Vertical Motion   **Name:** _____

Aim: To analyse the motion of a vertically moving projectile; one dropped straight down and the other thrown vertically upwards.

Equipment: Digital Camera, Metre ruler, Computer software, golf ball.

Method: PART A:

- Film a golf ball being dropped with a digital camera. Include a metre ruler in the shot, making sure the ruler is the same distance from the camera as the line of the golf ball's fall. The camera must be still so you will need a tripod.
- Using Quicktime software (or similar), mark the position of the top of the ball at every second frame on a clear piece of plastic (eg. a sheet protector). Measure the length of the ruler on the screen and calculate the ratio between the real-life distance and the distances on the screen. Fill in the table.

Conversion Factor = Length of metre ruler on screen: _____ mm. Since this value is the length of 1m in real life, simply divide any on-screen measurements (in mm) by this number. You don't have to adjust for m, cm or mm, because this conversion factor automatically accounts for this.

Frame Rate: 30 frames/second. Each frame is therefore $\frac{1}{30}$ of a second (or 0.033seconds) apart.

Falling Golf Ball						
1	2	3	4	5	6	7
Frame Number	Time (s)	Displacement on screen **from original position** (mm).	Displacement in real life **from original position** (metres). $\frac{Column\ 3}{conversion\ factor}$	Displacement (m) **during each time period. (from Col 4) Row 2 – Row 1, Row 3 – Row 2 etc.**	Mid-point times (s)	Average velocity (during each time period) (m/s) $\frac{Column\ 5}{0.067s}$ (and exact velocity at the mid-point time)
0	0.0	0	0	- - - - - -	0	0
2	0.067				0.033	
4	0.13				0.1	
6	0.2				0.167	
8	0.267				0.233	
10	0.33				0.3	
12	0.4				0.367	
14	0.467				0.433	
16	0.53				0.5	
18	0.6				0.567	
20	0.66				0.633	

The velocity of the ball should increase in a steady fashion; that is, its acceleration is constant.

In the final column, you have calculated the ball's average speed between Frame 0 and Frame 2, Frame 2 and Frame 4 and so on. The average speed of the uniformly accelerating ball between any two points is equal to the exact speed of the ball at the half way time between the two points.

Therefore, the average speed you calculated in Column 7 = the exact speed at the "mid-point times" shown in Column 6.

Tasks:

(a) Draw a **displacement vs time graph** (x-t graph) (Column 4 vs Column 2). Draw in a line of best fit.

(If you draw the graphs on Excel, choose Scatter graph and Scatter with only Markers. See below for using Excel to draw a line of best fit)

(b) Draw a **velocity vs time graph** (v-t graph) (Column 7 vs Column 6). Draw in a line of best fit.

(c) Calculate the gradient of the line of best fit on the velocity vs time graph. This gradient is the object's acceleration (since the gradient of a line on a velocity time graph is equal to the object's acceleration)

Gradient = acceleration = _____

Drawing a Line of Best Fit on Excel: if you have drawn the graphs on Excel, right click a marker on the graph and then click "Add Trendline". For the v-t graph check the "linear" button and tick "Display Equation on Chart". The equation should be about y = 9.8x. For the x-t graph check the "polynomial" button and tick "Display Equation on Chart". The equation should be about y = 4.9x².)

Method: PART B:

Throw the ball vertically upwards and record the ball's motion using a digital camera until it comes back down again.

Analyze the ball's motion using Quicktime.

Conversion factor = Length of metre ruler on screen: _____ mm

Frame Rate: 30 frames/second. Each frame is therefore $\frac{1}{30}$ of a second (or 0.033seconds) apart.

Use every third frame.

Golf Ball Thrown Upwards (use the first frame after the ball has left the thrower's hand)						
1	2	3	4	5	6	7
Frame Number	Time (s)	Displacement on screen **from original position** (mm).	Displacement in real life **from original position** (metres). $\frac{Column\ 3}{conversion\ factor}$	Displacement (m) during each 3-frame time period. **(from Col 4)** **Row 2 – Row 1,** **Row 3 – Row 2 etc.**	Mid-point times (s)	Average velocity (during each time period) (m/s) $\frac{Column\ 5}{0.1s}$
0	0.0	0.0	0	- - - - - - - - -	- - - - - - -	- - - - - - -
3	0.1				0.05	
6	0.2				0.15	
9	0.3				0.25	
12	0.4				0.35	
15	0.5				0.45	
18	0.6				0.55	
21	0.7				0.65	
24	0.8				0.75	
27	0.9				0.85	
30	1.0				0.95	
33	1.1				1.05	
36	1.2				1.15	
39	1.3				1.25	
42	1.4				1.35	
45	1.5				1.45	
48	1.6				1.55	
51	1.7				1.65	
54	1.8				1.75	
57	1.9				1.85	
60	2.0				1.95	

Note: after the ball reaches the top of its flight, the velocity changes from +ve to –ve and the displacement starts to decrease.

Tasks:

(a) Draw a **displacement vs time graph** (x-t graph) (Column 4 vs Column 2). Draw in a line of best fit (or, in Excel, add a polynomial trendline).

(b) Draw a **velocity vs time graph** (v-t graph) (Column 7 vs Column 6). Draw in a line of best fit (or add a linear "trendline").

(c) Calculate the gradient of the line of best fit on the velocity vs time graph.

Gradient = acceleration = _____

The equation for the v-t graph should be about y = -9.8x (since in this case we have defined upwards as a positive displacement). The equation for the v-t graph should be about y = -4.9x².)

(d) Discuss any possible sources of error.