Physics Module 3, Investigation Validation

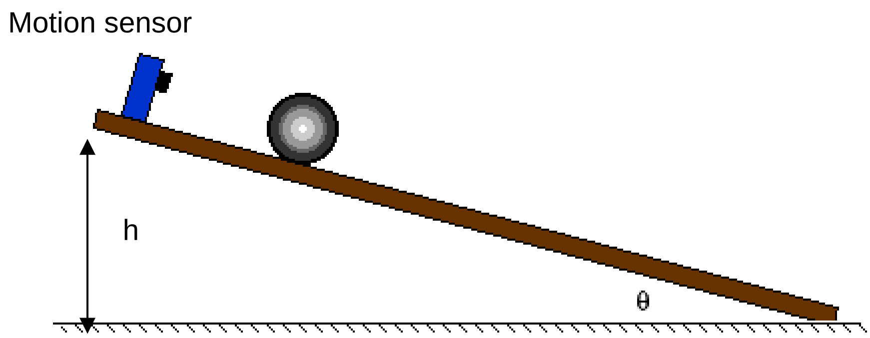
Name: ____

31

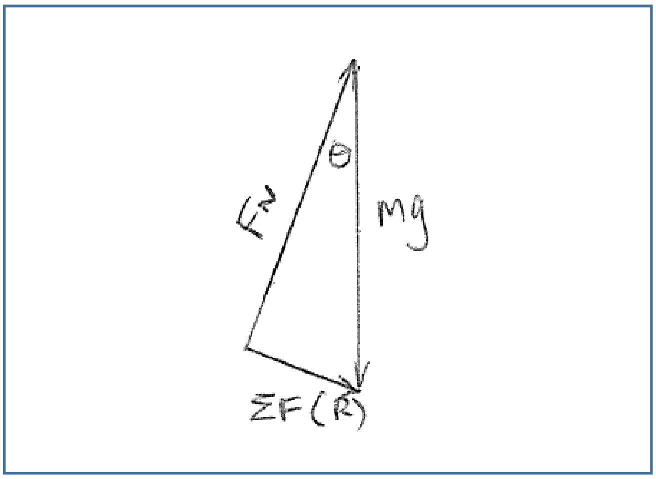
TIME ALLOWED: 55 minutes

Question One: Motion down an incline (20 marks)

Joan's group used a ramp they presumed to be frictionless to measure the acceleration due to gravity. They rolled a ball down the ramp and recorded the acceleration of the ball at different angles as measured by an ultrasonic motion detector and recorded on their Datalogger. The set-up is shown below. The length of the ramp was **1.4 metres** and they measured the height, h, at each angle.



a) **In the space on the right,** construct a **vector diagram** to show the forces acting on the ball, and the resultant of these forces. Include the angle, θ. (3 marks)



✓ 2 forces, correct directions

✓ Labels correct (inc. θ)

✓ Sum of forces shown correctly & labelled

b) Use your understanding of these forces and Newton's laws to clearly show that the acceleration of the ball is given by a = g sinθ (2 marks)

$\sin\theta = \frac{\Sigma F}{mg}$ ✓

$\Rightarrow \Sigma F = mg\sin\theta$

" $ma = mg\sin\theta$ ✓

$a = g\sin\theta$

The students recorded the following data

height (cm)	Angle, θ (°)	Sin θ	Acceleration (m s^{-2})			Mean acceleration (m s^{-2})
			Trial 1	Trial 2	Trial 3	
10	4.10	0.0714	0.71	0.75	0.76	0.74
20	8.21	0.143	1.61	1.47	1.52	1.53
30	12.4	0.214	2.81	2.62	2.95	2.79
40	16.6	0.286	2.80	2.88	2.85	2.84
50	20.9	0.357	3.75	3.68	3.70	3.71

✓✓ no mistakes

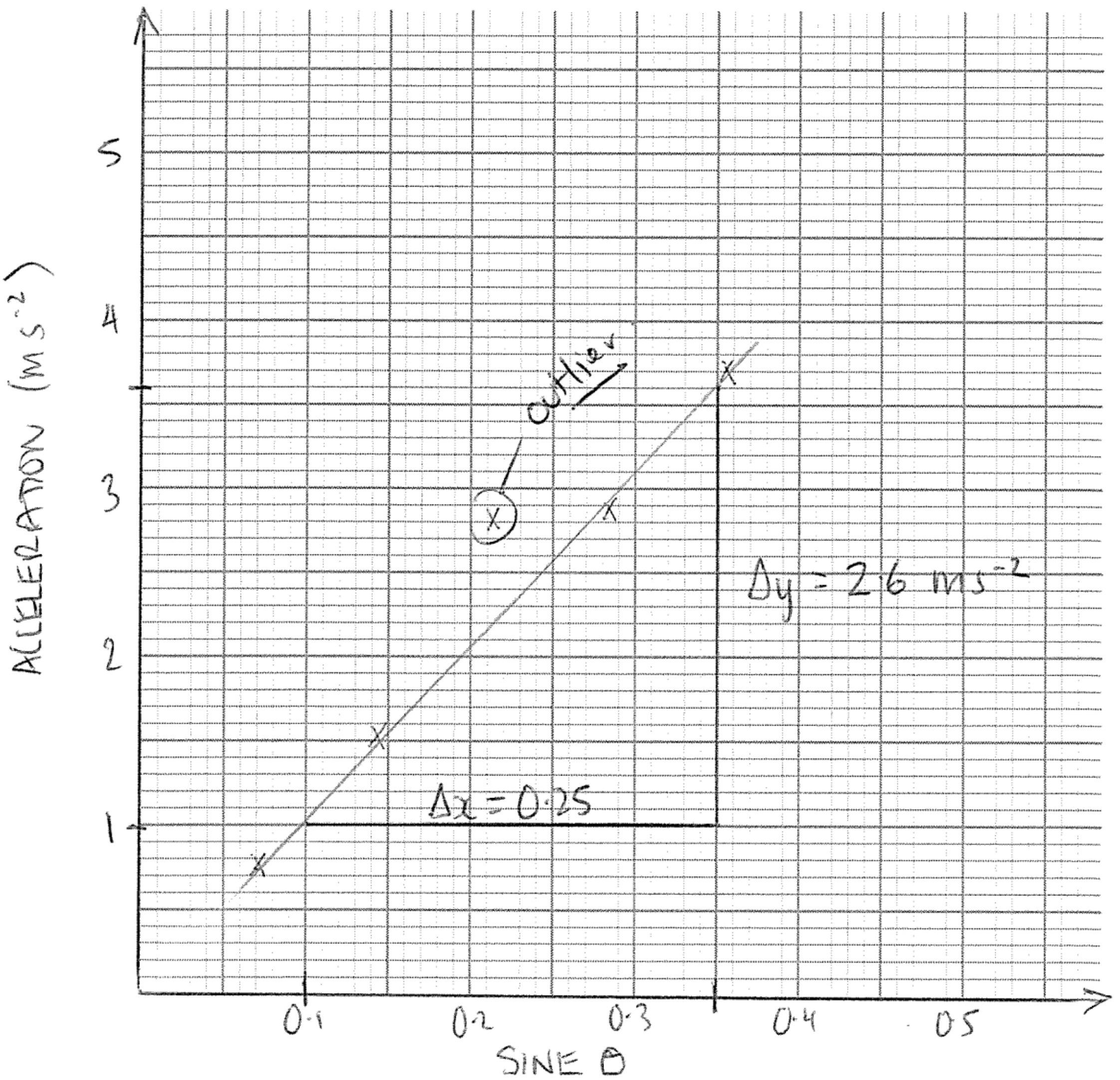
- x, y axes labelled & appropriate scales ✓
- plotting ✓
- outlier indicated & ignored for LOBF ✓✓

c) Complete the table (2 marks)

d) Plot acceleration against sin θ below and insert an appropriate line of best fit (4 marks)

or (• outlier not indicated LOBF correctly done with outlier ✓ out of 2)

ACCELERATION VS SINE OF RAMP ANGLE



/6

e) Showing all working and reasoning clearly, calculate the gradient of the line of best fit and use it to calculate the free fall acceleration due to gravity near the Earth's surface, g. (3 marks)

Indicates construction or graph ✓

$$m = \frac{\Delta y}{\Delta x} = \frac{2.6}{0.25} = 10.4\ ms^{-2}$$ ✓

$$g = \frac{a}{\sin\theta} = .m = 10.4\ ms^{-2}$$ ✓

f) Calculate the percentage difference between your value and the accepted value in Perth (as published in your data sheet) (1 mark)

$$100 \times \frac{10.4 - 9.8}{9.8} = 6.12\ \%$$ ✓

g) Is it likely that friction is causing some or all of the error? Explain. (1 mark)

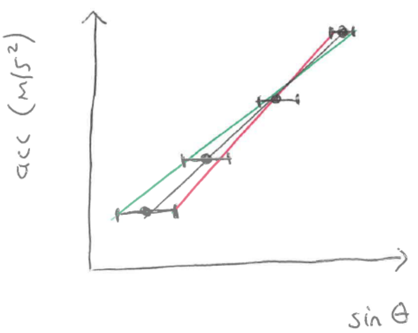
No, friction would result in an under-estimate. ✓

h) In an effort to explain the difference (calculated in part f), Joan suggested that due to thickness of their ramp and other factors, their measurement of the height of the end of the ramp was only accurate to within ±1 cm.

Using this assumption, and the graph that you constructed in part d), explain a method that you could use to test the effect that this would have on your calculated value of 'g' (you do not need to carry out this method on your graph, but you do need to explain it step by step).

(4 marks)

✱ Consider the graph; if the height of the ramp is off by ± 1cm, this would result in an uncertainty on sin θ, which we could represent with horizontal error bars. (eg.--)



Using these error bars, we could calculate the maximum & minimum possible gradient allowed by them (pictured left in red & green respectively). This, in effect, allows us to calculate an error in our value for 'g'.

Marking Key:

✓ - Use error in height (± 1cm) to calculate error in sin θ.

✓ - Put this error onto the graph in the form of horizontal error bars.

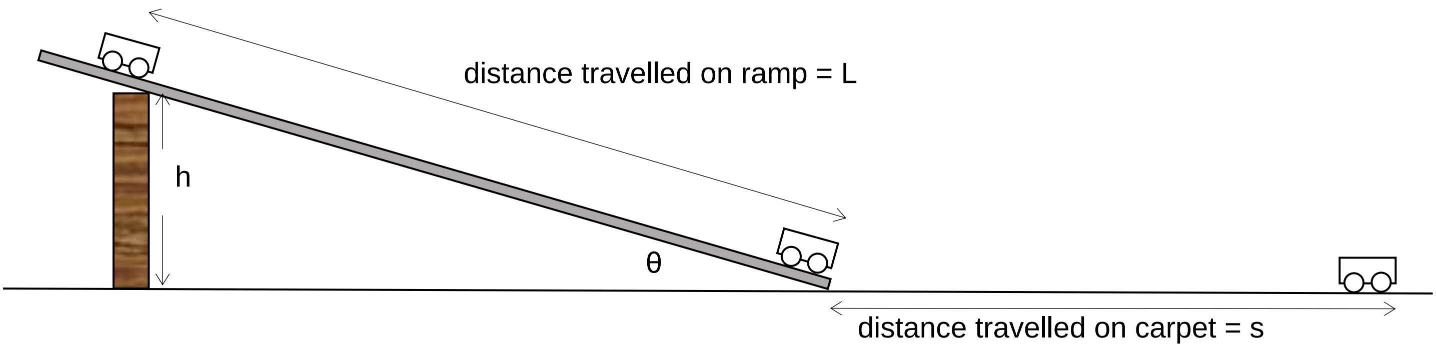
✓ - Use these error bars to construct new lines-of-best-fit, to calculate a maximum & minimum possible value for the gradient, and therefore for 'g'.

✓ - State 'g' with newly-calculated uncertainties.

Question Two - Friction (11 marks)

Joan and her group then carried out an investigation to study the effect of weight on the rolling friction force of a trolley.

Friction is a force which opposes motion when moving surfaces come into contact. Rolling friction is a complex type of friction present in the situation when wheels are rolling on a surface. Below is a diagram of the experiment.



Joan believed that the friction down the ramp was negligible, but she wanted to test this assumption. With the angle of the ramp, θ, set at 20º, they used a stopwatch to measure the time the trolley took to roll distance L down the ramp starting from rest (t). They obtained the following data:

L (m)	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)
1.2	0.83	0.87	0.86

a) Using an appropriate calculation, show that, based on this data, the friction appears to be negligible **within experimental error**. Justify your explanation. (3 marks)

Frictionless.

$a = g\sin\theta$
$= 9.8\sin 20°$
$= 3.3518$ ✓

$s = \cancel{ut}^{\,0} + \frac{1}{2}at^2$

$\rightarrow t = \sqrt{\frac{2 \times 1.2}{3.3518}}$

$= 0.846$ s ✓

this is between our lowest & highest measurements in the three trials, so it is reasonable to assume friction is negligible. ✓

b) Ignoring friction, calculate the expected speed at the base of the ramp (1 mark)

$v = u + at$
$= 0 + 3.3518 \times 0.846$
$= 2.84\ ms^{-1}$ ✓

or $\left(v = \sqrt{2as} = \sqrt{2 \times 3.3518 \times 1.2} = 2.84\ ms^{-1} \right)$

/4

Confident that the rolling friction was negligible, they group then changed the angle slightly to decrease the final speed of the trolley. At 15°, they calculated that the trolley speed should be 2.5 m/s at the base of the ramp.

The group performed three trials each measuring the distance travelled on the carpet by the trolley, loading the trolley up with different masses. They obtained the following data:

Ramp angle = 20°, Starting velocity u = 2.5 m s^{-1}							
Mass in trolley (g)	Weight in trolley (N)	Distance, s (m)			Mean distance (m)	Deceleration ($m\ s^{-2}$)	Average Friction Force (N)
		Trial 1	Trial 2	Trial 3			
100	0.98	6.23	6.40	6.3	6.31	0.495	0.0495
200	1.96	6.15	6.20	6.20	6.18	0.506	0.101
300	2.94	6.2	6.2	6.15	6.18	0.506	0.152
400	3.92	6.1	6.3	6.15	6.15	0-508	0·203

c) Calculate the values for the missing cells and fill them in the table. Show and explain your working clearly. (3 marks)

Deceleration:

$v^2 = u^2 + 2as$

$a = \frac{v^2 - u^2}{2s}$ ✓

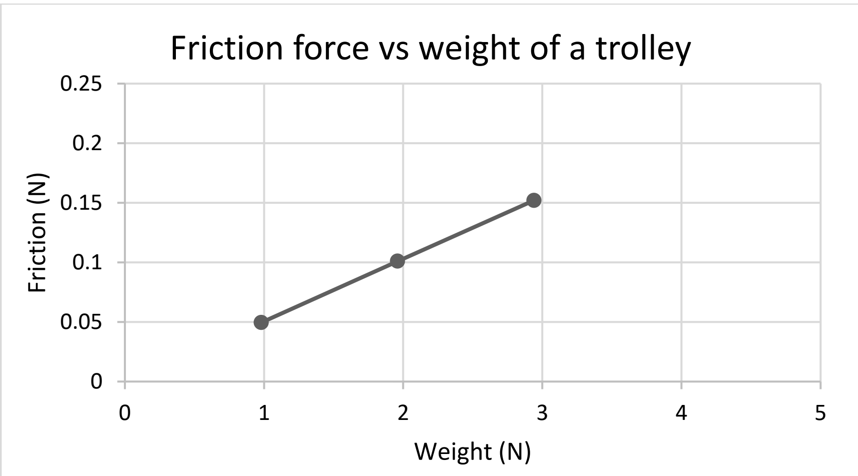
$= \frac{0 - 2.5^2}{2 \times 6.15} = 0.50813$ ✓

Friction $F_f = ma$

$= 0.4 \times 0.50813$

$= 0.203.$ ✓

This data is plotted below. You may wish to add your calculated data point.



d) We set out to investigate the relationship between friction force and weight of the trolley. Summarise this relationship in a sentence: (2 marks)

F_f is directly proportional to weight.

✓ ✓

e) You may have noticed that the students forgot to weight the trolley and include it in their calculations. The mass of the trolley was small (less than 100 g) but significant. Explain the effect of this mistake on the following by circling the correct words (2 marks):

i. The calculated decelerations on the carpet would have been **higher / lower / the same** in magnitude if they included the mass of the trolley in their calculations. ✓

ii. The calculated friction force would have been **higher / lower / the same** in magnitude if they included the mass of the trolley in their calculations. ✓

End of Validation