Physics Education Program

Name: ______________________________

Teacher: ______________________________

School: ______________________________

The Tower of Terror

student activity

Key Ideas

Acceleration, Centripetal Acceleration, Conservation of energy, Forces, Free fall, Kinetic energy, Potential energy, Velocity

Equipment

Accelerometer
Wristwatch with stopwatch feature
Triangulation device
Calculator
Pencils and clipboard

Activities with this symbol may be completed while you're lining up for the next ride, or after you leave Dreamworld.

Standard Achieved: Knowledge and Conceptual Understanding, Scientific Techniques and Scientific Investigation

VHA	HA	SA	LA	VLA	Not Attempted
• acquires, constructs and presents knowledge and understanding of *quantitative* concepts, ideas, theories and principles in complex and challenging situations	• acquires, constructs and presents knowledge and understanding of *quantitative* concepts, ideas, theories and principles in a complex and challenging situation	• acquires, constructs and presents knowledge and understanding of *quantitative* concepts, ideas, theories and principles	• acquires and presents knowledge of concepts, ideas and theories and principles	• recalls knowledge of physics concepts and ideas	• not attempted
• applies technology to gather and record valid data and information with discrimination	• applies technology to gather and record valid data and information	• uses technology to gather and record data and information	• uses technology to gather and record data and information in a limited manner	• uses technology to gather and record data and information in a very limited manner	• not attempted
• identifies relationships between trends, patterns, errors and anomalies in data and information	• identifies trends patterns errors and anomalies in data and information	• identifies obvious trends, patterns, errors and anomalies in data and information	• identifies obvious patterns and errors in data and information	• records data and information	• not attempted

The Tower of Terror

This page should be completed using Dreamworld's *Tower of Terror Information Brochure.*

V_{max}	=	**161 km/hr**
t	=	**7 seconds**
m_{car}	=	**6000 kilograms (average)**

What is the linear acceleration of the car? ______________________________

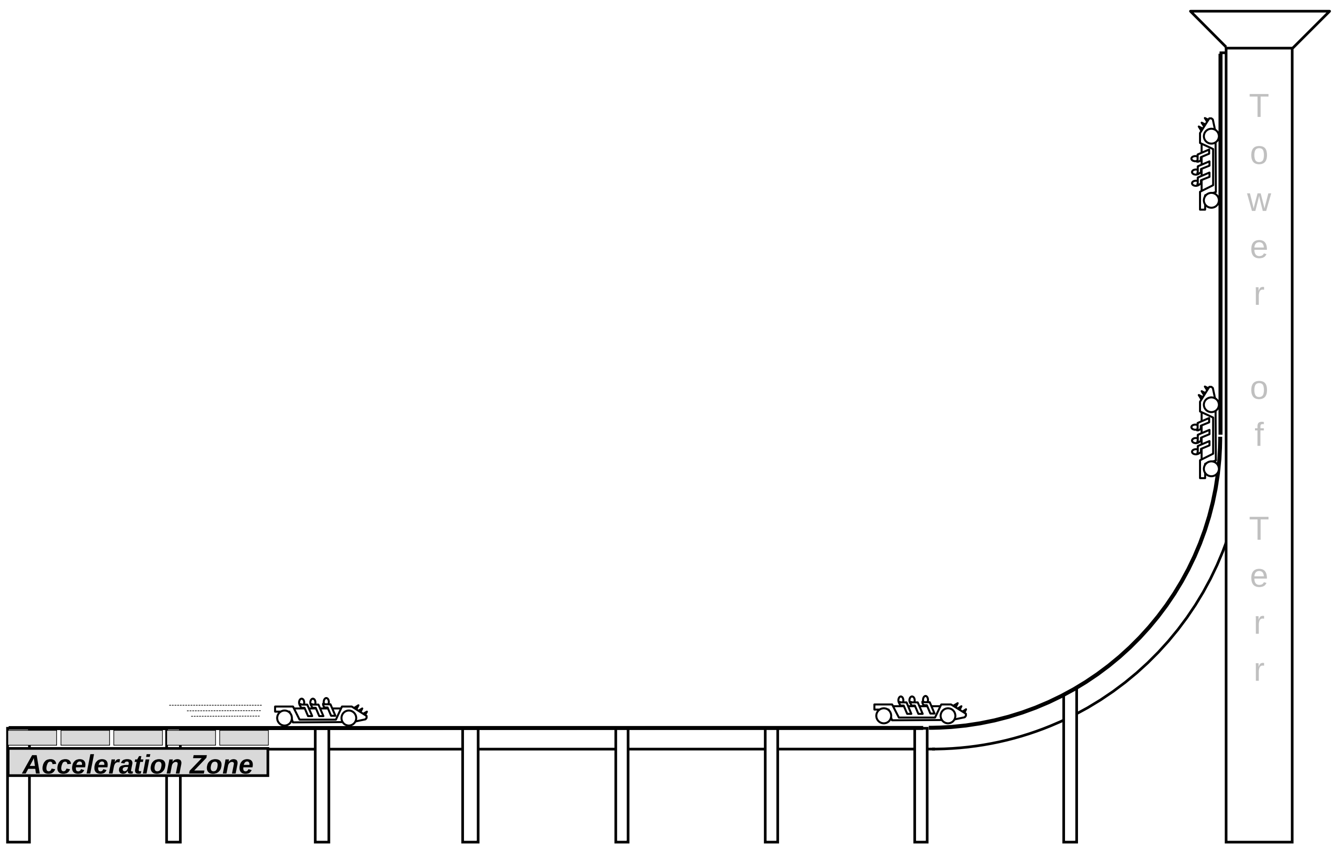
Where do riders experience 4.5g? ______________________________

What is the maximum height the car will reach? ______________________________

Where on the track will a vertical accelerometer read 0 g? ______________________________

How much energy is required to lift the car to its maximum height? ______________________________

What is the power requirement of the Tower of Terror in Megawatts? ______________________________



The Tower of Terror

Minimum Group Size: 2 students. If there are more than two people in your group, use the average of measurements made — this will improve the accuracy of the group's measurements

Objectives

The Tower of Terror is the perfect ride for learning about the relationships between linear acceleration and final velocity, centripetal acceleration and velocity, and kinetic and potential energy.

You will experience:

- *accelerations of up to 4.5* ***g****s*
- *weightlessness for almost 6.5 seconds*
- *speeds of up to 160 km/hr (44 ms^{-1})*

You will measure:

- *the horizontal, linear acceleration of the car*
- *the time for which the car accelerates horizontally*
- *the centripetal acceleration of the car*
- *the acceleration during freefall*
- *angles to various parts of the Tower*

Then you will be able to calculate:

- *the radius of the curved part of the track*
- *the height reached by the car*
- *the final velocity of the car using three methods for comparison*

Ride Measurements

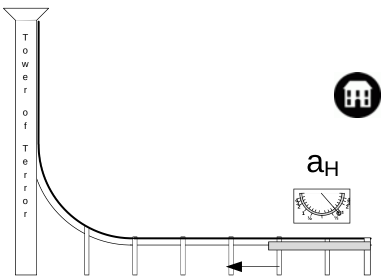
Read this activity sheet thoroughly prior to riding, to ensure you manage to take all the measurements required (missed measurements will delay you in queue time).

Ride the Tower of Terror in pairs. If you are using hand-made accelerometers, take measurements with:

- Student A wearing the horizontal accelerometer.
- Student B wearing the watch on one hand and vertical accelerometer on the other

Record your results as soon as you can after riding.

Student A's Measurements
Going up

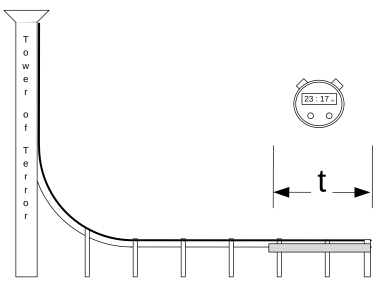


1. Horizontal accelerometer reading a_H = _____ ***g***s

2. Convert a_H to ms^{-2} a_H = ms^{-2}

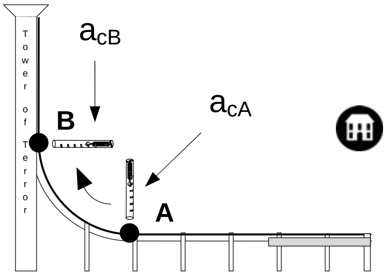
If you are using hand-made accelerometers, for the rest of the ride, observe the readings on the vertical accelerometer

Student B's Measurements
Going Up



3. Use your wristwatch/stopwatch to record the duration of the horizontal acceleration **t** = s

(ie the time for which your accelerometer is registering an acceleration)
YOU WILL NEED TO CONCENTRATE AT THIS POINT — LISTEN TO THE RIDE ATTENDANT BUT BE PREPARED FOR THIS MEASUREMENT



4. Vertical accelerometer reading at point A (the bottom of the curve going up)

a_{cA} = ________ gs

5. *Convert* a_{cA} *to* ms^{-2}

a_{cA} = ms^{-2}

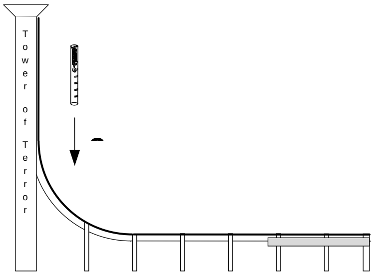
6. Vertical accelerometer reading at point B (the end of the curve going up)

a_{cB} = ________ gs

7. *Convert* a_{cB} *to* ms^{-2}

a_{cB} = ms^{-2}

Coming Down



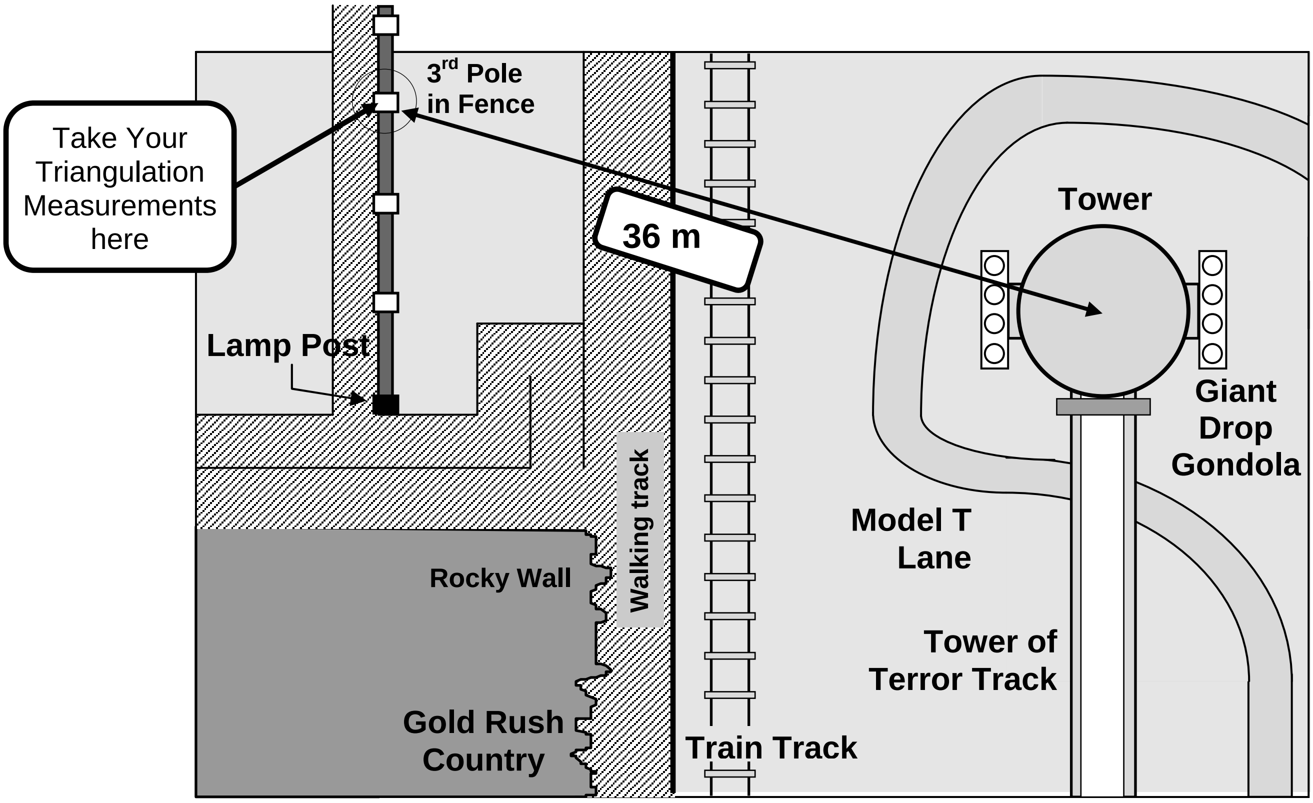
8. Vertical accelerometer reading during freefall
   (hold the accelerometer parallel to the tower during this part of the ride)

a_F = gs

If time permits, ride the Tower of Terror again to confirm your results.

Map

Tower of Terror Triangulation Measurements

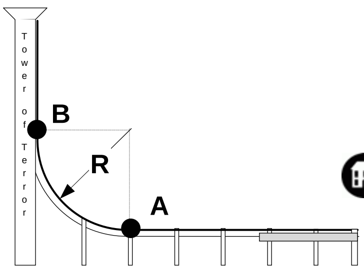


Find the third wooden pole from the junction between the rusty fence and rocky wall, as shown on the map above. The distance from this pole to the centre of the Tower is 36 metres.

Triangulation Measurements from Observation Point

At the observation point, the height of Point A (i.e. the height of the horizontal part of the track) is at ground level — so point A is 0 metres above the observation point.

Point B is at the same height as the "O" in the word "Terror" on the tower. You can see the join from the curved part of the track to the vertical part and this is where you should aim your triangulation device.



9. Angle to point B θ_B = ________ ^{0}

10. *Horizontal distance to point B* D_B = 36 m

11. Calculate the height of point B

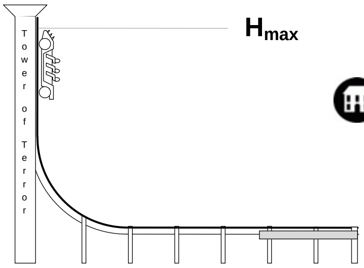
Workspace:

Equations:

H_B = m

$H = D \tan \theta$

12. The radius of curvature R from the diagram, is simply the height of point B. Enter the value again as R.



13. Measure the angle to the maximum height of the car. $\theta_C = \_\_\_\_\_\_ ^0$

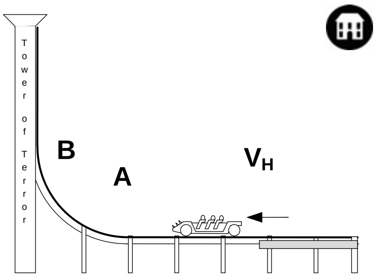
14. Using the horizontal distance to the tower, calculate H_{max}

Workspace:

$H_{max} = \_\_$ m

Ride Analysis

Final velocity — METHOD 1



15. Calculate the velocity of the car on the horizontal part of the track (just as leaves the acceleration zone) using the measurements you made with the horizontal accelerometer and the stopwatch at questions 2 and 3 above.

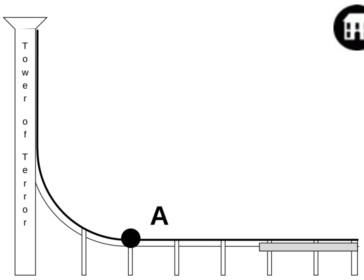
Workspace:

Equations:

$v = u + at$

v_H =		ms^{-1}
v_H =		km/h

Final velocity—METHOD 2



16.a. For point A, draw a force diagram for the mass in your *vertical accelerometer,* showing the measured net acceleration from question 5 above.

Force Diagram:

Equations:

$$a_c = \frac{v^2}{R}$$

16.b. Based on your force diagram, calculate the *centripetal* acceleration (*that is, the acceleration due to circular motion, ignoring gravitational acceleration*).

Work space:

$a_{cA} = \_\_\_\_\_\_\_\_ ms^{-2}$

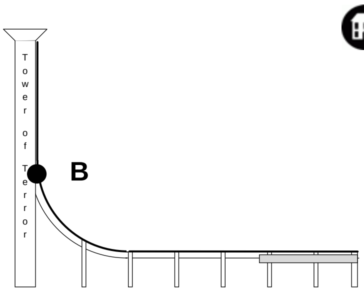
17. Use the value of a_{cA} calculated in question 16 to calculate the velocity of the car at point A.

Work space:

V_A = ms^{-1}

v_A = km/hr

Velocity at Point B



18.a. For point B, draw a force diagram for the mass in your *vertical accelerometer* showing the measured net acceleration from question 7 above.

Force Diagram:

Equations:

$$a_c = \frac{v^2}{R}$$

18.b. Based on your force diagram, what is the *centripetal* acceleration (*that is, the acceleration due to circular motion, ignoring gravitational acceleration*).

a_{cB} = ms^{-2}

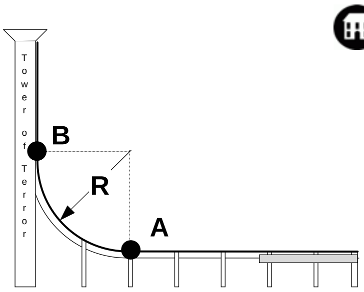
19. Use the value of a_{cB} determined in question 18 to calculate the velocity of the car at point B.

Work space:

V_B = ms^{-1}

V_B = km/h

20. Compare the velocities V_A and V_B and explain why they might be different.



21. At point B, the car has travelled a vertical distance R against gravity. Use the value of v_H which you calculated in question 15 for the initial velocity, u, and R calculated at question 12 for the height s, calculate the expected velocity v at point B.

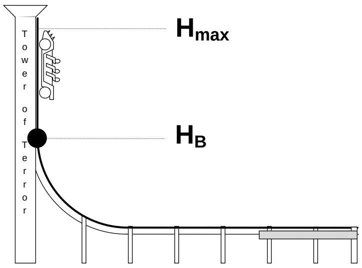
Work space:

Equations:

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

V_B = ms^{-1}

V_B = km/h



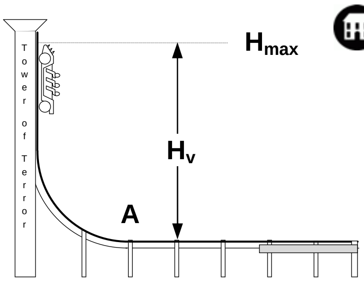
22. Use the maximum height of the car and the height of point B to determine the expected velocity of the car at point B after falling back down the track.

Work space:

V_B = ms^{-1}

V_B = km/hr

Final velocity — METHOD 3: Challenge



23. Determine the initial velocity of the car at Point A from nothing more than the vertical distance travelled by the car H_V, which you measured. You will need to use conservation of energy to combine the equations for kinetic and gravitational potential energy, and solve for v.

Workspace:

Equations:

KE = ½ m v^2

GPE = m g h

V_A = ms^{-1}

V_A = km/hr

Comparing results

24. Compare the values you obtained using methods 1, 2 and 3.

METHOD 1 (From q.15) V_A = _________ ms^{-1} = ____________km / h
(Horizontal Accelerometer Method)

METHOD 2 (From q.17) V_A = _________ ms^{-1} = ____________km / h
(Vertical Accelerometer Method)

METHOD 3 (From q.23) V_A = _________ ms^{-1} = ____________km / h
(Conservation of Energy Method)

25. Compare your three values for V_A calculated above with that suggested by Dreamworld (161km/h). Propose reasons for any discrepancies between these four values.

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