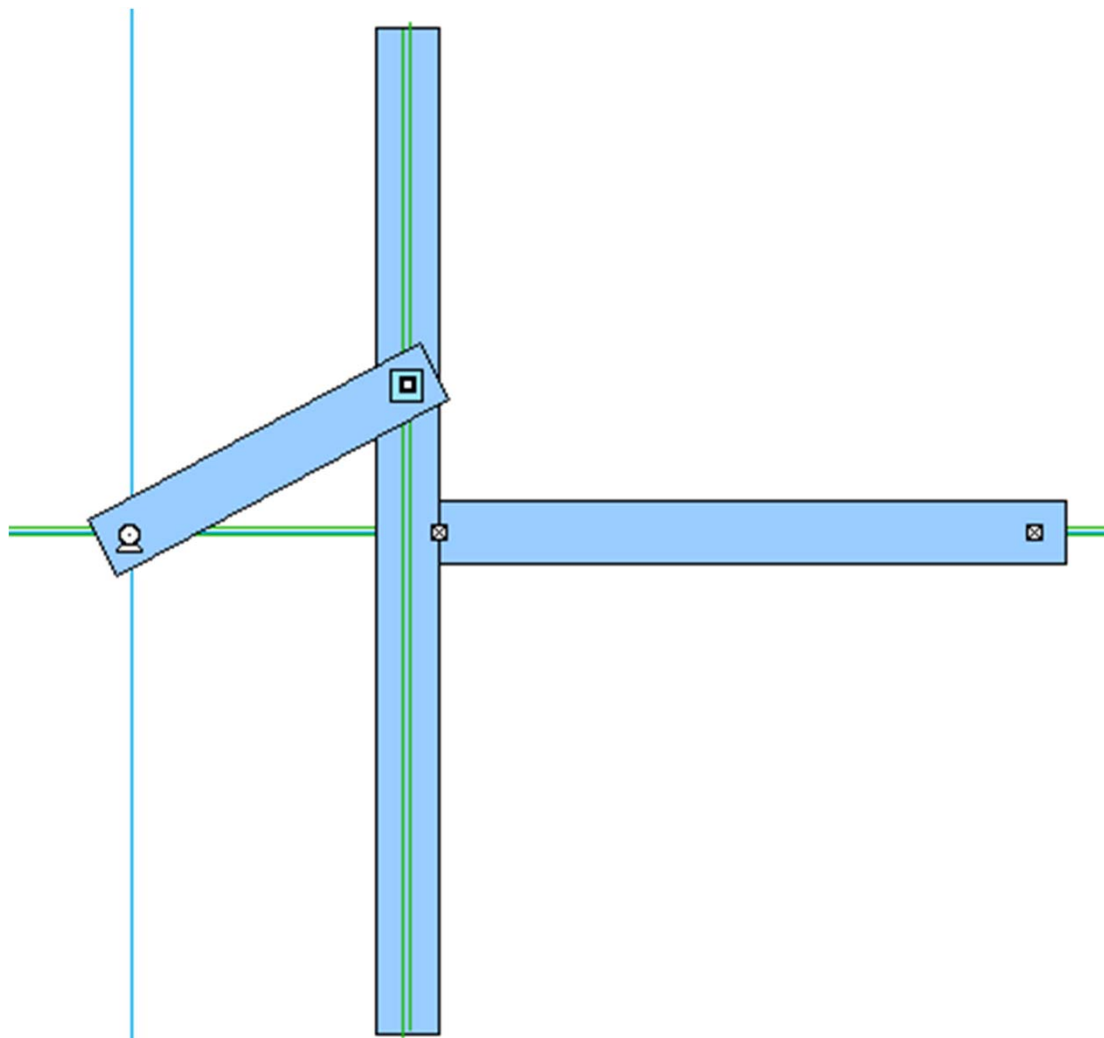
滑塊曲柄機構Working Model 2D圖



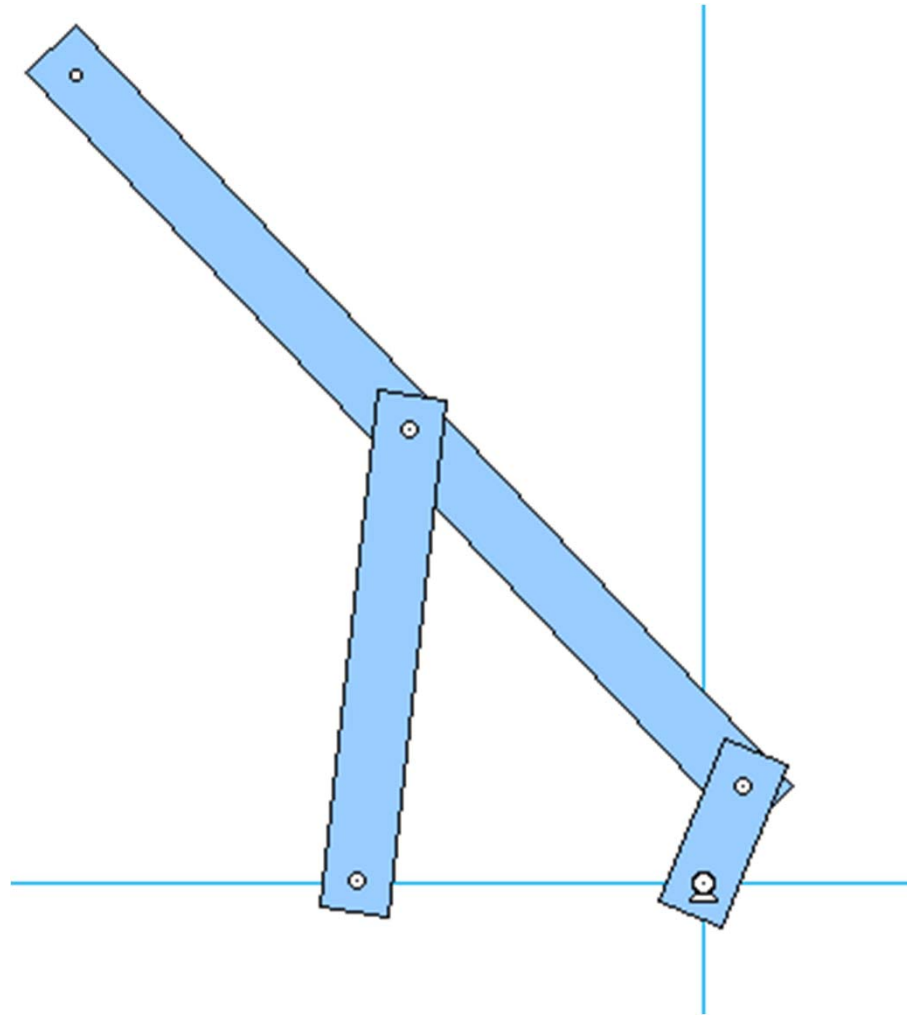
肘節機構Working Model 2D圖



蘇格蘭軌Working Model 2D圖

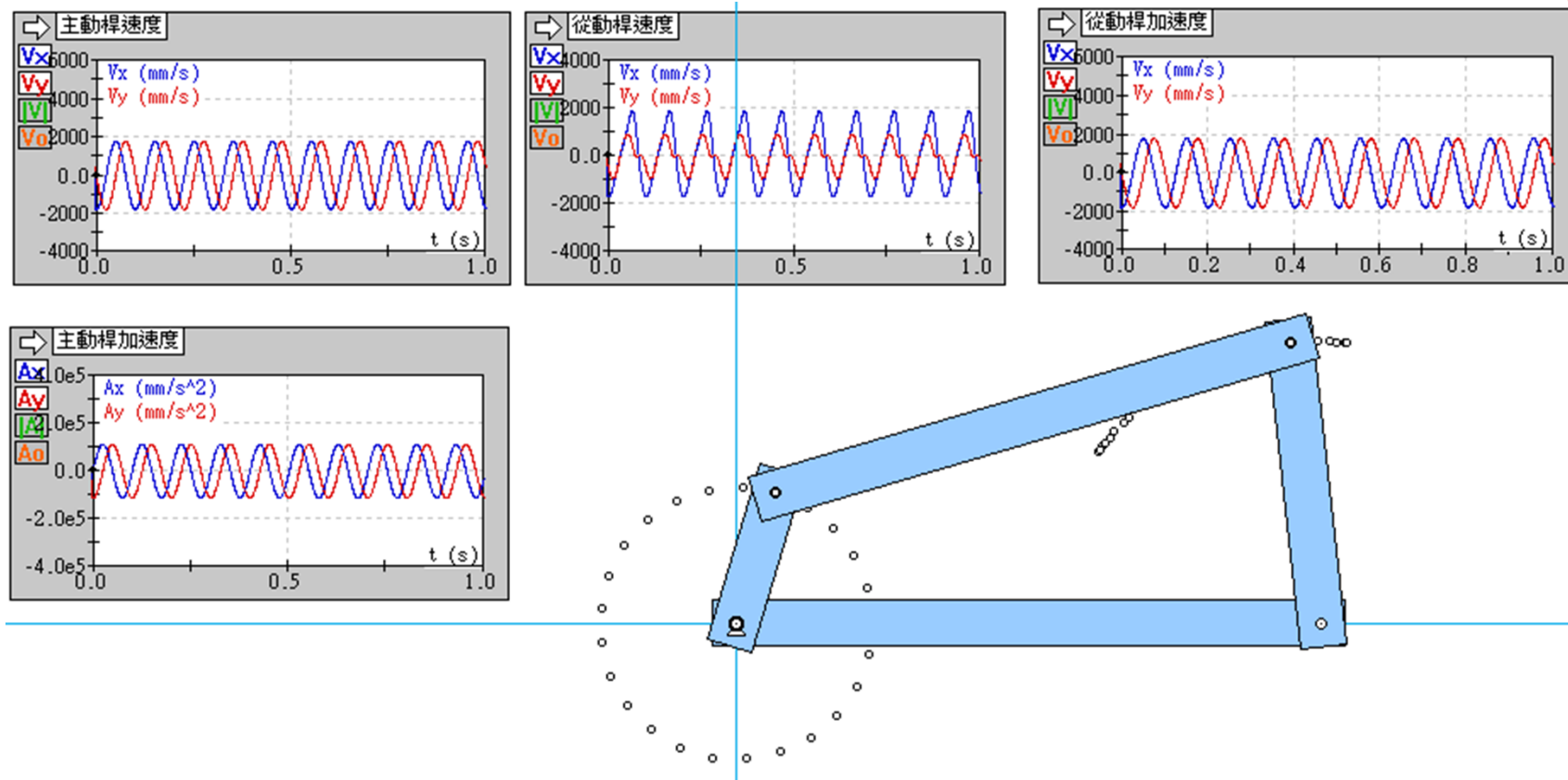


Chebyshev連桿機構Working Model 2D圖

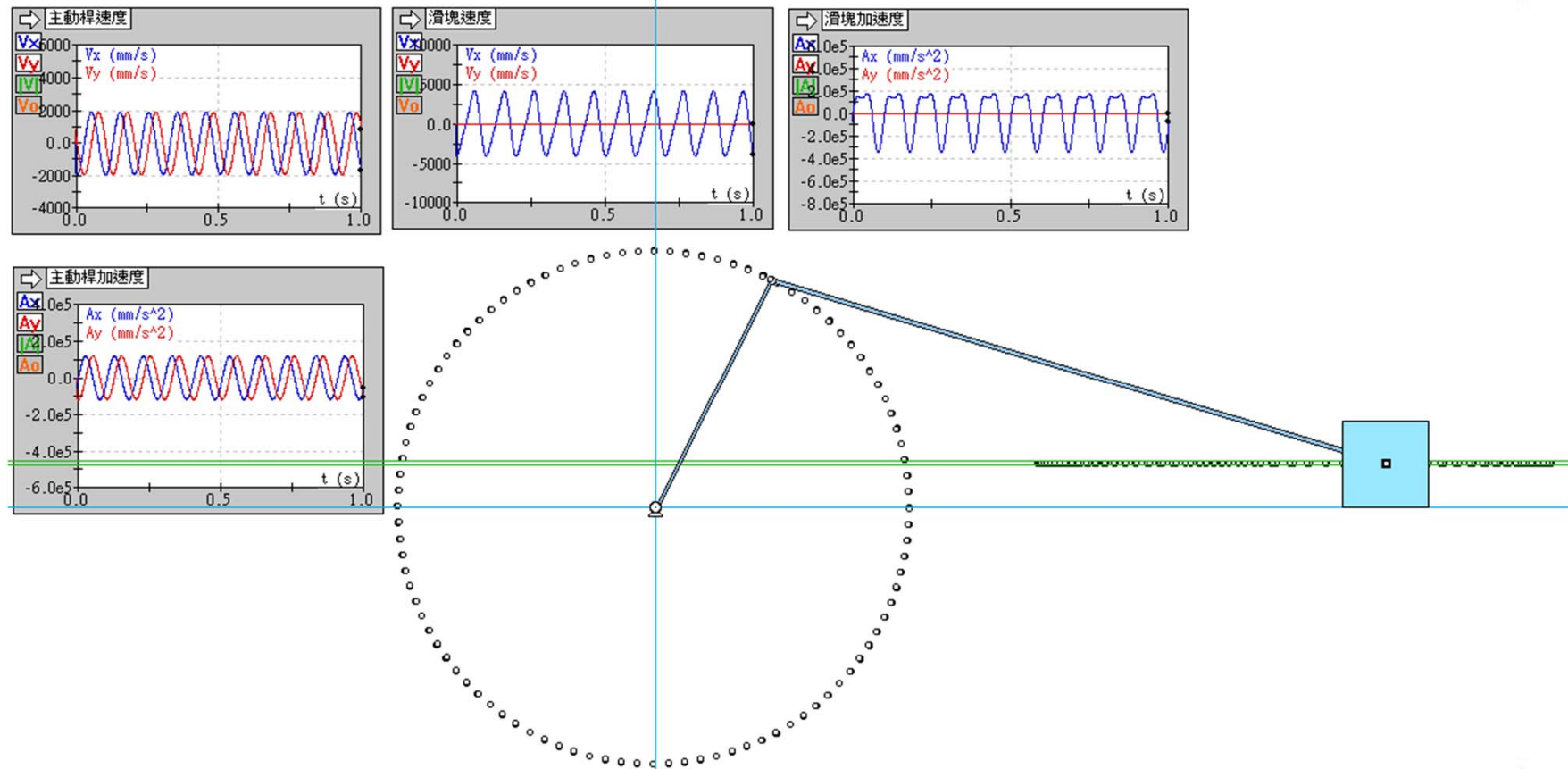


連桿機構之運動分析

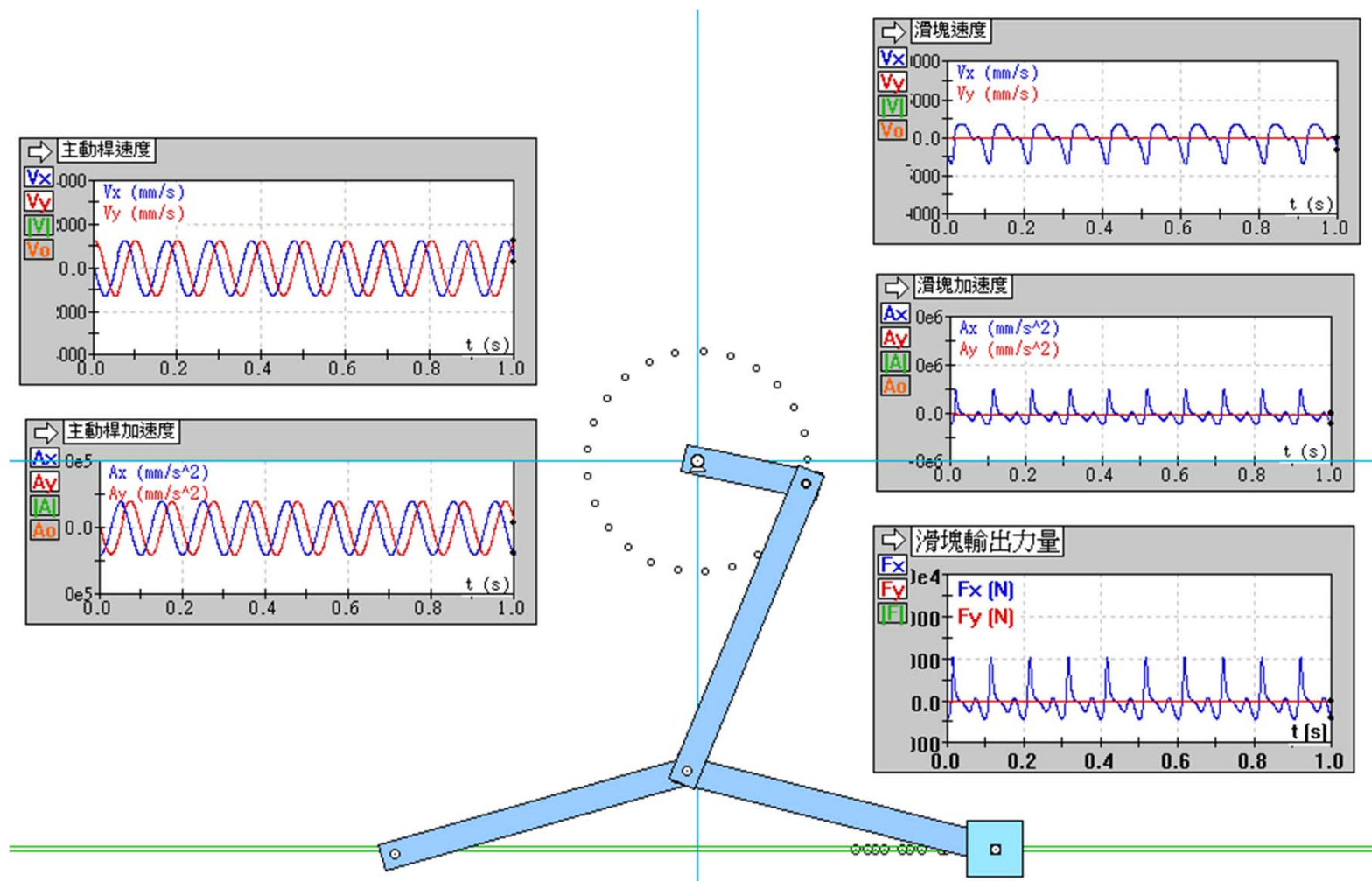
曲柄搖桿機構運動軌跡圖



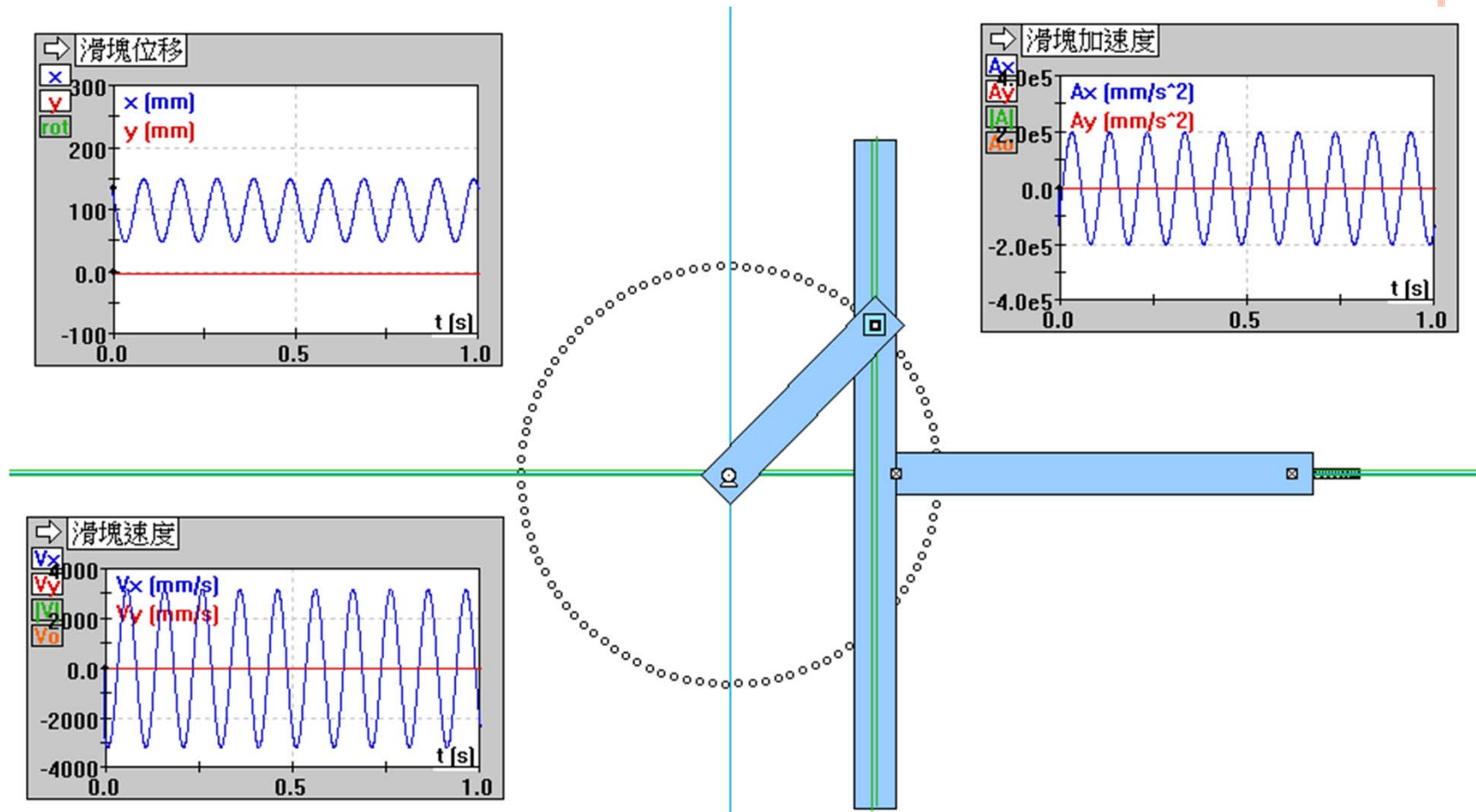
滑塊曲柄機構運動軌跡圖



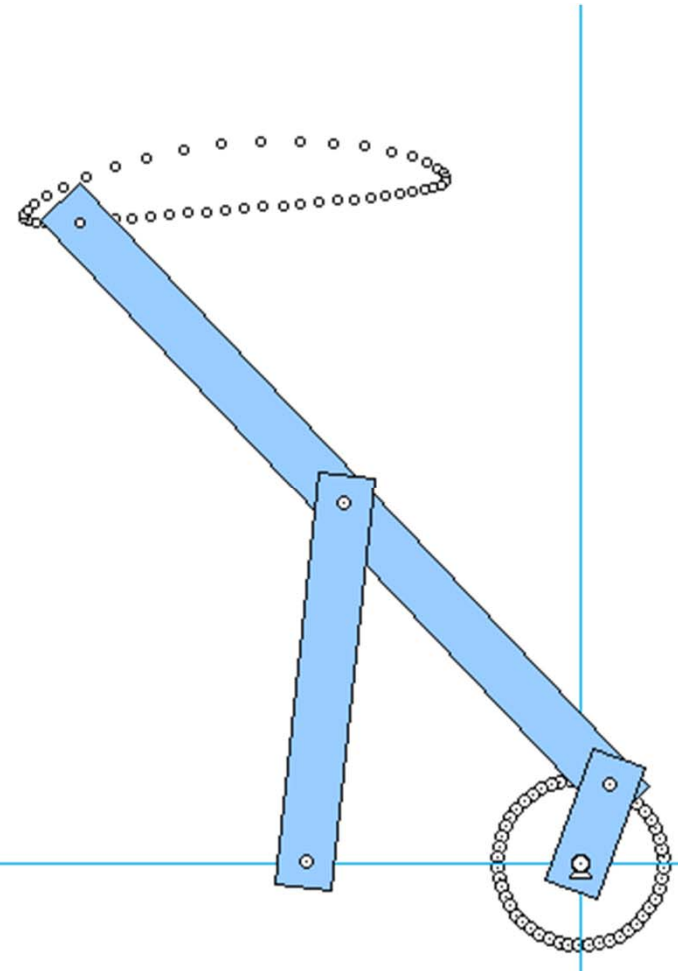
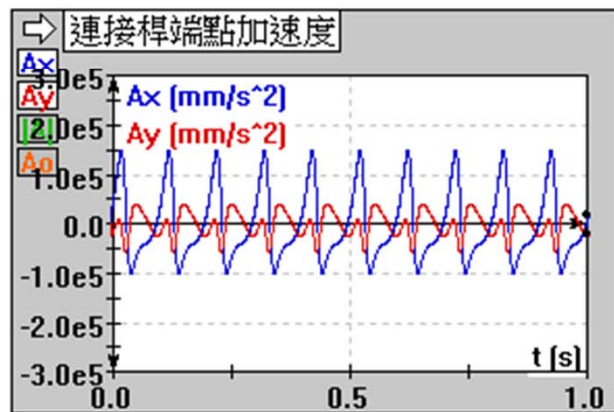
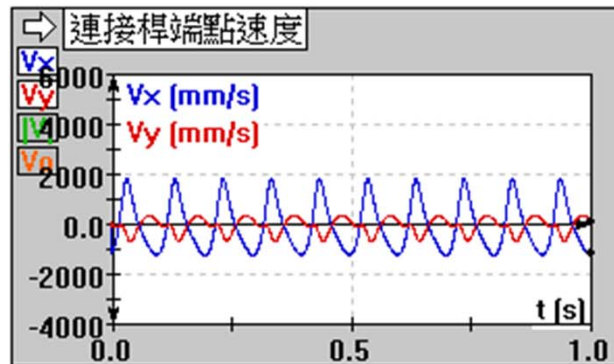
肘節機構運動軌跡圖



蘇格蘭軌運動軌跡圖



Chebyshev連桿機構運動軌跡圖



連桿機構之製作

曲柄搖桿機構成品



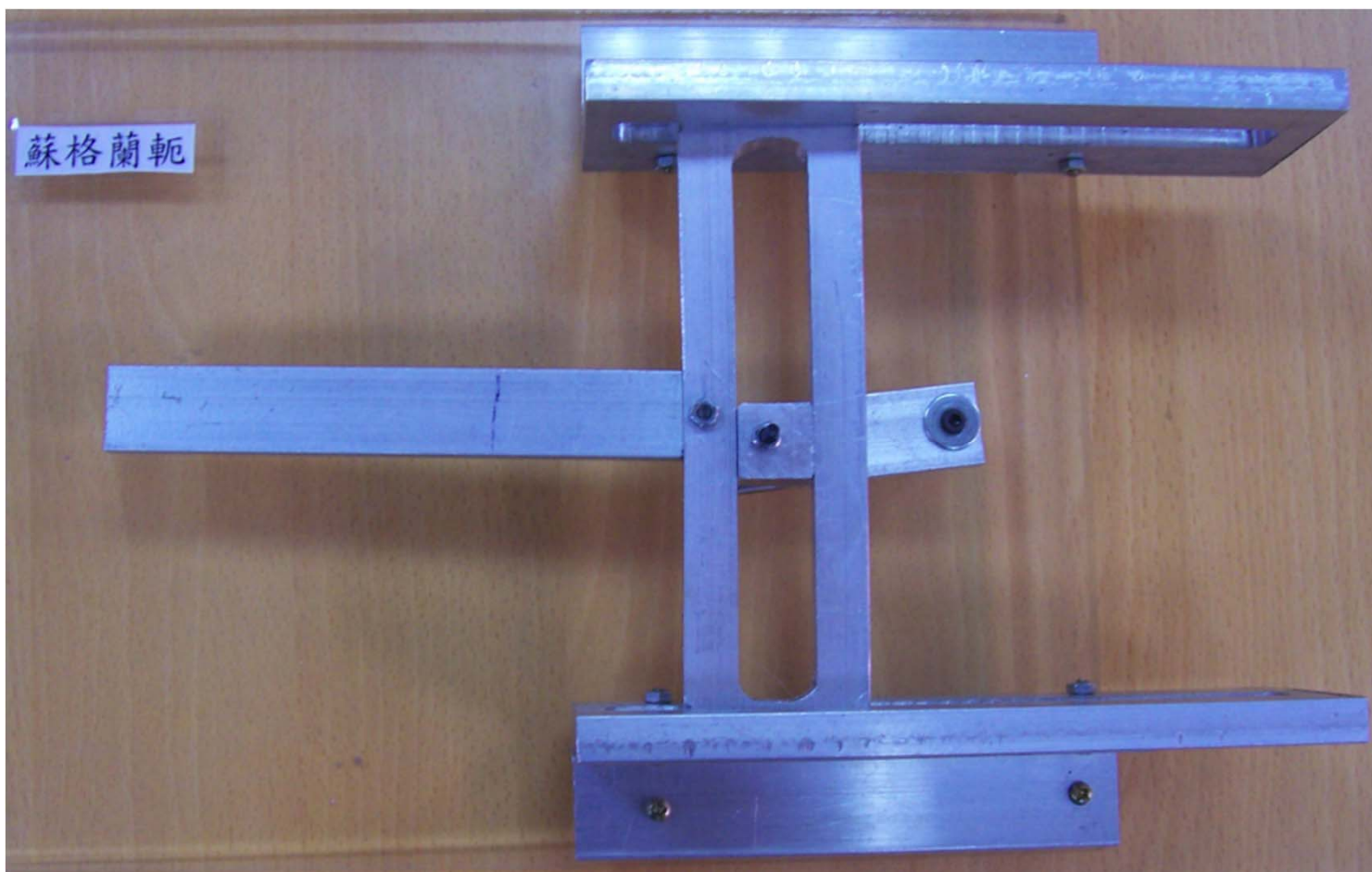
滑塊曲柄機構成品



肘節機構成品



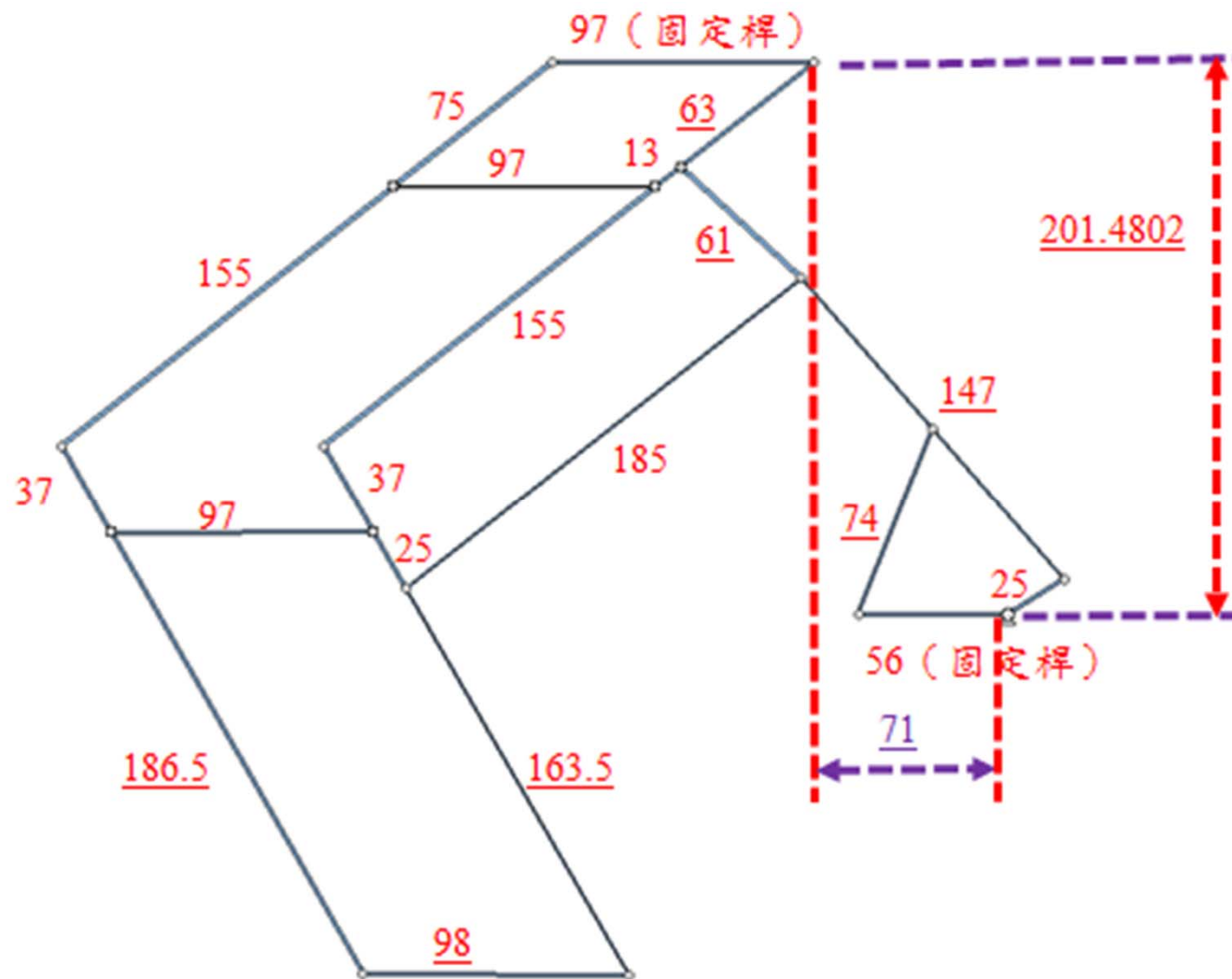
蘇格蘭軛成品



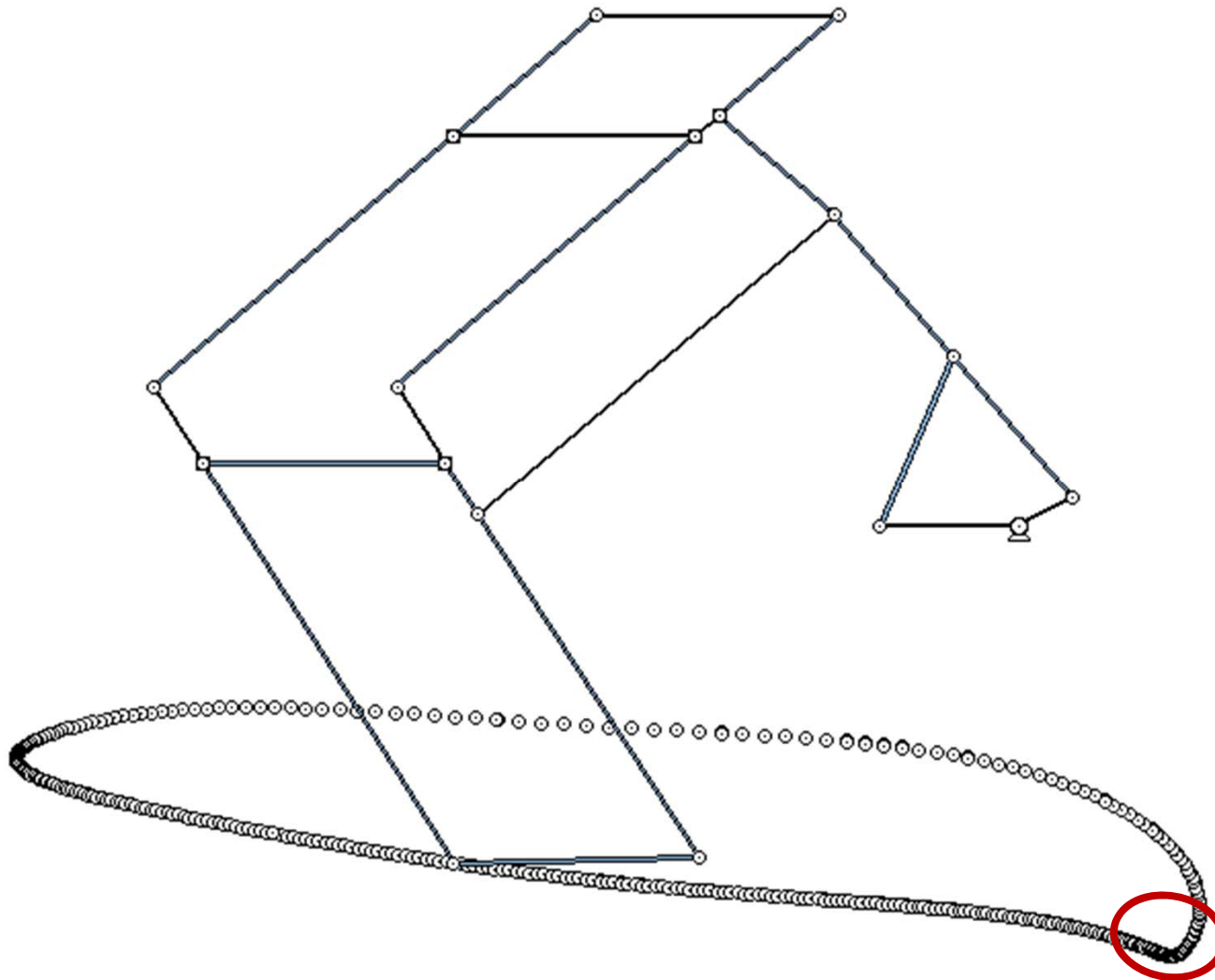
Chebyshev連桿機構成品



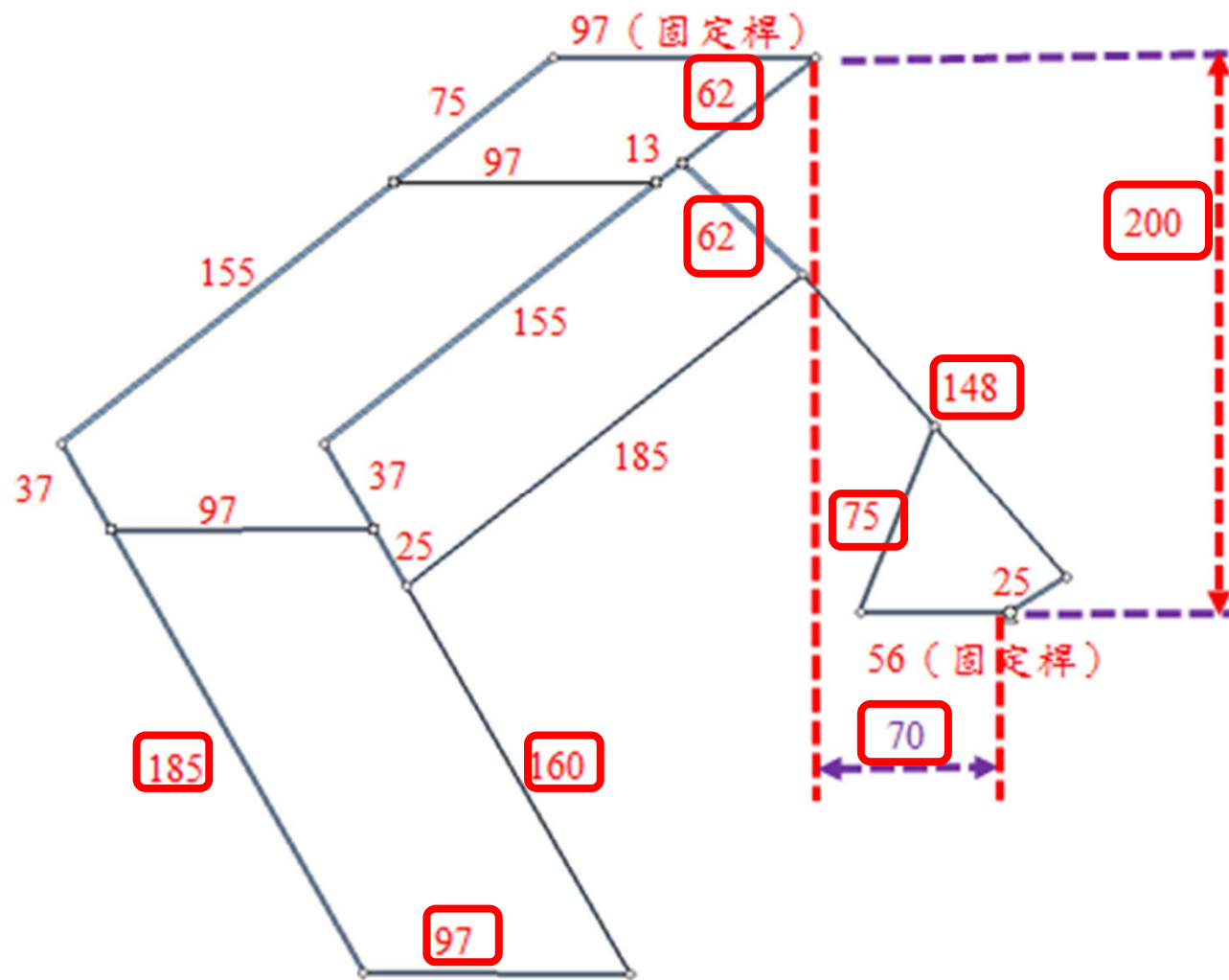
雙Chebyshev足步機構原始設計尺寸圖



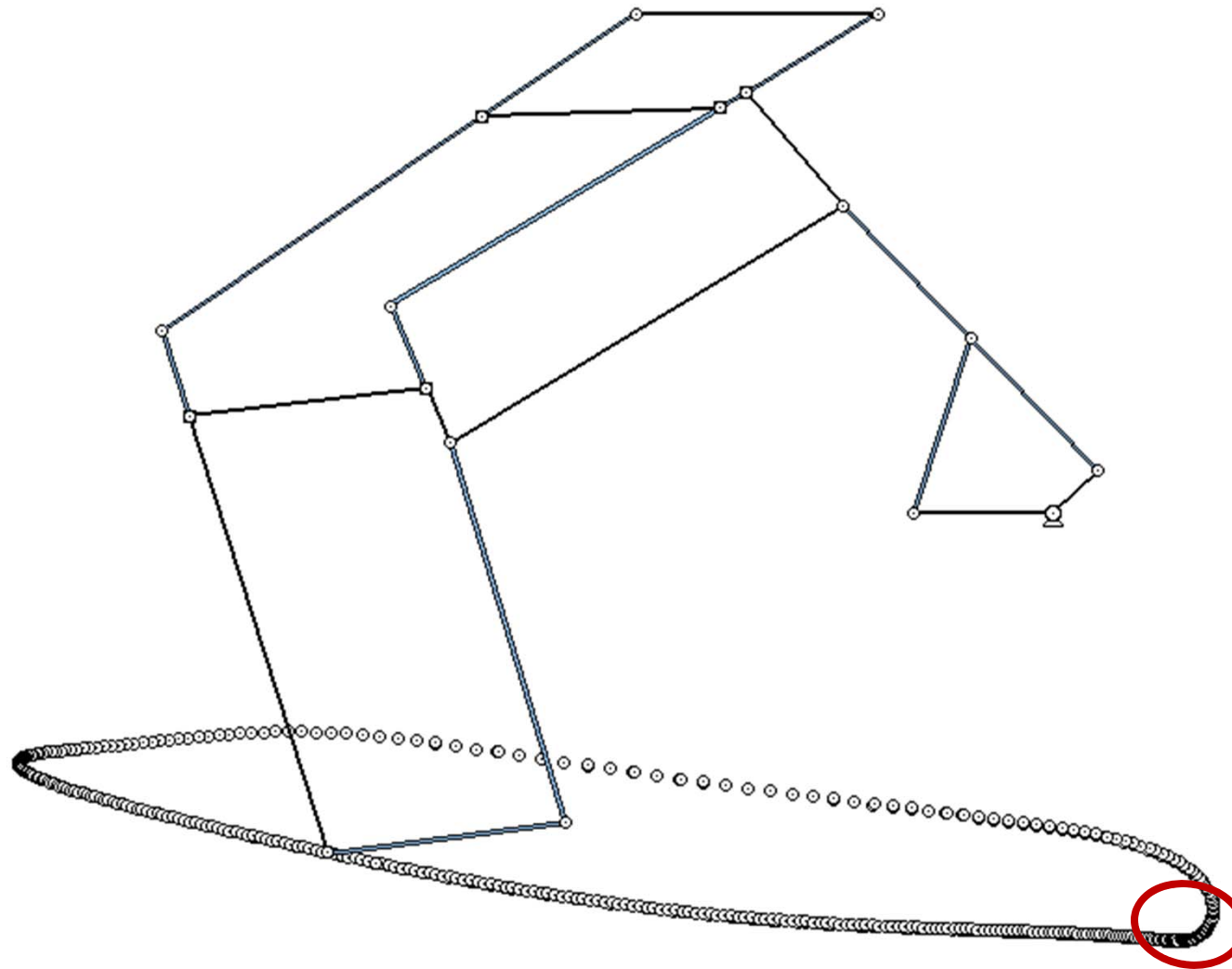
雙Chebyshev足步機構原始設計運動軌跡圖



雙Chebyshev足步機構修正設計尺寸圖



雙Chebyshev足步機構修正設計運動軌跡圖



本研究之特色 (1/2)

- 可將靜態之機構轉換成動態、連續作動之機構。
- 不需複雜之圖解法、數學式或撰寫程式過程即可求得各連桿機構之速度、加速度、作用力及運動軌跡圖。

本研究之特色 (2/2)

- 可經由改變動力源或連桿機構之尺寸、位置或種類以達成所要求之動作。
- 使機構設計過程更具彈性、省時及降低成本。

結 論 (1/2)

- 本研究可簡化連桿機構之設計流程、時間、製作及測試成本。
- 本研究完成曲柄搖桿機構、滑塊曲柄機構、蘇格蘭軛、肘節機構及Chebyshev連桿機構之加工、組裝、測試及模組化，可做為相關課程之教具。

結 論 (2/2)

- 本研究利用Working Model 2D軟體完成曲柄搖桿機構、滑塊曲柄機構、蘇格蘭軛、肘節機構及雙Chebyshev連桿機構之繪圖、模擬及分析，並計算機構特定位置之速度、加速度及作用力。
- 本研究完成雙Chebyshev足步機構之分析及尺寸修正。

謝謝聆聽
敬請指導