# Kinematics: Real life video analysis using Tracker

Name: _____   Class: 15S_____   Date: _____

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In this exercise, we will be using the software "Tracker" to investigate the motion of an object in the following scenarios.

1. An object sliding down an inclined slope.

2. A balloon dropped vertically.

3. A ball projected at an angle (projectile motion).


There are two worksheets which you need to complete for this exercise.

**Worksheet A** – to be completed as homework before lab session

**Worksheet B** – to be completed during the lab session

You will have to hand in both worksheets after the lab session.


<u>Before the lab session:</u>

1. Complete **Worksheet A**


<u>During the lab session:</u>

You will carry out the lab session in groups of 3 – 5.

Individually, you need to bring:

    1. Completed **Worksheet A**

    2. **Worksheet B**


As a group, you will need to have with you:

1. A school laptop issued to you.

2. A smartphone with video recording function. The format of the video file must be playable using QuickTime (example, .mov or .mp4).

3. Your smartphone logged into school's network to send your video via email. Alternatively you may use a **data transfer cable** to transfer the video file from the smartphone to the laptop.

**Worksheet A (to be completed as homework prior to lab session)**

**Scenario 1**

An object rolls down an inclined slope from rest. The slope is at an angle of $\theta$ to the horizontal.
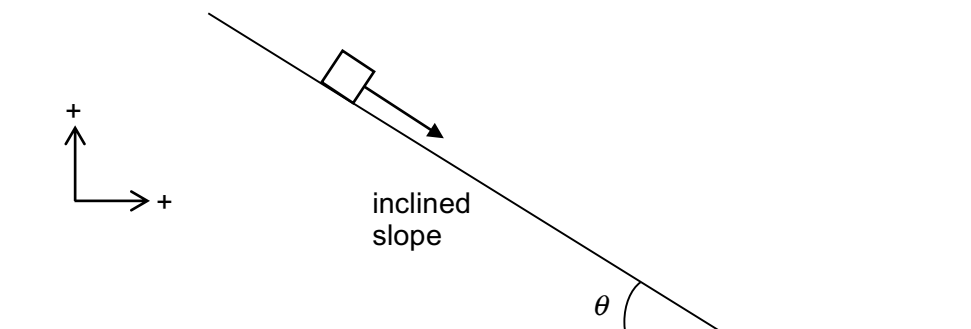


Based on what you have learned, answer the following questions. Take upward and rightward as positive direction.

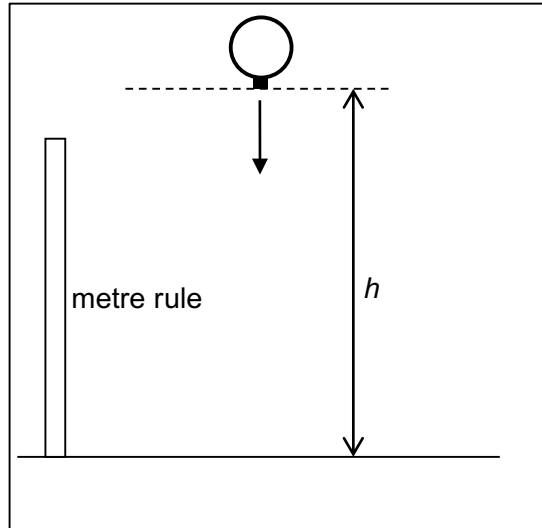1.  Sketch a graph to show how the horizontal velocity ($v_x$) varies with time ($t$).



2.  Sketch a graph to show how the vertical velocity ($v_y$) varies with time ($t$).

3. State an expression, in terms of $\theta$, for the acceleration of the object *along the slope*.

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**Scenario 2**



A balloon, inflated to a diameter of about 15 cm, is released from rest at a certain height $h$.

Based on what you have learnt, answer the following questions. Take upward as positive.

1. Sketch a labelled graph to show how the vertical velocity ($v_y$) varies with time ($t$)
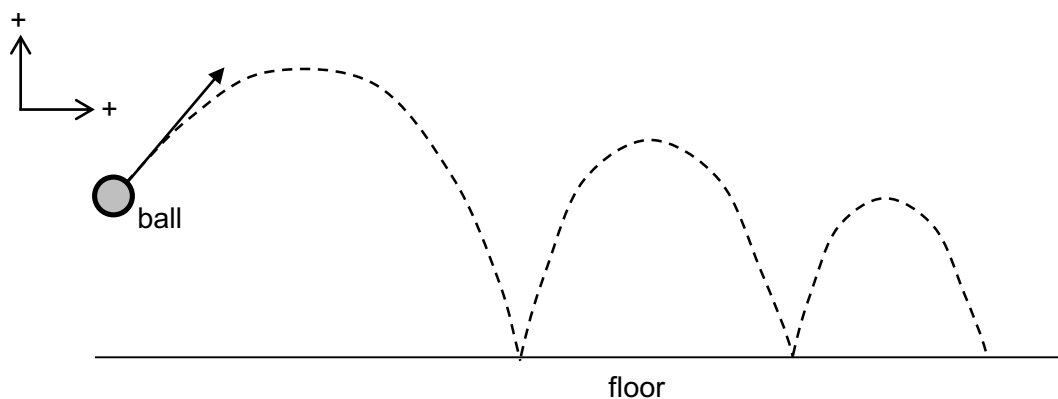
2. Describe the motion of the balloon during the fall as shown in your $v_y - t$ graph above.

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## Scenario 3

A ball is projected at an angle and allowed to bounce on the floor several times.



floor

Based on what you have learnt, answer the following questions. Take upward and rightward as positive.

1. Horizontal motion (x-direction)

   a. Sketch a graph to show how the horizontal velocity ($v_x$) varies with time ($t$).

   

   b. What is the value of the horizontal acceleration? State your assumptions.

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2. Vertical motion (*y*-direction)

    a. Sketch a graph to show how the vertical velocity ($v_y$) varies with time (*t*).

$v_y$

                                     *t*

    b. What is the value of the vertical acceleration when the ball is in mid-air?
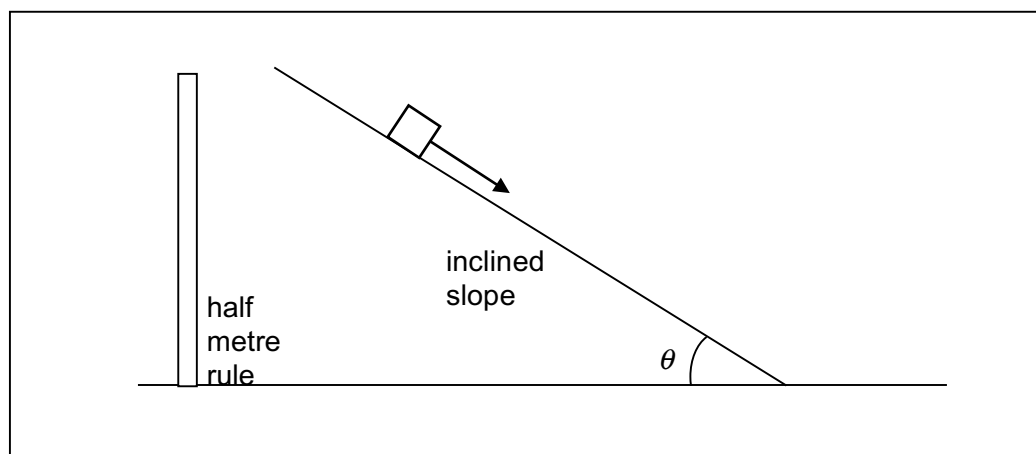
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## Worksheet B (to be completed during lab session)

### Section A – Video recording of scenarios 1 and 2

Before carrying out the video analysis using Tracker, you first need to video record the motion of the objects according to scenarios 1 and 2. The video for scenario 3 will be provided to you via LMS.

<u>Scenario 1</u>



1.  Get your friend to release the object provided at the top of the slope, while you video record the motion of the ball.
2.  Place a half metre rule in the background close to where the slope is. The half metre rule is used as a distance calibration object for the Tracker software.
3.  Measure the angle $\theta$ and record it for **Section C**.
4.  As you record, make sure that you are able to capture the motion from the top to the bottom of the slope. **Ensure that the camera does not move while it is recording, and that the camera is not slanted.**
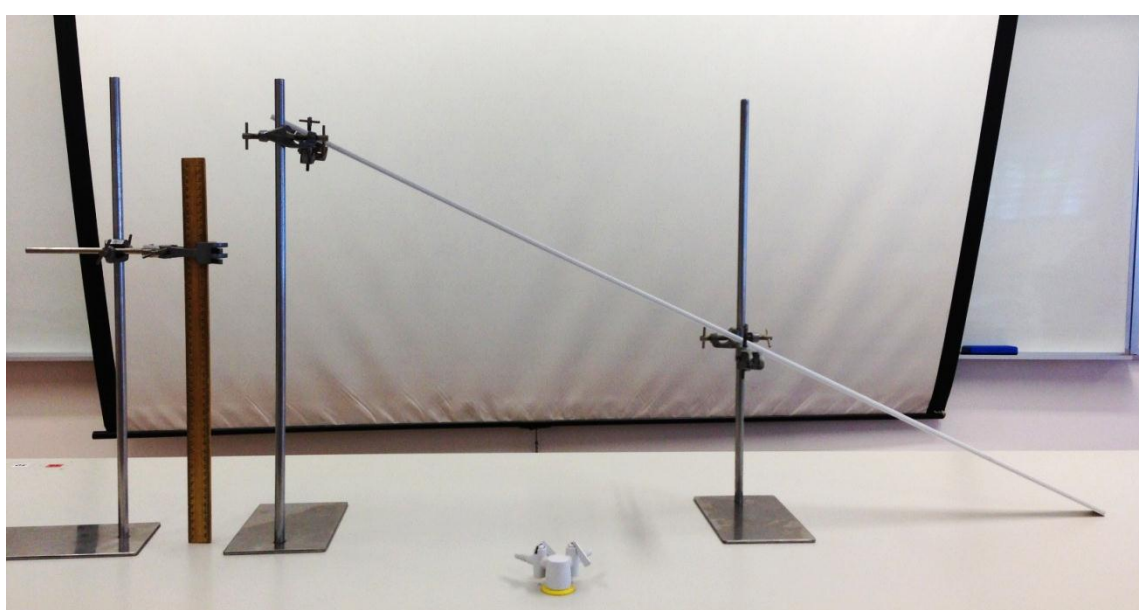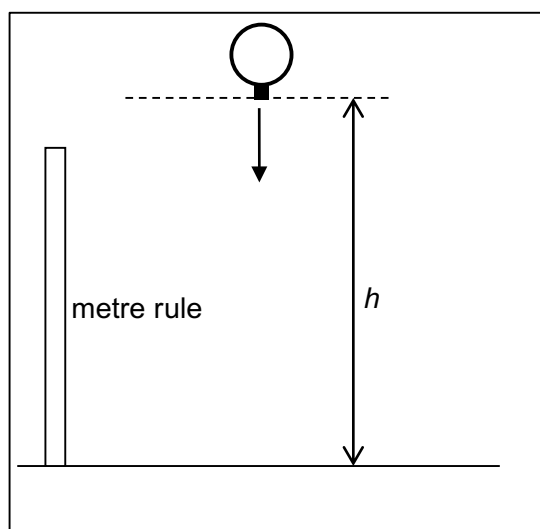
1. Inflate the given balloon to a diameter of approximately 15 cm.

2. Cut a small piece of paper (about 2.0 cm by 2.0 cm) and use a tape to attach it to the end of the balloon where it is tied. You are advised to colour the paper black or dark blue so that you can track it easily.

3. Place a metre rule in the background close to where you are going to release the balloon. The metre rule is used as a distance calibration object for the Tracker software.

4. Get your friend to release the balloon **with the paper at the lowest position** from approximately the top of his/her head. This height $h$ is approximately the height of your friend which you will verify graphically later.

5. As you record, make sure that you are able to capture the motion of the balloon from the point of release to the point of impact with the floor. **Ensure that the camera does not move while it is recording, and that the camera is not slanted.**

**Section B – Video analysis of the motion using Tracker**

Now that you have finished the video recording of the two scenarios, you are ready to use Tracker to analyse the motion. The following instructions will step you through the process using the video for scenario 3 (bouncing ball).

1.   Import the recorded videos to your laptop. Save them to a location easily accessible by you (e.g. Desktop).

2.   Launch Tracker software from the shortcut on your desktop.

3.   Click on **Video → Import**. Select the movie which you wish to import.
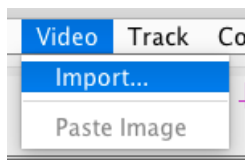


4.   Once the video is imported, click on  button and select the **New → Calibration Stick**. A calibration stick will appear on the video. You may change its colour to something more distinct one. Drag the ends of the stick to the metre rule and set the value of the stick to 1.000 as shown below.
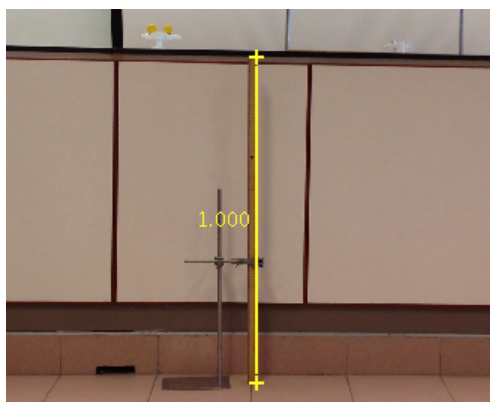


5.   Using the slider and the Step forward button , find the frame of the video where the ball just left the thrower's hand. Right-click below the slider and click **Set start frame to slider (XX)** where XX is your frame number.
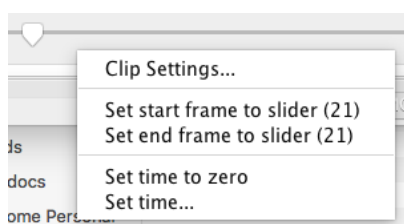


6.   Continue to find the frame of the video where the ball has finished its 3<sup>rd</sup> bounce. Right-click below the slider and click **Set end frame to slider (XX)** where XX is your frame number.



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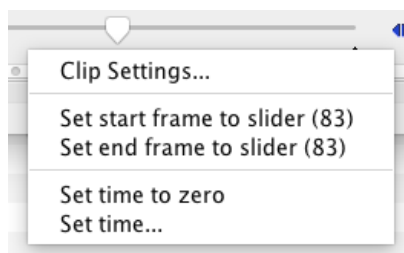
7. Click ◄ to return to your video's starting frame. Click ┼─ to add the coordinate axes. Drag the axes so that the origin is approximately the centre of the ball.



+ve x-direction
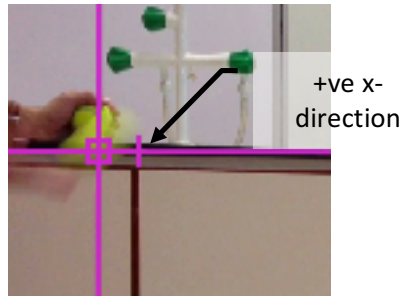
Click ┼─ again to hide the coordinate axes.

8. Click ✳ Create or **Track** → **New** and create a new point mass. Shift-click on the approximate centre of the tennis ball to mark your first data point. The video will automatically move forward by 1 frame so that you can mark the next data point. Continue to track the motion of the tennis ball until the video reaches your end frame.
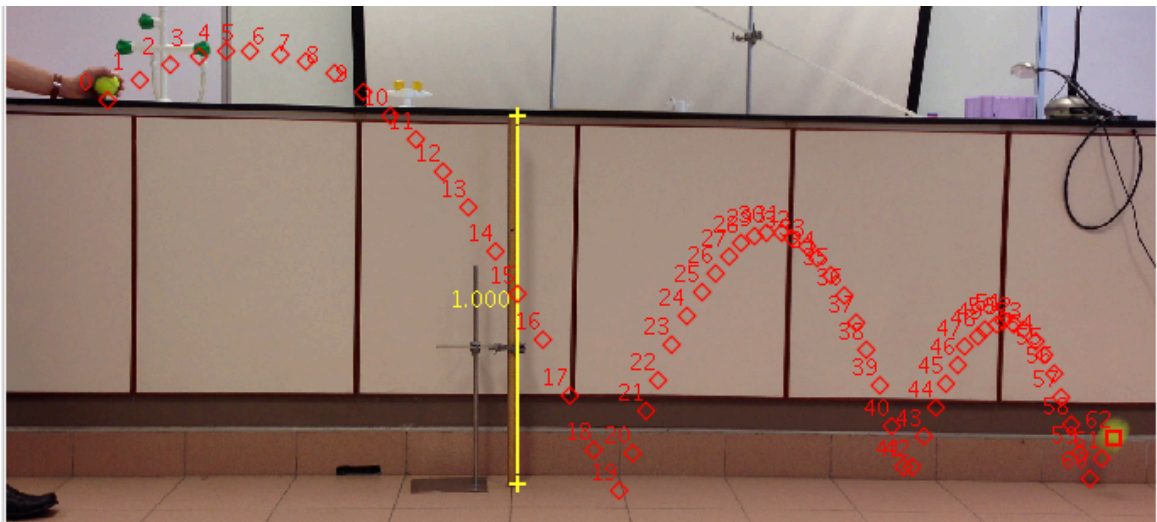


9. You should see a x – t graph on the right side of Tracker. Click Plot and choose to display 2 graphs. Click on the vertical axes and select *vx* for one of the graph and *vy* for the other graph.









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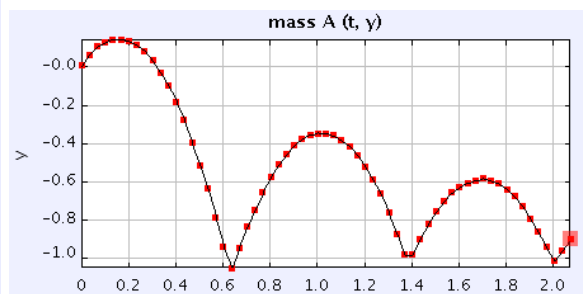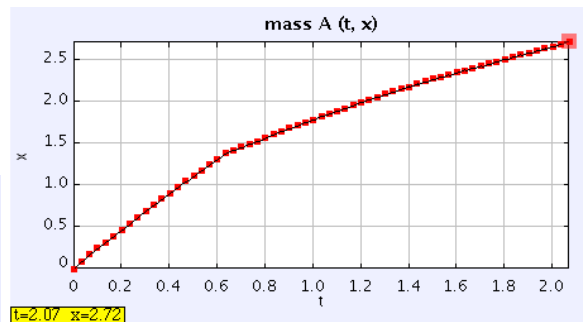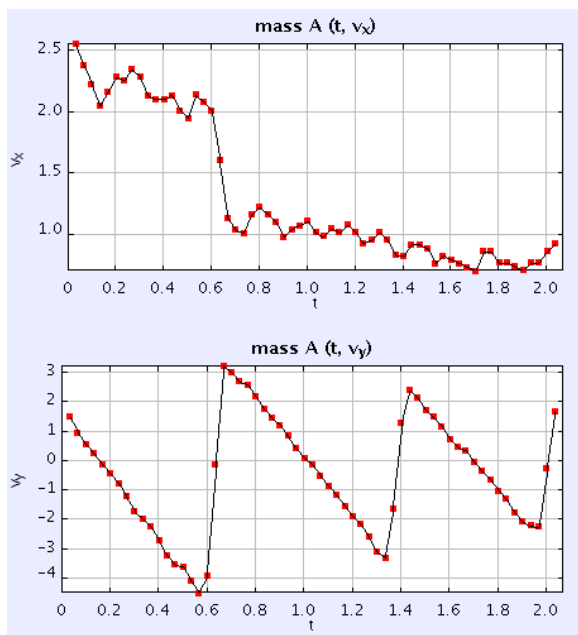
10. You can right-click on any graph and select **Snapshot**. A new window appears with the graphs and you can choose to save the graphs as images. This is a good way to document your graphs and compare them after class. Obtain the displacement – time and velocity – time graphs for both horizontal and vertical directions.
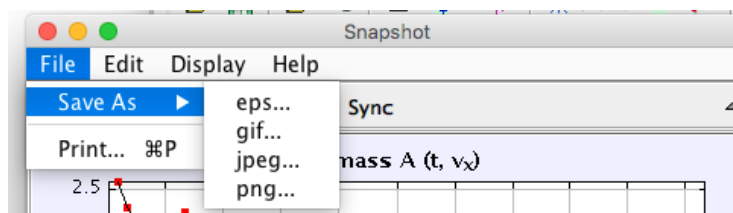


## Using Linear Fit to determine gradient

11. Double-click on the $x – t$ graph to bring up the **Data Tool**. Click **Analyze → Curve Fits**. Make sure the **Fit Name** is "*Linear*" and the Autofit option is checked. Now, by dragging on the graph, you can select the data points that you would like to do a curve fit. By looking at the value of **A**, you can deduce the gradient of that particular straight line Tracker has fitted for you.
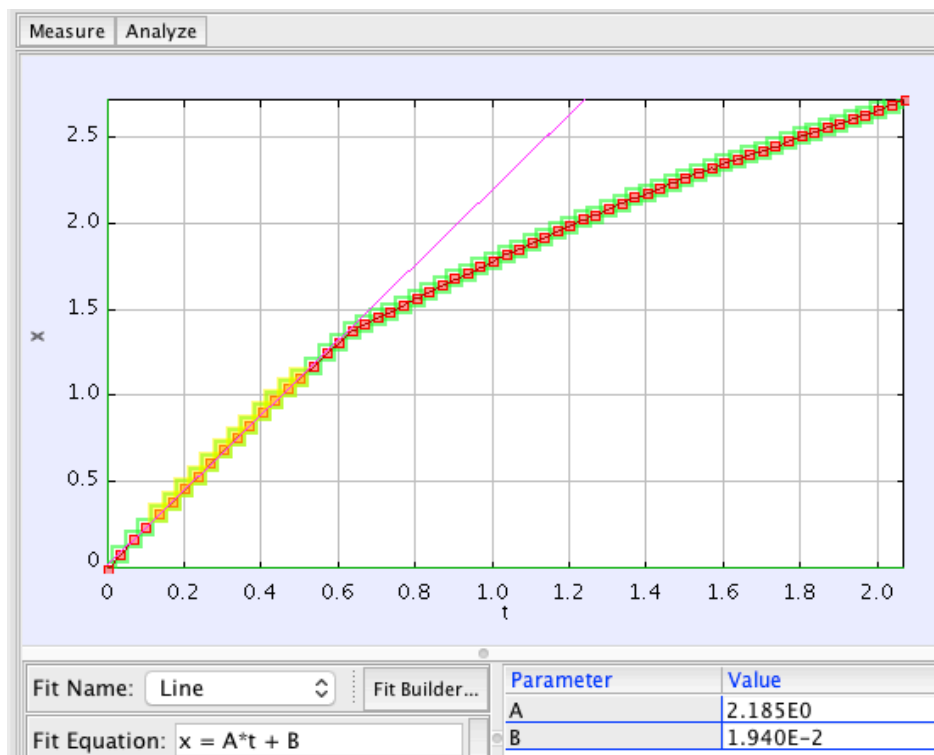


## Using Curve Fit to determine the mathematical model

12. Double-click on the $y – t$ graph to bring up the **Data Tool**. Click **Analyze → Curve Fits**. It is obvious that the relationship between y and t is not linear. Based on what we know from the topic of Kinematics, displacement can be related to time in a quadratic equation $s = ut + \frac{1}{2}at^2$.

Change **Fit Name** to "*Parabola*". The **Fit Equation** shows an equation with 3 parameters $A$, $B$ and $C$ in the form of $y = At^2 + Bt + C$.



Click on the small rectangle next to Fit Equation to change the colour of the curve fit to something more

distinguishable. Uncheck the lines option for *y* so that we can observe how well the curve fits our data points.

Drag on the graph to select the first set of data points from *t* = 0 s to when the value of *y* reach the first minimum. Make sure Autofit option is checked. You would see something similar to the screenshot below.
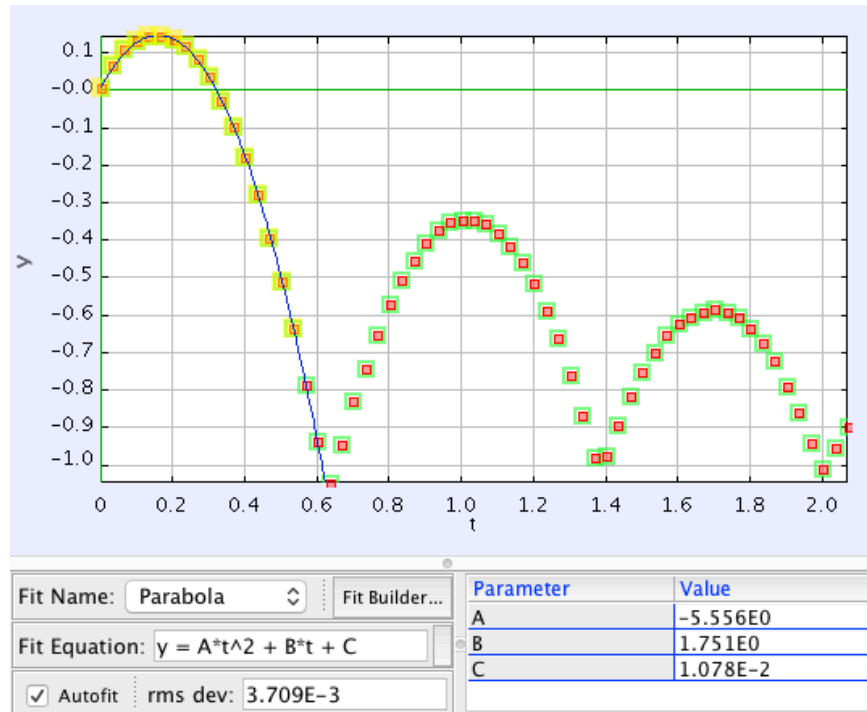
## Section C – Analysing the graphs

An object slides down an inclined slope from rest. The slope is at an angle of $\theta$ to the horizontal.
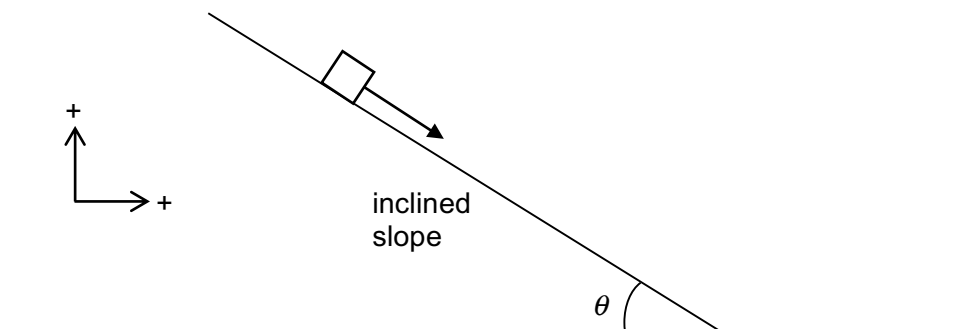


*Based on the video analysis in Tracker*, answer the following questions. Take upward and rightward as positive.

1. On the axes below, sketch the $v_x - t$ graph obtained in Tracker. Using **Step 11** of **Section B**, determine the equation of the graph.



   Equation of graph: ..............................................................................................................

2. On the axes below, sketch the $v_y - t$ graph obtained in Tracker. Using **Step 11** of **Section B**, determine the equation of the graph.



   Equation of graph: ..............................................................................................................

3. Measure the angle θ of the inclined slope using the protractor given. Hence calculate the theoretical value of the acceleration *along the slope*.

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4. Based on the velocity-time graphs obtained in Tracker, estimate the horizontal and vertical accelerations.

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5. Hence, calculate the acceleration along the slope using your answers in part 4.
   (*hint: Pythagoras' theorem*).
   Compare this value to the theoretical value in part 3. Explain any difference if any.

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Scenario 2
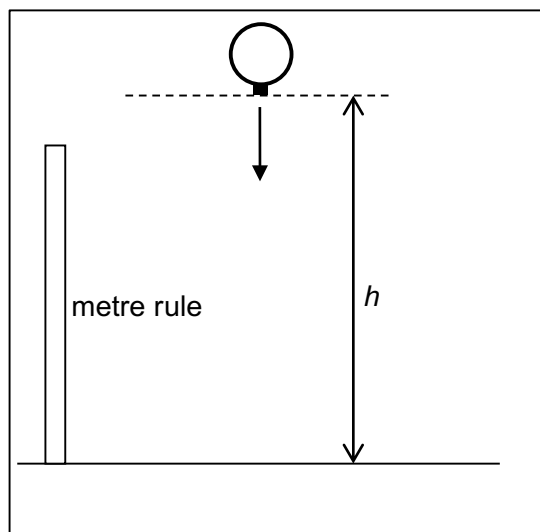
A balloon is released from rest at a certain height *h*.

*Based on the video analysis in Tracker*, answer the following questions. Take upward as positive.

1. Sketch the $v_y$-*t* graph obtained in Tracker



2. Does the shape of the graph in Tracker agree with your graph in **Worksheet A**? Suggest a reason for your answer.

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3. Base on your $v_y$-*t* graph in Tracker, estimate the initial acceleration of the cube. Comment on this acceleration value.

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4. Using your $v_y$-$t$ graph in Tracker, estimate the height $h$ of your friend who released the balloon during video recording. Verify with your friend.

Scenario 3

A ball is projected at an angle and allowed to bounce on the floor several times.
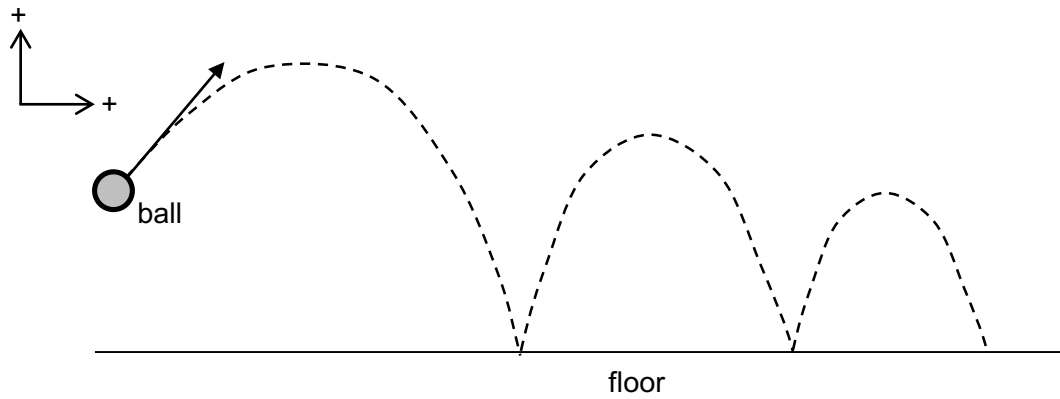


*Based on the video analysis in Tracker*, answer the following questions. Take upward and rightward as positive.

Horizontal motion ($x$ – direction)

Adjust your graphs so that you can see both $x - t$ and $v_x - t$ graphs at the same time.

1. You should observe that the data point on the $v_x - t$ graph display a lot of fluctuations. Suggest a reason for the fluctuations.

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2.  Using the $x - t$ graph and following **Step 11** of **Section B**, determine the horizontal component of the ball's velocity before and after the first bounce.

Before first bounce, $v_x$ = .................................................................................................

After first bounce, $v_x$ = ..................................................................................................

3.  On the axes below, sketch the $v_x$-$t$ graph if the fluctuations were minimal.

$v_x$

$t$

4.  Compare this graph with the graph you have sketched in Worksheet A. Comment on the differences.

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Vertical motion ($y$ – direction)

5.  Using the $y - t$ graph and following **Step 12** of **Section B**,

a.  determine the equation relating vertical displacement $y$ and time $t$ from $t = 0$ to just before the first bounce;

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b.  estimate a value of acceleration of free-fall from the above equation.

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6. Using the $v_y - t$ graph, determine another value of the acceleration of free-fall. Comment on the values of the 2 accelerations as compared to the theoretical value.

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7. On the axes below, sketch the $v_y - t$ and $a_y - t$ graphs.

$v_y$

$t$

8. Compare this graph with the graph you have sketched in Worksheet A. Comment on the differences.

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END