GRADE 12 PHYSICS

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CW Physics, Science & Math Program Activities

A correlation with the Ontario Science Curriculum Physics, Grade 12, University Preparation

Dynamics (B)	Energy (C)
B1.1 analyse technological devices that apply the principles of the dynamics of motion B2.1 use appropriate terminology related to dynamics B2.2 solve problems related to motion, including projectile and relative motion, by adding and subtracting two dimensional vector quantities, using vector diagrams, vector components and algebraic methods B2.4 predict, in qualitative and quantitative terms, the forces acting on systems of objects and plan and conduct an inquiry to test their predictions B2.7 conduct inquiries into the uniform circular motion of an object and analyse, in qualitative and quantitative terms, the relationships between centripetal acceleration, centripetal force, radius of orbit, period, frequency, mass and speed B3.1 distinguish between reference systems (inertial and non-inertial) with respect to the real and apparent forces acting within such systems B3.2 explain the advantages and disadvantages of static and kinetic friction in situations involving various planes	C2.1 use appropriate terminology related to energy and momentum, including, but not limited to: work, work–energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum–impulse theorem, elastic collision, and inelastic collision C2.2 analyse, in qualitative and quantitative terms, the relationship between work and energy, using the work–energy theorem and the law of conservation of energy, and solve related problems in one and two dimensions

JOURNAL ENTRY

CATEGORY	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Knowledge and Understanding Demonstrates an understanding of the relationship between forces and the acceleration of an object in linear and circular motion	- demonstrates limited understanding of relationships between forces and acceleration	- demonstrates some understanding of relationships between forces and acceleration	- demonstrates considerable understanding of relationships between forces and acceleration	- demonstrates thorough understanding of relationships between forces and acceleration
Inquiry Applies technical skills and procedures of a problem solving process	- design experiments involving energy transformations and the law of conservation of energy, with limited competence	- design experiments involving energy transformations and the law of conservation of energy, with moderate competence	- design experiments involving energy transformations and the law of conservation of energy, with competence	- design experiments involving energy transformations and the law of conservation of energy, with a high degree of competence
Communication Communicates the results of the investigation	- uses scientific terminology, symbols, and standard (SI) units with limited accuracy and effectiveness	- uses scientific terminology, symbols, and standard (SI) units with some accuracy and effectiveness	-uses scientific terminology, symbols, and standard (SI) units with accuracy and effectiveness	- uses scientific terminology, symbols, and standard (SI) units with a high degree of accuracy and effectiveness
Making Connections Analyses the effect of a net force on the linear and circular motion of an object in quantitative terms using calculations, free-body diagrams and written descriptions	- proposes courses of practical action in designing a roller coaster ride with limited clarity and precision	- proposes courses of practical action in designing a roller coaster ride with some clarity and precision	- proposes courses of practical action in designing a roller coaster ride with clarity and precision	- proposes courses of practical action in designing a roller coaster ride with a high degree of clarity and precision

VOCABULARY

ACCELERATION
ACCELEROMETER (VERTICAL OR HORIZONTAL)
CENTRIPETAL ACCELERATION
CENTRIPETAL FORCE
DISPLACEMENT
DISTANCE
ENERGY
FORCE
FRICTION
FREE-BODY DIAGRAM
G-FORCE
GRAVITATIONAL POTENTIAL ENERGY
GRAVITY
JOULE
KINETIC ENERGY
LAW OF CONSERVATION OF ENERGY
MASS
NEWTON
POWER
SPEED
TENSION
TRACK PROFILE
VELOCITY
WATT
WEIGHT
WORK

USEFUL EQUATIONS

KINEMATICS

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta d = \tfrac{1}{2}(v_1 + v_2)\,\Delta t$$

$$a = \frac{v_2 - v_1}{\Delta t}$$

$$v_2 = v_1 + a\Delta t$$

$$\Delta d = v_1\,\Delta t + \tfrac{1}{2}\,a\Delta t^2$$

$$v_2^2 = v_1^2 + 2a\Delta d$$

ENERGY

$$W = f\Delta d$$

$$KE = \tfrac{1}{2}\,mv^2$$

$$\Delta PE_g = mg\Delta h$$

$$P = \frac{W}{\Delta t}$$

$$E_{Total} = E'_{Total}$$

DYNAMICS

$$F_{net} = ma$$

$$F_f = \mu F_N$$

$$F_g = mg$$

$mv2\ m4\pi2\ r\ 22$

$$F_c = \frac{mv^2}{r} = \frac{m4\pi^2 r}{T^2} = m4\pi^2 r f^2$$

USEFUL EQUATIONS

A) DISTANCE, VELOCITY AND ACCELERATION

d = Distance travelled (m)
v_a = Average velocity (m/s)
v_i = Initial velocity (m/s)
v_f = Final velocity (m/s)
a = Acceleration (m/s2)
t = Time taken (s)
$v_a = d/t$

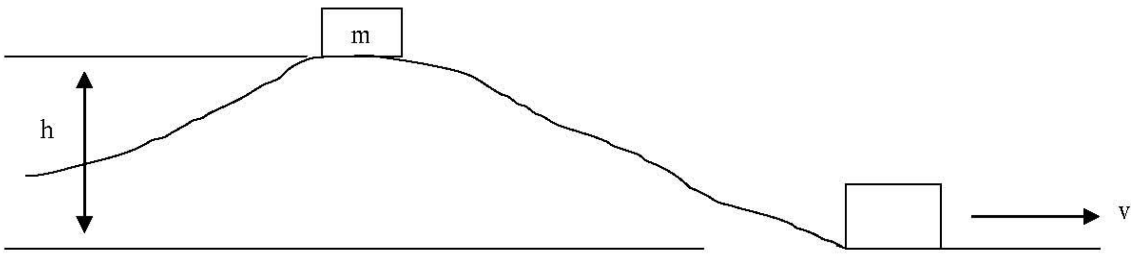
FOR MOTION UNIFORMLY ACCELERATED FROM REST

$d = ½ at^2$
$d = ½ (v_f t)$
$v_f = at$

FOR MOTION UNIFORMLY ACCELERATED FROM INITIAL VELOCITY (v_i)

$d = (v_f+v_i)\ t/2$
$d = v_i t + 1/2\ at^2$
$d = v_f t – 1/2\ at^2$
$v_f = v_i + at$
$v_i = v_f – at$
$a = (v_f – v_i)\ /t$

B) POTENTIAL AND KINETIC ENERGY



PE = Gravitational Potential Energy, (J)
= mgh

KE = Kinetic Energy, (J)
= 1/2 mv^2(Body in translational motion)

where:
- m = Mass (kg)
- h = Height (m)
- g = Acceleration due to gravity = 9.8 m/s^2
- v = Velocity (m/s)

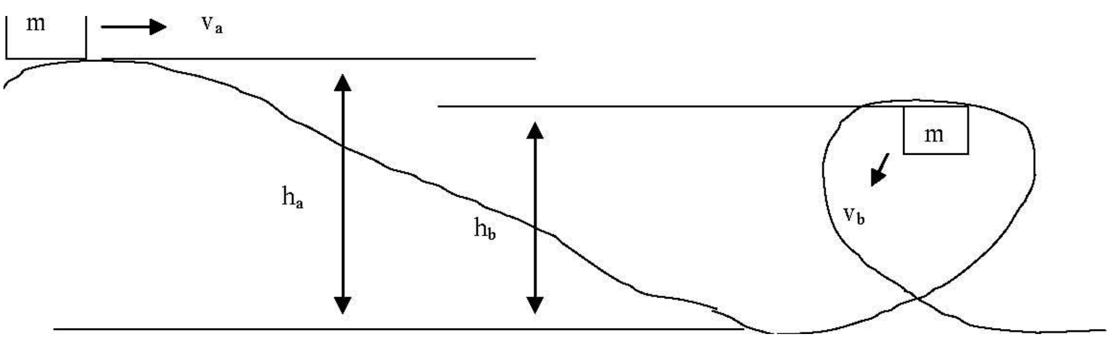
Assume that there is no energy loss and that the object is at rest at the top of the hill.

$PE_{TOP} = KE_{BOTTOM}$

Example:

$$mgh = 1/2mv^2,\ v^2 = 2gh,\ v = (2gh)^{½}$$

Considering the change in potential and kinetic energy possessed by a coaster train at the top of the lift (Point a) and the top of the vertical loop (Point b) as follows:



$$PE_a + KE_a = PE_b + KE_b$$
$$mgh_a + 1/2\ mv_a^2 = mgh_b + 1/2\ mv_b^2$$
$$v_b = (2g\ (h_a - h_b) + v_a^2)^{½}$$

NOTE: Assume no energy loss in the above cases.

C) CENTRIPETAL FORCE

F = Centripetal force (N) where: m = Mass (kg)
v = Velocity (m/s)
r = Radius of the rotational path(m)

$= mv^2/r$

D) LINEAR MOMENTUM

p = Linear momentum of a body of linear motion (kg m/s)

= mv where: m = Mass(kg)
v = Velocity (m/s)

E) FORCE AND PRESSURE

p = Pressure (N/m^2 or Pa)
=F/A where: A = Area (m^2)
F = Force (N)

F) MOTOR SPEED, LIFT CHAIN SPEED, AND TENSION

v = Velocity of the lift chain (m/s)
$= \frac{PNn}{1000}$

F = Chain tension (N)
$= \frac{W}{v}$

where:

P = Chain pitch (mm)
N = Number of the sprocket
n = Rotational speed of the sprocket (r.p.m.)
W = Power of motor (W)

G) POWER

P = Power (W)
$= \frac{W}{t}$

$= \frac{E}{t}$

where: W = Work (J)
E = Energy (J)
t = Time (s)

A) TIME

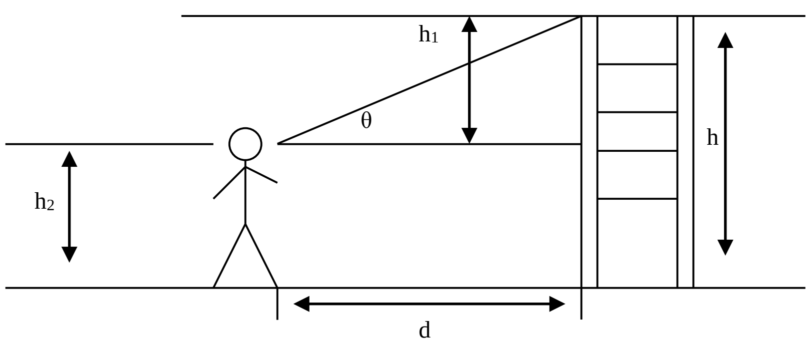
Time can easily be measured by using a stop watch.

B) DISTANCE

Since the normal operation of the ride cannot be interfered with, measurements of distances directly in the ride area are **absolutely not allowed**. For safety reasons, measurements of heights, distances and diameters can be estimated remotely by using the following methods:

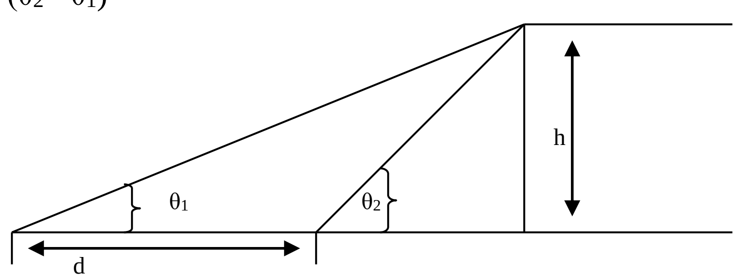
I *Distance and Diameter*
Determine the distance to be measured by means of your pacing.

II *Height*
1) By means of trigonometric calculations, height can be determined by one of the following methods:
$h_1 = dTAN\theta$
h_2 = Height from the ground to your eye level
h = Total height
$= h_1 + h_2$

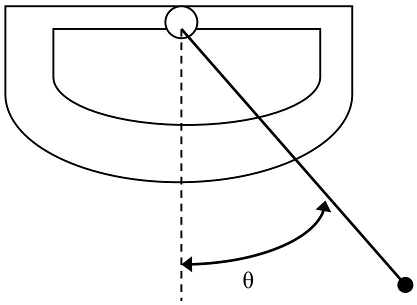


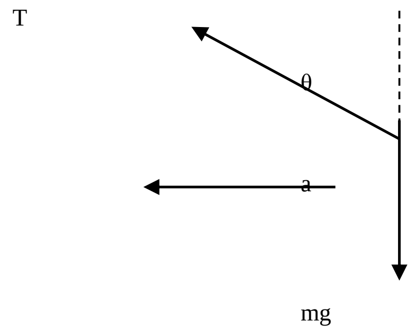
2) Measure the angles θ_1 and θ_2 with a protractor (actually, the horizontal accelerometer) at two different locations as illustrated below:

$h = d (SIN\ \theta_1\ sin\ \theta_2/SIN\ (\theta_2 - \theta_1)$



C) LATERAL OR LONGITUDINAL ACCELERATION
This instrument consists of a protractor, a weight and a string as illustrated in the sketches below:





T = Tension on the string
m = Mass
$g = 9.8 m/s^2$
a = Acceleration

where:

$T \cos\theta + mg$
$T \sin\theta = ma$
hence $a = g \tan\theta$

To measure lateral acceleration, hold the protractor in front of you so that the straight edge is horizontal and is perpendicular to the direction of travel.

To measure longitudinal acceleration, hold the protractor in such a way that the straight edge is horizontal and is parallel to the direction of travel.

FERMI QUESTIONS

What are Fermi Questions?

Fermi Questions are estimation questions that involve very large or sometimes very small numbers. They are named in honour of Enrico Fermi (1901 - 1954), a famous physicist and professor. He often asked his students to solve problems that required indirect measurements, assumptions, and estimates. He expected solutions with detailed descriptions and calculations, although he did not consider the accuracy of the final answer to be as important as process used to obtain a good solution.

What approach do I take to solve a Fermi Question?

- Think of what assumptions, measurements, and estimations you will need to make to solve the problem.
- Perform any direct and indirect measurements. Record your data.
- Perform calculations to solve the problem. Consider the units of all numerical quantities carefully.
- Ask yourself if the answer is "within the ballpark" and if your answer has an appropriate number of significant digits.

How do I write a solution to a Fermi Question?

- List any assumptions you needed to solve the problem.
- Write a detailed description of the measurements and estimates you made.
- Show the mathematical steps you used to come up with an answer.
- Remember to round off your answer.
- Write a concluding statement.

How would you solve the following typical Fermi Question?

Pretend that you could accelerate uniformly from rest and travel directly from here to the orbit of the moon. Assume that your acceleration has the same magnitude as the average acceleration of **The Bat** down its first slope. How long would it take you to get to moon's orbit?

The equation involving the variables uniform acceleration, initial velocity, and time is $\Delta d = v_i \Delta t + a\Delta t^2/2$.Because v_i is zero, this equation simplifies to $\Delta d = a\Delta t^2/2$.Solving for Δt, we have $\Delta t = 2\Delta d/a$. Thus, to solve this Fermi Question, we must determine values for the distance from earth to the moon and the average acceleration of **The Bat** during its first drop.

FERMI QUESTIONS

Assumption 1: The distance from the earth to the moon is approximately 400 000 km, or about 4.0 x 108 m.(Use at the two most significant digits for this type of estimation.)

Assumption 2: The person or group solving this problem would have to figure out a close value for the acceleration of **The Bat**. This process will not be shown here, but when you are solving this type of problem, be sure to take measurements and make appropriate calculations. For our calculations here, we will use a value of 3.5 m/s^2, but be careful, this value is NOT the true value!

Calculations:

$$\Delta t = \sqrt{\frac{2\Delta d}{a}} = \sqrt{\frac{2\,(4.0 \times 10^{8}\ \text{m})}{3.5\ \text{m/s}^2}} = 1.5 \times 10^{4}\text{s}$$

Thus, starting from rest and experiencing uniform acceleration of about 3.5 m/s^2, it would take about1.5 x 10^{4}s to reach the moon’s orbit. This time is about 4.2 h. (There are 3.6 x 10^3 s/h)

EXERCISES

Any or all of the exercises described here will assist in preparing you for a successful trip to Canada's Wonderland for the Physics, Science & Math program. The instructions consist of specific instructions as well as more general instructions for open-ended activities. The open-ended components allow for individuality and creativity. Suggestions for making a track profile and answering Fermi (estimation) questions are found elsewhere in this manual.

LIST OF EXERCISES

A Using Body Measurements
B Building Accelerometers
C Finding Unknown Heights Indirectly
D Measuring Linear Acceleration
E Measuring Centripetal Acceleration
F Analyzing Vertical Motion
G Analyzing Friction
H Drawing a Track Profile
I Analyzing Rotating Motion
J Building a Model of a Ride
K Researching Amusement Park Rides
L Solving Fermi (Estimation) Questions

EXERCISES

EXERCISE A: USING BODY MEASUREMENTS

When you visit Wonderland, your skill at estimating distances will help you solve a variety of questions.

Objective To practice using body measurements to estimate distances.

Materials A metre stick and/or a metric measuring tape

Procedure and Observations

1. Use a metre stick and/or a measuring tape to determine the distances indicated in the table below. For each of the personal measurements, circle the one that you think is the most appropriate to remember (for example, you would be more likely to remember that your height is 1.76 m than 1760 mm).

Personal Measurement	Distance			
	m	dm	cm	mm
height				
arm span				
hand span				
length of your shoe				
average pace (e.g. toe to toe)				

2. Use your personal measurements to determine several unknown distances. Then use a metre stick or measuring tape to check your accuracy. Examples of unknown measurements are:
    - the length of a lab bench (use hand spans and/or shoe lengths)
    - the length of a hallway (use your arm span and/or average pace)
    - distances of your own design

Application

Paul and Shamilla are working together at Wonderland to determine the surface area of a certain rectangular space. Paul, whose average pace is 54 cm, determines that the width of the rectangle is 18.5 paces. Shamilla, whose average pace is 48 cm, determines that the length is 32 paces. Determine the surface area of the rectangular space. (How many significant digits should your final answer have?)

EXERCISES

EXERCISE B: BUILDING ACCELEROMETERS

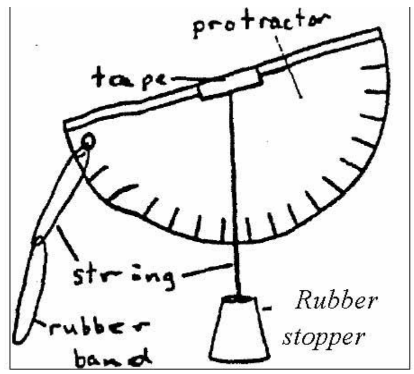
There are two main types of accelerometers that you can use to take measurements at Wonderland: a horizontal accelerometer and a vertical accelerometer. If commercial accelerometer kits are available, you can follow the instructions to build these accelerometers. If the kits are not available, you can design and build your own accelerometers by following the suggestions below. (**Please refer to Accelerometer Guidelines**)

Objective To construct and calibrate a horizontal accelerometer and a vertical accelerometer.

Materials

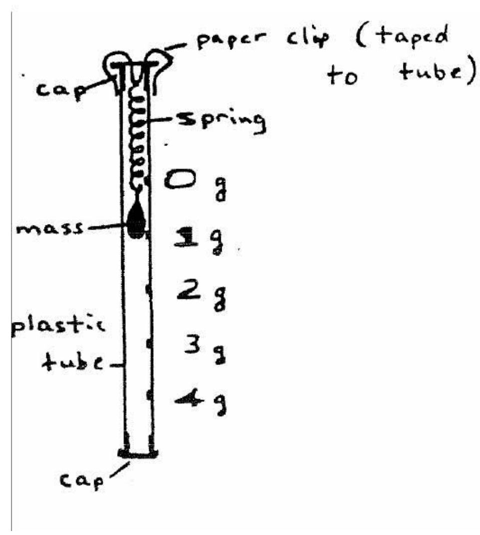
- for the horizontal accelerometer: a protractor, a one-holed rubber stopper, string, tape, a rubber band
- for the vertical accelerometer: a clear plastic tube with a cover at each end, a small, sensitive spring or rubber band, two equal masses, such as the lead sinkers used in fishing, a paper clip, masking tape

Procedure



1. Use the diagram at the right as a guideline to construct the horizontal accelerometer. The rubber band connected to the second piece of string is needed only if you expect to take the accelerometer onto any rides at Wonderland. (Wonderland's strict safety rules mean that any instrument taken on a ride must be tethered to your arm.)

2. Assemble the vertical accelerometer by using the diagram at the right as a reference.
   - Label the bottom of the mass "1g".
   - Tie a second, equal mass to the first one to determine how much the spring (or rubber band) stretches. Label the new position of the first mass "2g".
   - Use the amount stretched per mass added to calibrate other positions on the accelerometer, such as "0 g", "3 g", and "4 g".
   - Remove the bottom mass, and place the cap on the bottom of the tube.
   - If you intend to take this accelerometer onto any rides at Wonderland, add a rubber band for a tether.



EXERCISES

Applications

1. How do you think you could use a horizontal accelerometer to help you determine the height of a tree?

2. Does the spring or rubber band you used in the vertical accelerometer obey Hooke's law for springs? Explain.

3. Determine the spring constant for the spring or rubber band in your vertical accelerometer.

Extensions

1. Calibrate your horizontal accelerometer so you can use it to determine acceleration directly. Apply the equation $a = g \sin \theta$, where $g = 9.8$ m/s^2 and θ is any angle to the horizontal.

2. Use a free-body diagram to prove that $a = g \sin \theta$.

EXERCISES

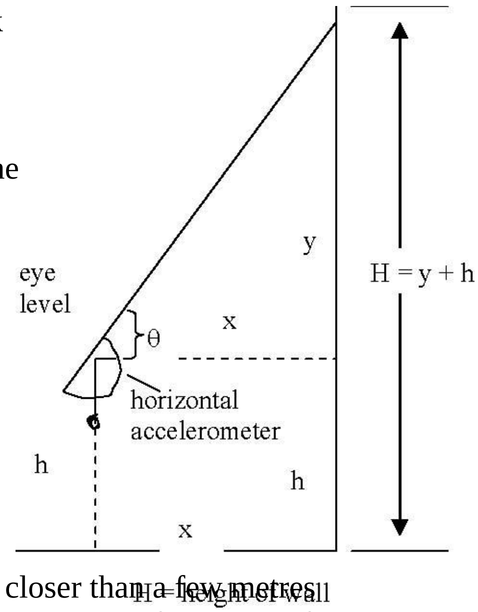
EXERCISE C: FINDING UNKNOWN HEIGHTS INDIRECTLY

Your trip to Wonderland will involve measuring heights of rides and other objects. Since you will be unable to measure such heights directly, you should develop skill in determining heights in other ways.

Objective To learn various ways of determining unknown heights indirectly.

Materials A horizontal accelerometer; a protractor; a metre stick

Procedure and Analysis



1. Use the diagram at the right as reference to help you determine the height of the wall in your classroom.
   - Pace off 5 or 6 regular paces from the wall.
   - Use your horizontal accelerometer to determine the angle that the top of the wall is above the horizontal.
   - Draw a scale diagram to determine the height (in paces) of the wall above your eye level. Convert your answer to metres.
   - Measure the height of your eyes above the floor.
   - Calculate the total height of the wall.

2. Repeat Procedure step 1, but this time assume you cannot get closer than a few metres from the wall. You will need to measure two angles, one when you are a few metres from the wall, and the other when you are farther from the wall.

3. Use your measured values from Procedure steps 1 and 2 to calculate the height of the wall using trigonometry rather than scales diagrams.

4. Compare your results with the results of other students. Devise a way to determine the percent error of each of your calculations

5. Choose a much higher unknown height outdoors, such as the height of a tree or electric transmission line. Use your horizontal accelerometer and either a scale diagram or trigonometry to determine the unknown height.

   Compare your answer with that of other students.

Application

Angie stands beside a sign in the heliport area of Wonderland that indicates that the horizontal distance to a portion of a particular ride is 74 m. Using her horizontal accelerometer, she discovers that the top of the ride is 21° above the horizontal. Angie’s eyes are about 1.5 m above the ground. What is the height of the top of the ride above the ground?

EXERCISES

EXERCISE D: MEASURING LINEAR ACCELERATION

The name "horizontal accelerometer" implies that this instrument should be capable of measuring the rate of acceleration of something that is accelerating linearly forward. How would you hold the accelerometer to indicate your own acceleration as you start increasing your speed from an initial velocity of zero? Discuss this with other students and your teacher before you tackle the exercise here.

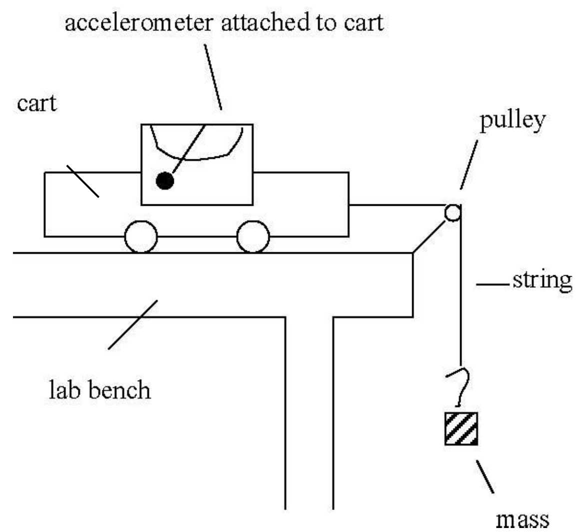
Objective To use the horizontal accelerometer to determine the acceleration of a cart undergoing uniform acceleration and to check the result using at least one other method.

Materials A horizontal accelerometer; a lab set-up similar to what you would have used to learn about Newton's second law of motion. (One alternative is shown in the diagram in EXERCISE B. An air track with related apparatus provides another alternative.)

Procedure and Analysis

1. Attach the horizontal accelerometer to the cart, as illustrated in the diagram.
   - As the cart accelerates forward, measure the angle that the string or bead makes with the vertical.
   - Use the angle to calculate the linear acceleration. (Apply the equation $a = g \sin\theta$.)
   - Devise at least one other way to check your result.

2. Repeat Procedure step 1 using a different mass suspended from the string so that a different acceleration occurs.



Applications

1. Domenic is viewing a horizontal accelerometer from the side while sitting on a ride at Wonderland. Suddenly the ride accelerates forward and the maximum angle that Domenic observes on the accelerometer is 18^o.What maximum acceleration did Domenic experience?

EXERCISES

2. Using a horizontal accelerometer, Soo Jin discovers that the linear acceleration she experiences at the beginning of a certain ride is 0.36 g. What angle did she observe on her accelerometer during this acceleration?

Extensions

1. Describe how you would determine the maximum (negative) acceleration of a moving object that slows down rapidly, coming to a stop. If your teacher approves your method, try it. What suggestions would you make for improving the results?

2. Use your horizontal accelerometer in a subway car, a bus, or a car to determine the maximum positive and negative accelerations experienced under normal conditions.

(NOTE: If you do this in a car, be sure to exercise safety.)

EXERCISE E: MEASURING CENTRIPETAL ACCELERATION

A horizontal accelerometer has yet another use: measuring centripetal acceleration. (What are the other uses of a horizontal accelerometer?) You will find many opportunities to measure centripetal acceleration on various rides at Wonderland. (Refer also to Exercise I, which emphasizes speeds and frequencies of rotating motions.)

Objective To use the horizontal accelerometer to determine the centripetal acceleration of objects undergoing uniform circular motion, and to check the results using another method

Materials A horizontal accelerometer; a student willing to get dizzy; a stopwatch (or a clock with a second hand); a metre stick; a rotating platform (with various related apparatus)

Procedure and Analysis

1. In a group, discuss how you would hold the horizontal accelerometer in order to measure your centripetal acceleration as you are undergoing uniform circular motion. Does everyone in class agree?

CAUTION: For the next step, have two or three students in your group ready to act as spotters in case the rotating student loses his or her balance.

2. Choose a location away from desks, etc., and have a student rotate at a constant rate while holding the accelerometer with his or her arm outstretched.
   - Use a stopwatch (or clock with a second hand) to determine the time for five rotations. Then calculate the period of rotation.
   - As the student is rotating, take several readings of the angle (θ) observed on the horizontal accelerometer. Find an average of these readings.
   - Calculate the magnitude of the average centripetal acceleration of the rotating student's hand using the equation $a = g \sin\theta$.
   - Calculate the magnitude of the centripetal acceleration using the equation for centripetal acceleration involving the period of rotation.
   - Compare the centripetal accelerations found. Explain possible reasons for any differences.

3. Design your own procedure steps to determine the centripetal acceleration at some location on a rotating platform. Perform the calculations and comparisons described in Procedure step 2.

Applications

EXERCISES

1. Andrea used a horizontal accelerometer to determine the centripetal acceleration of different parts of a rotating ride at Wonderland. At one part, she observed that the accelerometer registered 15º. What was the magnitude of the centripetal acceleration?

2. You and some friends are on Wonderland's **Antique Carrousel** as it is rotating at a constant rate. You are using horizontal accelerometers to determine the centripetal acceleration at different distances from the centre of rotation. Do you expect all the readings to be the same? Explain your answer.

Extension

Use your horizontal accelerometer in a car or bus to determine the centripetal acceleration as the vehicle is traveling in a curved path (for example, around a comer).

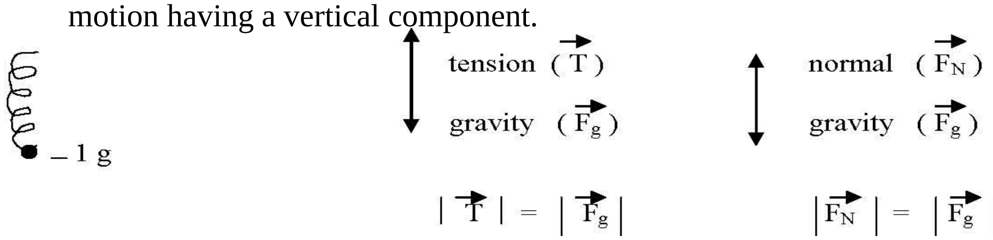
EXERCISE F: ANALYZING VERTICAL MOTION

You can use a vertical accelerometer to help you analyze vertical motion. An interesting observation about using a vertical accelerometer is that the measurement it indicates while you are holding onto it is directly related to the sensation your body feels at any instant. Try to relate what you observe using the vertical accelerometer to what you feel during any motion.

In order to understand the meaning of any reading on the vertical accelerometer, it might be better to think of the accelerometer as a "force meter." For example, when the accelerometer is held at rest, the downward force of gravity on the mass is balanced by the upward force of the spring on the mass, so the net or resultant force is zero. Thus, the acceleration is zero. (Of course it's zero: it is not even moving!) But this position is labelled "1 g" because that is the force your body would feel when something pushes or pulls you upward to balance the force of gravity. This situation is illustrated in the diagrams below.

(a) Mass at rest in a (b) Free-body diagram for (c) Free-body diagram for a
vertical accelerometer mass at rest on the spring person on a ride with vertical acceleration = 0

Objective To use a vertical accelerometer to analyze examples of vertical motion and curved motion having a vertical component.



Materials A vertical accelerometer calibrated in terms of "g".

Procedure and Analysis

1. Check to be sure your vertical accelerometer is properly constructed and calibrated. (For example, the "1 g" position should be at the bottom of the suspended mass, and the spacing between "0 g", "1 g", "2 g", etc., should be equal.) Inform your teacher of any difficulties with the accelerometer.

2. As a group, discuss how you would demonstrate each of the motions listed below to the rest of your class. In each case, you would have to use the vertical accelerometer to verify that the motion involves the force indicated in the question.
   - With upward vertical motion of the accelerometer, the reading is 1 g.
   - With downward vertical motion of the accelerometer, the reading is 1 g.
   - The accelerometer undergoes free fall. (What is the reading now?)
   - The accelerometer undergoes free fall while rigidly attached to a free-falling object or held securely by a free-falling student. (CAUTION: The student should land softly, not rigidly.)
   - The accelerometer reads more than 1 g during vertical motion, then during curved motion.

- The accelerometer reads about 0.5 g during vertical motion, then during curved motion.
- The accelerometer, which initially is traveling upward, reads zero during linear motion, then during curved motion.

3. Draw a free-body diagram for each situation described in step 2 above. (The “body” in this case is the mass suspended from the spring or rubber band.)

4. As a class, share the demonstrations and free-body diagrams, and discuss what you have learned about using a vertical accelerometer to analyze vertical motion.

Applications

1. Jasvinder finds that at a certain part of one of the roller coaster rides at Wonderland the reading on his vertical accelerometer 2.5 g.

   (a) Do you think the roller coaster was travelling over the crest of a hill or getting to the bottom of a valley when Jasvinder took this reading? Explain.

   (b) Draw a free-body diagram of both the mass in the accelerometer and Jasvinder when this reading was taken. What acceleration was each “body” undergoing? (Include the direction of the acceleration.)

Extension

Describe how you would use a vertical accelerometer to determine the maximum acceleration in an elevator. If possible, try it either in your school or in a high-rise building.

EXERCISE G: ANALYZING FRICTION

When was the last time you thanked your physics teacher for being kind to you? You should do so every time she or he tells you to ignore friction in solving a mechanics problem. Ignoring friction makes a problem easier to solve, but it does not provide a realistic situation. Being able to analyze the effects of friction is a very important part of designing and safely operating many amusement park rides, including roller coasters.

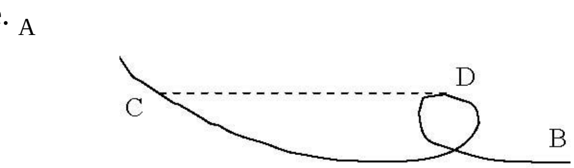
Objective To apply the law of conservation of energy to estimate the amount of friction experienced by a moving object.

Materials A track with at least one vertical loop; a ball; a metre stick or metric ruler; apparatus needed to determine the speed of a moving ball (e.g., a photo gate timer connected to a computer)

Procedure and Analysis

1. Using the diagram below as a reference, you can use the following steps to determine what portion of the input energy goes to overcoming the friction acting on a moving ball.
   - With the ball at rest at the starting position (A), determine an expression for the ball's gravitational potential energy relative to the position (B) where you can measure its speed. Express the potential energy in terms of the ball's mass, m. (Can you tell why the mass of the ball does not have to be known to solve this problem?)
   - Devise a way to measure the speed with which the ball leaves the track at position B after having been released from rest at position A. (If you do not have a photo gate timer available, try using your knowledge of projectile motion to solve this problem. All you would need is a metre stick and an understanding of equations.)
   - Use the ball's speed at B to calculate an expression for its kinetic energy in terms of the ball's mass, m.
   - Calculate what portion of the ball's initial maximum potential energy was used to overcome friction.

2. Predict what will happen if you release the ball from rest from position C which is at the same position horizontally as position D, which is the inside top of the loop
   - Verify your prediction experimentally.
   - Give reasons for what you observe.



3. Can you or other members of your group think of other ways of determining the amount of friction on a moving steel ball? If so, try to carry out an investigation with your teacher's approval.

EXERCISES

Application

Any roller coaster ride that resembles the looped track that was part of this exercise is called a "gravity ride". Why do you think this is so?

Extension

Using the same ball-and-track apparatus, devise and carry out your own experiment to solve some other problem(s).

EXERCISE H: DRAWING A TRACK PROFILE

In previous Physics, Science & Math Days at Wonderland, some of the most impressive projects submitted by students have been track profiles of roller coasters. There are seven roller coasters at Wonderland, and any one would provide your group with a challenge to create a detailed track profile. Learning how to draw a track profile using a toy track will help you better understand how to draw a profile of a real coaster.

Objective To use a toy track to practice drawing a track profile of a roller coaster ride.
Materials A toy track that resembles a roller coaster (e.g., a toy racing car track); a metre stick and/or metric ruler; a protractor; a stopwatch

Procedure and Analysis

1. Read about the assignment called MAKING A ROLLER COASTER TRACK PROFILE. Some of the information you can place on the final profile includes:
   - distance measurements, including lengths, heights; and radii of curves
   - angle measurements, including the banking angle of any banked curves
   - speeds at various locations, especially at the tops of hills and the bottoms of valleys
   - accelerations of the moving object at various locations
   - the forces on the object in motion
   - energies at various locations, including input energy, gravitational potential energy, kinetic energy, energy dissipated ("lost") due to friction
   - other quantities you can think of

2. Together with the other members of your group, brainstorm ideas about how to accomplish the objective of this exercise.
   - Make a list of measurements you will need.
   - Make a list of calculated quantities you will be able to label on the track profile.
   - Decide on how to share the responsibilities with other members of the group.

3. Draw a sketch of the toy track and on it, place as many measurements as possible. Complete the calculations of the quantities you decided to find out.

4. Make the final track profile of the toy track, drawn to scale. Place as much information as you can on the profile.

Application

Describe how the process for making a track profile of a roller coaster at Wonderland would differ from the process you used to make the profile of a toy track.

Extension

Use a reference to find out what is meant by a friction slope. Add the friction slope to your track profile.

EXERCISE I: ANALYZING ROTATING MOTION

There are many non-roller-coaster rides at Wonderland that apply physics principles and are excellent choices to analyze in detail. You can use a much different device, a bicycle, to practice analyzing the circular motion of rotating rides. Exercise E also deals with circular motion, with emphasis on using the horizontal accelerometer. This exercise emphasizes the frequency of rotation and instantaneous speeds.

Objective To use a multi-speed bicycle to analyze circular motion at different speeds.

Materials A multi-speed bicycle; a metric ruler and/or metre stick; a stopwatch; a horizontal accelerometer

Procedure and Analysis

1. Bring a multi-speed bicycle to the classroom. Set up the bike (for example, up-side-down) so the rear wheel can rotate when the pedals are cranked by hand. With the gear shift set at the lowest gear, create a uniform circular motion of the pedals. Devise a way to find the frequency and instantaneous speed of one pedal and the air valve in the rear tire. Calculate the ratio of the speed of the valve to the speed of the pedal. (These are instantaneous speeds.) Calculate the ratio of the frequency of rotation of the rear tire to the frequency of rotation of the pedals. Record all of your measurements and calculations.

2. Repeat #1 above at least once more using a different gear.

3. Use an appropriate equation to find the centripetal acceleration of the rear tire valve. Also calculate the centripetal acceleration of a point half-way between the valve and the centre of the wheel. Explain the relationship between centripetal acceleration and the distance from the centre of rotation.

Application

Jonathan estimates that the diameter of a certain Ferris wheel ride is 17 m. He determines that the period of rotation of the ride is 75 s.

Calculate:

- the instantaneous speed of a rider on the Ferris wheel
- the frequency of rotation of the ride
- the centripetal acceleration experienced by a rider.

Extension

Devise and carry out your own experiment that uses a bicycle and relates to rides at Wonderland.

EXERCISE J: BUILDING A MODEL OF A RIDE

A great way to learn how a ride operates and simultaneously link physics to technology is to build a model of a ride. Before beginning this project, decide whether or not your school would like to hold a contest to see which group can produce the [best/most original/least expensive/most advanced technologically/or any other criteria] model.

Objective To design and build a model of an amusement park ride, and to relate the design to a ride at Wonderland that has similar characteristics.

Materials These will be listed in your proposal.

Procedure and Analysis

1. In a group, brainstorm ideas about how you would go about designing and building one of the types of amusement park rides listed below.
   - a loop-the-loop roller coaster (with banked curves and perhaps a corkscrew)
   - a non-loop roller coaster (resembling a wooden coaster)
   - a rotating ride with one axis of rotation
   - a rotating ride with two axes of rotation
   - a pendulum ride with a counterbalance to the main passenger car.

2. After deciding which type of ride your group would like to build, write a proposal indicating the design and the materials and tools needed to construct the model. Submit the proposal to your teacher. After your proposal has been approved, begin the construction of the model.

3. If possible, try allowing some object to go for a ride on your model. The object might be a marble, a steel ball, a rubber ball, a toy car, or a doll. Describe how you would modify your model to improve it. If possible, carry out the modifications.

Application

Compare your model to a ride at Wonderland that has similar characteristics.

Extension

Organize a contest within your class, school, or district to judge whose models are best in whatever categories are agreed upon.

EXERCISE K: RESEARCHING AMUSEMENT PARK RIDES

Students are often surprised at how much there is to learn about amusement parks. These parks are big business in North America. They apply many principles of physics and engineering. The changes in amusement parks that have occurred in the past 100 years or so are fascinating. Every year, hundreds of thousands of students across North America attend Science-Physics-Math-Technology Days at amusement parks.

Objective To research and report on some aspect or aspects of amusement parks.

Procedure

1. Find resources that have information about amusement parks and the rides in them. Some of the general resources you might find in researching this topic are:
   - books
   - magazines (Use a CD-ROM with magazine article summaries or use the vertical file in your school resource centre.)
   - movies or videos, if they are available

2. Choose a specific theme to focus on, such as one of the following:
   - the historical developments of amusement park rides
   - the physics principles of a particular type of ride
   - the technological aspects of developing and constructing a new ride
   - safety aspects of amusement park rides
   - the social implications of amusement parks, including careers

3. Research the topic you are trying to find out about.

4. Report on your findings in a written report, a poster, or some other medium, such as a video.

EXERCISE L: SOLVING FERMI (ESTIMATION) QUESTIONS

Learning how to determine quantities that involve both estimations and calculations will come in handy not only on your trip to Wonderland, but also in other areas of your life. Practicing answering estimation questions (also called Fermi questions) will help you develop this useful skill.

Objective To practice solving Fermi (estimation) questions that involve indirect measurements, estimated quantities, and calculations.

Procedure

1. Read the section which describes what a Fermi question is, how to approach solving this type of question, and how to write your solution.

2. Choose several of the questions listed below, and solve them. In all cases, show your solutions in detail.

   a) Find the surface area of the floor of a classroom, hallway, or cafeteria. (Use your average pace to determine distances here.)

   b) Find the surface area and volume of all the glass in the windows of your school. (Use your hand span and/or arm span to measure distances here.)

   c) Determine the volume of air in your classroom in both cubic metres and litres. (Use your body measurements to help you find distances here.)

   d) Estimate the volume (in litres) of all the drinks except water consumed in your school from September to June.

   e) What volume of water (in litres) is used to flush toilets in your school each week?

   f) Calculate the number of holes in all the acoustic tiles in the ceiling of your classroom.

   g) How many hairs are there on your head?

   h) If you were riding in a car from Toronto to Montreal, what distance (in metres) would the car travel during the time your eyes are closed due to blinking?

   i) How high could you climb a rope by using the energy provided by a non-diet soft drink?

   j) What is the mass in kilograms of all the bananas consumed in Canada in one year?

   k) What would be the cost of gasoline, in dollars, to drive an average car a distance equivalent to the distance between the earth and the sun?

l) What energy (in joules) is required to toast a single slice of bread?

m) What is the linear speed (in metres per second) of a person standing in your school due to the earth's rotational motion?

n) How many atoms wear off during one rotation of a car tire?

o) How many grains of salt are there in a salt shaker?

Application

Make up five challenging Fermi questions that you or other students can do at Wonderland on Physics, Science & Math Day. Bring them on your trip and solve them on that day.

Extension

Make up your own Fermi questions that you can work on in school, then solve them.

GRADE 12

AMUSEMENT RIDE ACTIVITIES

PHYSICS DAY ASSIGNMENT

TIME WARP

FLIGHT DECK

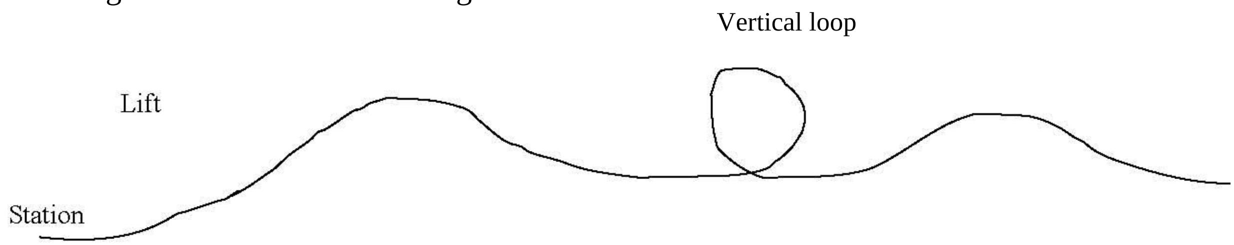
THE BAT

TWIRL & FLING RIDES:

NIGHT MARES
ORBITER
SLEDGE HAMMER

MAKING A ROLLER COASTER TRACK PROFILE

A track profile is a two-dimensional diagram of a roller coaster track. You might imagine that some giant has taken the roller coaster ride and opened it outward from the station so it ended up in a straight line as shown in the diagram.



On a track profile, both horizontal and vertical distances can be labelled using appropriate scales. A possible horizontal scale might be 1.0 cm = 10 m, so for a track that is 800 m long, the diagram would be 80 cm long. If necessary, the vertical scale can be different from the horizontal scale. To draw a track profile accurately, you will need several direct and indirect measurements as well as estimates and calculations.

Many details besides distances can be shown on the track profile. This assignment is open-ended, and you are expected to include as much information as you can on your final product. The information below will give you clues about some of the data you may try to include in your final track profile diagram.

POSSIBLE RIDES TO ANALYZE (Choose one ride per group.)

Time Warp	**The Bat**	**Flight Deck**
Night Mares	**Orbiter**	**Sledge Hammer**

SUGGESTED INSTRUMENTS TO HELP IN MEASUREMENTS AND CALCULATIONS

- horizontal accelerometer (which can double as a protractor)
- vertical accelerometer
- stopwatch (or watch with second hand)
- calculator
- ruler
- protractor
- body measurements (e.g., arm span, hand span, height, pace, length of shoe, etc.)

AUTHENTIC PROBLEM

The riders' experience of thrill is centered on forces that act on the body while in circular motion. You have been asked to submit a proposal to Canada's Wonderland to create a new ride for the park that maximizes the thrills associated with circular motion. In this exercise you will use your knowledge of Grade 12 Physics to collect data, make observations, measurements and calculations on your ride. You will later use this information and your own creative ideas to design a new amusement ride for the park. The commission will go to the design/build firm that demonstrates the best application of the physics principles outlined.

PART A: GATHERING BACKGROUND INFORMATION

DATA COLLECTION

Length of one car: ___________ m
Mass of one car: ___________ kg
# of cars in train: ___________

Check-point	Top of 1st Hill	1st Dip	Camelback (5)	Overbank (6)	Camelback (8)
Time to location					
Transit Time					
Distance					
Height					
g-force					
speed					

PART B: EXPLORATION QUESTIONS

In order to complete your task you will first need to collect some basic information, which you will later draw on in designing your amusement ride.

1. **[B3.1, B2.4]** Did you feel more force going into or out of the overbank (6)? Explain.

2. **[B2.4, B2.7]** Describe the sensations of weight at the following points. Use your vertical accelerometer and compare the readings with your sensations.

   a) going down the first hill

   b) at the bottom of the first hill

   c) at the middle of the overbank

3. **[B2.4]** Sketch a free body diagram of the forces acting on yourself at:

   a) bottom of the first hill

   b) top of first camelback

4. At the top of the first camelback you are travelling along a parabolic path. How does this determine what you feel as the train continues along the path? Confirm this with a measurement (graph, accelerometer, app)?

5. How does your position in the train affect your ride? Use your values for maximum and minimum acceleration and compare them to those of a friend. Also compare where these forces occurred.

PART C: PROCEDURAL CALCULATIONS

Before you begin the design process, you will need to use the data that you have previously collected to perform calculations which you will later need to consider in designing your amusement ride.

Use the space for calculations

1. Find the speed of the train knowing its length and the time it takes to pass a certain point and populate the observation table.__________ m/s

2. **[C2.1, C2.2]** Use conservation of energy to determine the speed of the train at the top of the first camelback(assume a frictionless track). __________ m/s

3. **[B2.7]** Calculate the centripetal acceleration at the top of the first camelback.__________ m/s^2.

4. **[B2.7]** Find the centripetal force at the top of the first camelback using the entire mass of the train and its passengers (assume that every person on the train has a mass of 60 kg and thatthe mass of the train is 1.9×10^4 kg).__________ N

5. **[B2.7]** Find the normal force acting on your body in terms of the centripetal force and the force of gravity at the top of the first camelback.__________ N

6. Compare your answer in part 3 to the value from the vertical accelerometer or the data collected by your app (use a percent variation calculation). For what reason(s) might these two values differ?

7. Using measured accelerations and calculated speeds for the second camelback, calculate the radius of curvature for that portion of track.

PART D: ROLLER COASTER DESIGN REPORT PROPOSAL

[B1.1, B2.1, B2.2, B2.4, B2.7, B3.1, C2.2]
Canada's Wonderland requires a design report proposal from your firm, which outlines the key components and justifications for your "winning" design. This report is the crucial make or break document that will determine whether your firm will win this contract. You will extract different elements from your previous work to submit with this report as well as summarizing your results. In your proposal you will need to include:

1. A track profile of the first hill and first overbank.

2. A Free Body Diagram of the riders at the:

    a. bottom of the first hill

    b. top of the overbank

3. A written report outlining considerations that need to be taken in order to build an amusement ride (e.g., speed and g-forces).

4. Outline the key features of your ride and justify why your proposal should be the one to win the contract.

AUTHENTIC PROBLEM

Canada's Wonderland's internal research department has determined that the riders' experience of thrill is centered on forces that act on the body while in circular motion. Your design and build firm has been asked to submit a proposal to Canada's Wonderland to create a new amusement ride for the park that maximizes the thrills associated with circular motion. In this exercise you will use your basic knowledge of Grade 12 Physics to collect data, make observations, measurements and calculations on your ride. You will later use this information and your own creative ideas to design a new amusement ride for the Park. This proposal will be submitted to your teacher (an "official agent" of Canada's Wonderland). The commission will go to the design/build firm that demonstrates the best application of the basic physics principles outlined.

PART A: GATHERING BACKGROUND INFORMATION

DATA COLLECTION

Length of one car: ___________ m

Using the vertical accelerometer find the location of the maximum and minimum g forces acting on you.

Maximum g force: ___________ g's Location: ______________________

Minimum g force: ___________ g's Location: ______________________

Find the sign indicating the distance to the base of the first hill: __________ m

Use the horizontal accelerometer to find the angle of inclination of the first hill from this same point: _________ degrees

Calculate the height of the first hill: ___________ m

Find the sign indicating the distance to the base of the first loop: __________ m

Use the horizontal accelerometer to find the angle of inclination of the first loop from this same point: _________ degrees

Calculate the height of the first loop: ___________ m

Measure the time for the entire length of the train to pass a point on the top of the first hill: _______ s

Measure the time for the entire length of the train to pass a point on the top of the first loop: ________ s

PART B: EXPLORATION QUESTIONS

In order to complete your task you will first need to collect some basic information, which you will later draw on in designing your amusement ride.

1. **[B3.1, B2.4]**Did you feel more force going into or out of the loop? Explain.

2. **[B2.4][B2.7]** Why is the first loop at a smaller height than the first hill?

3. **[B2.4] [B2.7]** Describe the sensations of weight at the following points. Use your vertical accelerometer and compare the readings with your sensations.

   a)going down the first hill

   b)at the bottom of the first hill

   c)climbing the first loop

   d)at the bottom of the first loop

4. **[B2.4]** Sketch a free body diagram of the forces acting on yourself at:

   a) bottom of the first loop

   b) top of first loop

PART C: PROCEDURAL CALCULATIONS

Before you begin the design process, you will need to use the data that you have previously collected to perform calculations which you will later need to consider in designing your amusement ride.

Use the space for calculations

1. Find the speed of the train knowing its length and the time it takes to pass a certain point on top of the first hill __________ m/s

2. Using the same procedure as question 1, find the speed of the train at the top of the first loop __________ m/s

3. **[C2.1, 2.2]** Use conservation of energy to determine the speed of the train at the top of the first loop (assume a frictionless track) __________ m/s

4. **[C2.2]** Account for any differences in your answers for questions 2 and 3.

5. **[B2.7]** Calculate the centripetal acceleration at the top of the first loop (assume the height you measured for the loop is the diameter of the loop) __________ m/s^2

6. **[B2.7]**Find the centripetal force at the top of the first loop using the entire mass of the train and its passengers (the mass of each empty car is 662 kg and assume that every person on the train has a mass of 60 kg) __________ N

7. **[C2.2]** Looking at your information above, find the speed of the train at the bottom of the first loop (assume there is no gravitational potential energy at the bottom of the first loop) __________ m/s

8. **[B2.2]**Find the normal force acting on your body in terms of the centripetal force and the force of gravity at the bottom of the first loop __________ N

PART D: ROLLER COASTER DESIGN REPORT PROPOSAL

[B3.1, B2.2, B2.4, B2.7, B1.1, C2.1 and C2.2]

Canada's Wonderland requires a design report proposal from your firm, which outlines the key components and justifications for your "winning" design. This report is the crucial make or break document that will determine whether your firm will win this contract. You will extract different elements from your previous work to submit with this report as well as summarizing your results. In your proposal you will need to include:

1. A track profile of the first hill and first loop.

2. A Free Body Diagram of the riders at the first loop:

   a) bottom of the loop

   b) top of the loop

3. A written report outlining considerations that need to be taken in order to build an amusement ride (e.g., speed and g-forces).

4. Outline the key features of your ride and justify why your proposal should be the one to win the contract.

AUTHENTIC PROBLEM

Canada's Wonderland's internal research department has determined that the riders' experience of thrill is centered on forces that act on the body while in circular motion. Your design and build firm has been asked to submit a proposal to Canada's Wonderland to create a new amusement ride for the park that maximizes the thrills associated with circular motion. In this exercise you will use your basic knowledge of Grade 12 Physics to collect data, make observations, measurements and calculations on your ride. You will later use this information and your own creative ideas to design a new amusement ride for the park. This proposal will be submitted to your teacher (an "official agent" of Canada's Wonderland). The commission will go to the design/build firm that demonstrates the best application of the basic physics principles outlined.

PART A: GATHERING BACKGROUND INFORMATION

DATA COLLECTION

Length of one car: ___________ m
Length of train: ___________ m

Using the vertical accelerometer find the location of the maximum and minimum g forces acting on you.
Maximum g force: ___________ g's Location: _____________________
Minimum g force: ___________ g's Location: _____________________

Find the sign indicating the distance to the base of the first hill: __________ m

Use the horizontal accelerometer to find the angle of inclination of the first hill from this same point: _________ degrees

Calculate the height of the first hill: ___________ m

Find the sign indicating the distance to the base of the first loop: __________ m

Use the horizontal accelerometer to find the angle of inclination of the first loop from this same point: _________ degrees

Calculate the height of the first loop: ___________ m

Measure the time for the entire length of the train to pass a point on the top of the first hill: _______ s

Measure the time for the entire length of the train to pass a point on the top of the first loop: _____ s

PART B: EXPLORATION QUESTIONS

In order to complete your task you will first need to collect some basic information, which you will later draw on in designing your amusement ride.

1. **[B3.1, B2.4]**Did you feel more force going into or out of the loop? Explain.

2. **[B2.4, B2.7]** Why is the first loop at a smaller height than the first hill?

3. **[B2.4, B2.7]**Describe the sensations of weight at the following points. Use your vertical accelerometer andcompare the readings with your sensations.

   a)going down the first hill

   b)at the bottom of the first hill

   c)climbing the first loop

   d)at the bottom of the first loop

4. **[B2.4]** Sketch a free body diagram of the forces acting on yourself at:

   a)bottom of the first loop

   b)top of first loop

PART C: PROCEDURAL CALCULATIONS

Before you begin the design process, you will need to use the data that you have previously collected to perform calculations which you will later need to consider in designing your amusement ride.

Use the space for calculations

1. Find the speed of the train knowing its length and the time it takes to pass a certain point on top of the first hill __________ m/s

2. Using the same procedure as question 1, find the speed of the train at the top of the first loop __________ m/s

3. **[C2.1, C2.2]** Use conservation of energy to determine the speed of the train at the top of the first loop (assume a frictionless track) __________ m/s

4. **[C2.2]** Account for any differences in your answers for questions 2 and 3.

5. **[B2.7]** Calculate the centripetal acceleration at the top of the first loop (assume the height you measured for the loop is the diameter of the loop) __________ m/s^2

6. **[B2.7]** Find the centripetal force at the top of the first loop using the entire mass of the train and its passengers (the mass of each empty car is 662 kg and assume that every person on the train has a mass of 60 kg) __________ N

7. **[C2.2]** Looking at your information above, find the speed of the train at the bottom of the first loop (assume there is no gravitational potential energy at the bottom of the first loop) __________ m/s

8. **[B2.7]** Find the normal force acting on your body in terms of the centripetal force and the force of gravity at the bottom of the first loop __________ N

PART D: ROLLER COASTER DESIGN REPORT PROPOSAL

[B1.1, B2.1, B2.2, B2.4, B2.7, B3.1, C2.2]

Canada's Wonderland requires a design report proposal from your firm, which outlines the key components and justifications for your "winning" design. This report is the crucial make or break document that will determine whether your firm will win this contract. You will extract different elements from your previous work to submit with this report as well as summarizing your results. In your proposal you will need to include:

1. A track profile of the first hill and first loop.

2. A Free Body Diagram of the riders at the first loop:

   a) bottom of the loop

   b) top of the loop

3. A written report outlining considerations that need to be taken in order to build an amusement ride (e.g., speed and g-forces).

4. Outline the key features of your ride and justify why your proposal should be the one to win the contract.

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AUTHENTIC PROBLEM
Canada's Wonderland's internal research department has determined that the riders' experience of thrill is centered on forces that act on the body while in circular motion. Your design and build firm has been asked to submit a proposal to Canada's Wonderland to create a new amusement ride for the park that maximizes the thrills associated with circular motion. In this exercise you will use your basic knowledge of Grade 12 Physics to collect data, make observations, measurements and calculations on your ride. You will later use this information and your own creative ideas to design a new amusement ride for the Park. This proposal will be submitted to your teacher (an "official agent" of Canada's Wonderland). The commission will go to the design/build firm that demonstrates the best application of the basic physics principles outlined.

PART A: GATHERING BACKGROUND INFORMATION

DATA COLLECTION

Length of one car: ___________ m
Length of train: ___________ m

Using the vertical accelerometer find the location of the maximum and minimum g forces acting on you.
Maximum g force: ___________ g's Location: _____________________
Minimum g force: ___________ g's Location: _____________________

Find the sign indicating the distance to the base of the first hill: __________ m

Use the horizontal accelerometer to find the angle of inclination of the first hill from this same point:
_________ degrees

Calculate the height of the first hill: ___________ m

Find the sign indicating the distance to the base of the loop: __________ m

Use the horizontal accelerometer to find the angle of inclination of the loop from this same point:
_________ degrees

Calculate the height of the loop: ___________ m

Measure the time for the entire length of the train to pass a point on the top of the first hills ______ s

Measure the time for the entire length of the train to pass a point on the top of the loop: _______ s

PART B: EXPLORATION QUESTIONS

In order to complete your task you will first need to collect some basic information, which you will later draw on in designing your amusement ride.

1. **[B2.4, B3.1]**Did you feel more force going into or out of the loop? Explain.

2. **[B2.4, B2.7]** Why is the loop at a smaller height than the first hill?

3. **[B2.4, B2.7]**Describe the sensations of weight at the following points. Use your vertical accelerometer and compare the readings with your sensations.

   a)going down the first hill

   b) at the bottom of the first hill

   c) climbing the loop

   d) at the bottom of the loop

4. **[B2.4]** Sketch a free body diagram of the forces acting on yourself at:

   a) bottom of the loop

   b) top of loop

PART C: PROCEDURAL CALCULATIONS

Before you begin the design process, you will need to use the data that you have previously collected to perform calculations which you will later need to consider in designing your amusement ride.

Use the space for calculations

1. Find the speed of the train knowing its length and the time it takes to pass a certain point on top of the first hill __________ m/s

2. Using the same procedure as question 1, find the speed of the train at the top of the first loop __________ m/s

3. **[C2.1, C2.2]** Use conservation of energy to determine the speed of the train at the top of the first loop (assume a frictionless track) __________ m/s

4. **[C2.2]** Account for any differences in your answers for questions 2 and 3.

5. **[B2.7]** Calculate the centripetal acceleration at the top of the first loop (assume the height you measured for the loop is the diameter of the loop) __________ m/s^2

6. **[B2.7]**Find the centripetal force at the top of the first loop using the entire mass of the train and its passengers (the mass of each empty car is 662 kg and assume that every person on the train has a mass of 60 kg) __________ N

7. **[C2.2]** Looking at your information above, find the speed of the train at the bottom of the first loop (assume there is no gravitational potential energy at the bottom of the first loop) __________ m/s

8. **[B2.7]**Find the normal force acting on your body in terms of the centripetal force and the force of gravity at the bottom of the first loop __________

PART D: ROLLER COASTER DESIGN REPORT PROPOSAL

[B3.2, B2.2, B2.4, B2.7, B1.1, and C2.1, C2.2]

Canada's Wonderland requires a design report proposal from your firm, which outlines the key components and justifications for your "winning" design. This report is the crucial make or break document that will determine whether your firm will win this contract. You will extract different elements from your previous work to submit with this report as well as summarizing your results. In your proposal you will need to include:

1. A track profile of the first hill and loop.

2. A Free Body Diagram of the riders at the loop:

   a) bottom of the loop

   b) top of the loop

3. A written report outlining considerations that need to be taken in order to build an amusement ride(e.g., speed and g-forces).

4. Outline the key features of your ride and justify why your proposal should be the one to win the contract.

PART A: DATA COLLECTION

Estimated radius of ride: ___________ m

Using the vertical accelerometer find the location of the maximum and minimum g forces acting on you.

Maximum g force: ___________ g's Location: _____________________
Minimum g force: ___________ g's Location: _____________________

Calculate the period and frequency of the ride

Period _________s
Frequency ________Hz

PART B: CONCEPTUAL QUESTIONS

1. **[B2.4, B2.7]**What sensations do you feel as the ride starts turning in a circle? Why is this so?

2. **[B2.4. B2.7]**At the middle where the ride spins, does the center appear to be going faster or slower than the passenger compartments?

3. **[B2.4, B2.7]** Sketch a free body diagram of the forces acting on yourself during the ride's vertical position at:

   a) bottom of the ride

   b) top of the ride

4. **[B2.4]** At the top of the ride in it's vertical position (when you are upside down) why do you feel that you are being pushed outward instead of falling down?

PART C: CALCULATIONS

Use the space for calculations

1. Calculate the circumference of the ride.

2. Using your answer from question 1 and the period of revolution, calculate the tangential velocity of the passenger compartments as they travel in a circular path(assuming that it remains constant)
___________m/s

3. **[B2.7]**Calculate the centripetal acceleration of the ride
___________ m/s^2

4. **[B2.4, B2.7]**Calculate the centripetal force on a passenger assuming that each person on the ride has a mass of
60 kg ___________ N

PART A: DATA COLLECTION

Estimated radius of ride: ___________ m

Using the vertical accelerometer find the location of the maximum and minimum g forces acting on you.

Maximum g force: ___________ g's Location: ______________________
Minimum g force: ___________ g's Location: ______________________

Calculate the period and frequency of the ride

Period _________s
Frequency ________Hz

PART B: CONCEPTUAL QUESTIONS

1. **[B3.1]**As the ride starts, what do you notice about the gondolas? Why is this so?

2. **[B3.1]**Where in the ride do you feel pressed against your seat the most?

3. **[B2.7]** At the middle where the ride spins, does the center appear to be going faster or slower than the gondolas?

4. **[B2.7]** Sketch a free body diagram of the forces acting on yourself during the ride's vertical position at:

   a) bottom of the ride

   b) top of the ride

5. **[B2.7, B3.1]** At the top of the ride in it's vertical position (when you are upside down) why do you feel that you are being pushed into your seat instead of falling out of your seat?

PART C: CALCULATIONS

Use the space for calculations

1. Calculate the circumference of the ride.

2. Using your answer from question 1 and the period of revolution, calculate the tangential velocity of the gondolas as they travel in a circular path (assuming that it remains constant) __________m/s

3. **[B2.7]**Calculate the centripetal acceleration of the ride __________ m/s^2

4. **[B2.4][B2.7]** Calculate the centripetal force on the gondola if the mass of an empty gondola is 330 kg and assuming that each person on the ride has a mass of 60 kg __________ N

SLEDGE HAMMER

PART A: DATA COLLECTION

Estimated radius from centre of ride to centre of each seating cluster (primary axis): ___________ m

Estimated radius from centre of each seating cluster to passenger compartment (secondary axis): __________ m

Time for one revolution around primary axis: __________ s

Time for one revolution around secondary axis: __________ s

PART B: CONCEPTUAL QUESTIONS

1. **[B2.4]**Where on this ride do you feel that you are being pushed outside of the passenger compartment? Why is this so?

2. **[B2.7]**As you observe the primary and secondary rotation, note whether they are the same or different. Does this have any effect on the sensations you feel on the ride?

3. **[B2.7]**Would you experience a greater thrill if the primary and secondary rotation moved opposite to each other or in the same direction? Explain.

4. **[B2.4]** Sketch a free body diagram of the forces acting on yourself on the ride.

PART C: CALCULATIONS

Use the space for calculations

1. Calculate the circumference around the primary axis.

2. Calculate the circumference around the secondary axis.

3. Using your answer from question 1 and two and the period of revolution, calculate the tangential velocity of the clusters and the passenger compartments as they travel in a circular path (assuming that the velocity remains constant) __________m/s

4. **[B2.7]** Calculate the centripetal acceleration around the primary axis __________ m/s^2

5. **[B2.7]** Calculate the centripetal acceleration around the secondary axis __________ m/s^2

GRADE 12

OTHER ACTIVITIES

RIDE SAFETY EXERCISE

EXPLORING THEME PARK CAREERS

JOB SEARCH

THEME PARK ENERGY

WATER & PLANTS

PROBABILITY & CHANGE

RIDE SAFETY EXERCISE

Canada's Wonderland provides for the safety of their guests in many ways. Security personnel walk the grounds, making sure Park rules are followed by all guests and Park staff. Park ride operators are well informed about the rides and are always watching to be sure that the ride is operating properly and safely. Rules are posted at each ride and are to be obeyed for a safe and enjoyable ride.

Select two different types of rides and answer the following questions on the table.

QUESTIONS	FIRST RIDE	SECOND RIDE
1. What is the name of the ride?		
2. What type of ride is it? (Is it a wooden roller coaster, loop-the-loop roller coaster, circular ride, etc?)		
3. Do you have to be a certain height to ride the ride? If so, how is this height measured?		
4. What safety checks does the ride operator make prior to starting the ride?		
5. How does the ride operator start and stop the ride?		
6. Does the ride have a lap bar or safety belt that holds you firmly in the seat? If so, what form of safety belt is used and how does if work?		
7. Are there specific rules or restrictions posted at the ride? If so, what are they?		
8. What other safety features or operation checks do you see on the ride?		
GENERAL QUESTIONS		
9. Why is there a height rule for some rides and not others?		
10. Which rides are more likely to have safety belts or lap bars?		

EXPLORING THEME PARK CAREERS

Just like the real world, a theme or amusement park offers many career opportunities. In fact, an amusement park is a microcosm, a community regarded as a miniature world.

Your job here is to identify at least one Park career/job for each occupational cluster listed below. After you identify the career/job, you will need to complete the chart by listing a few basic skill requirements and the education necessary to be successful in that particular job.

Good luck on your job search!

Occupational Cluster & Identified Job	Job Description	Necessary Education
1. Agri-business/ Natural Resources		
2. Manufacturing		
3. Business/ Office		
4. Health		
5. Public Service		
6. Environment		
7. Communications/ Media		
8. Hospitality/ Recreation		
9. Marketing/ Distribution		
10. Personal Services		
11. Marine Science		
12. Construction		
13. Transportation		
14. Consumer/ Homemaking		
15. Fine Arts/ Humanities		

JOB SEARCH

To build an amusement park like Canada's Wonderland, to keep it going and to keep it growing, involves many people with different educational backgrounds doing lots of different things.

Take a break or use some of the time you might be waiting in line to do a little thinking about what jobs must be filled to successfully operate Canada's Wonderland. Divide your jobs into two categories: jobs easily observed and those that must take place behind the scenes. You may discover a job you might like to have in the future!

a) Jobs easily observed:

1 ______________________ 2 ______________________ 3 ______________________

4 ______________________ 5 ______________________ 6 ______________________

7 ______________________ 8 ______________________ 9 ______________________

10 _____________________ 11 _____________________ 12 _____________________

b) Jobs behind the scenes:

1 ______________________ 2 ______________________ 3 ______________________

4 ______________________ 5 ______________________ 6 ______________________

7 ______________________ 8 ______________________ 9 ______________________

10 _____________________ 11 _____________________ 12 _____________________

c) Select one of the jobs that you identified that might be of interest to you in the future.
1. What job did you select? ____

2. Write a job description for your job ____
____
____
____
____

3. What education is necessary for your job?____________________________________

4. What do you expect is the annual salary of your job? $ __________________________

CONCESSION STANDS

We are all aware that a great deal of emphasishas beenplaced on healthdiets and exercise.We are also aware thatbecause of this emphasis, cancer rates and heart disease will pose less of a risk for many people in the future.Attimes, however, it seems people are obsessed with theirweight. The goal of this activity is to calculate what your personal food energy intake should be to maintain your present body weight. Also, you'll be askedto estimate howmuch weight you've lost or gained during your stay atCanada'sWonderland.To do this, you'll need a goodenergy guide, which your teacher willprovide in order tokeep a record of your food energy intake throughout the day.

FOOD ITEM	ENERGY (kj)
slice of pepperoni pizza	795
brownie with nuts	611
bag of potato chips	481
chocolate chip cookie	231
hamburger	1054
soft drink (350 ml)	552
coffee (reg.)	8
danish	653
spaghetti & meat sauce	1389
french fries (reg.)	883
cheeseburger	1276
2 pieces of battered fish	1331
jumbo hot dog	1271
taco (reg)	778
pretzel	490

Your body's total energy needs can be grouped, into these categories:

1) Energy to support basal metabolism
2) Energy for muscular activity
3) Energy to digest and metabolize food

To get an estimate of energy expenditure, you will have to estimate the number of joules you use in each of these categories.

Basal Metabolism Rate (BMR) is the minimum amount of energy your body needs at rest (not sleeping though), and while not digesting any food. This energy is used to simply maintain a living body. The BMR varies from one person to another and usually changes with age. In general, the younger the person, the higher the BMR. As it turns out, BMR is influenced by body surface area - but not weight. The larger the body surface area, the higher the BMR. Another factor that affects BMR is gender. Males have a higher BMR than females. BMR accounts for about 60% of your total energy expenditure per day.

Energy for muscular activity accounts for nearly 30% of our body's energy expenditure. Muscle contraction uses a large number of joules; this is the reason people exercise when they want to lose weight. The longer an activity lasts, the more energy is used. Also, the heavier the person, the more effort is needed to move. Hence, measurement of physical activity is expressed as joules per mass per unit time joule/kilogram/min).

Energy to digest and metabolize food is referred to as Specific Dynamic Action of Food (SDA) and accounts for about 10% of our daily energy expenditure. After consuming food, many different cells participate in secreting enzymes and absorbing nutrients, along with muscle contraction that moves the food along the digestive tract. These living cells need energy to fuel the process.

PROCEDURE

A) Calculating BMR

There are a number of ways to measure BMR, some of which rely on elaborate equipment and calculations.You will be using a method adopted from an activity devised by Roberta Williams at the University of Nevada in Las Vegas.

First you must determine your own height and mass. Your calculations will assume you are fully clothed (you ARE aren't you?!) and wearing shoes.

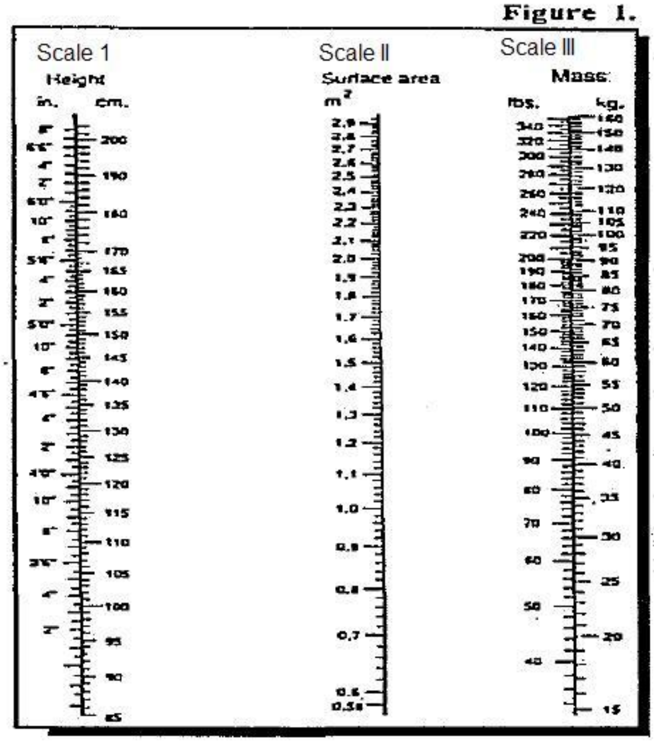
Your height _______________ m Your mass _______________ kg

Next, you will use this data to determine your body's surface area. Use Figure 1 and the directions below to estimate your surface area and record this value.

Table 1. – Basal Metabolic Rate Constants*					
BMR, J/V4h			BMR, J/V4h		
AGE	MALE	FEMALE	AGE	MALE	FEMALE
10	199.8	188.1	29	157.9	146.6
11	194.8	181.4	30	157.5	146.6
12	189.8	176.0	31	156.7	146.6
13	185.6	168.8	32	155.8	146.2
14	183.5	164.2	33	155.4	146.2
15	179.7	160.4	34	155.0	146.2
16	176.0	155.8	35	154.6	145.8
17	173.9	152.5	36	154.2	145.4
18	171.0	150.0	37	153.7	144.9
19	168.8	148.7	38	153.7	144.5
20	167.2	147.9	39	153.3	144.1
21	164.6	147.4	40-44	152.5	142.8
22	164.2	147.4	45-49	151.6	141.6
23	163.4	147.4	50-54	150.0	138.6
24	162.1	147.1	55-59	147.0	137.4
25	160.9	147.1	60-64	144.5	134.1
26	160.0	138.2	65-69	140.3	132.4
27	159.2	138.2	70-74	137.0	130.3
28	158.3	146.6			

* Adapted from W. M. Boothby: Handbook of Biological Data (1956)

Figure 1.



Next, use Table 1 to determine your BMR Constant based on your sex and age.
Your BMR Constant __________

Now, multiply your Surface Area by your BMR Constant to determine your BMR for a One Hour Record
BMR1HR __________

FOOD ITEM	ENERGY (kj)
slice of pepperoni pizza	795
brownie with nuts	611
bag of potato chips	481
chocolate chip cookie	231
hamburger	1054
soft drink (350 ml)	552
coffee (reg.)	8
danish	653
spaghetti& meat sauce	1389
french fries (reg.)	883
cheeseburger	1276
2 pieces of battered fish	1331
jumbo hot dog	1271
taco (reg)	778
pretzel	490

B) CALCULATING PHYSICAL ACTIVITY

Your muscles need energy in order to move. Table 2 lists the total energy expended in joule/kilograms for various activities. In the following data table, you must recall all your activities from when you woke up this morning until the time you leave the Park, minute by minute! To estimate the number of joules you burned due to physical activity, add up the number of minutes spent in each category and multiply by the appropriate number from Table 2. Then multiply this number by your mass in kilograms (kg). This is the total amount of energy (in joules) you burned due to physical activity since waking up this morning. Record in Table 3.

Table 2. Examples of Daily Energy Expenditures

Type of Activity	Total energy Expended (J/kg/min)
No Activity	**0.00**
Sleep	
Very Light	**0.04**
Sitting, standing, driving, typing, playing musical instruments, sewing, ironing, walking slowly	
Light	**0.08**
Walking at moderate speed, light housework, garage work, restaurant trades, golf, sailing, table tennis, volleyball, carrying light loads	
Moderate	**0.10**
Walking fast or jogging, weeding and hoeing, scrubbing floors, carrying heavy loads, cycling at moderate speed, skiing, dancing	
Heavy	**0.29**
Walking quickly up hill, climbing stairs, basketball, weight lifting, swimming, climbing, football	
Severe	**0.46**
Tennis, running	
Very Severe	**0.58**
Wrestling, boxing, racing	

Modified from Food and Nutrition Board. Recommended Dietary Allowances, 1980

Table 3 – Activity (from Table 2)	(A) # min.	(B) Energy Expended per kg. (from Table 2)	(C) Your mass (kg)	(A)(B)(C) Energy Expended (J)

C) SPECIFIC DYNAMIC ACTION

To estimate your SDA, simply add the joules calculated for today's Total BMR to those calculated for physical activity, then multiply by **.11**.

BMR/HR __________ x Hours You've Been Awake __________ Today's BMR.

[Today's BMR + Physical Activity (from Table 3)] x .11 = SDA

[__________ + __________] x .11 = __________ joules
SDA

D) TOTAL ENERGY REQUIREMENT FOR TODAY'S ACTIVITY

Now simply add all three categories: Today's BMR + Physical Activity + SDA. This will be your total energy expended since you woke up this morning.

__________ + __________ + __________ = __________joules
BMR Physical Activity SDA Total Expenditure for Today

E) ENERGY INTAKE

In Table 4, list everything you have consumed since you woke up, except for water. Use your food energy guide to estimate your total energy intake.

Table 4

Items Consumed	Energy (J)

F) SUMMARY

If your total expenditure and total intake are within 10% of each other, you most likely maintained your mass. Since 32263 joules equal about one kilogram of body fat, if you expended 32263 joules more than you consumed, you lost one kilogram. If you ate too many "amusement park goodies", you probably gained mass. Keep in mind that you have NOT taken into account the time of day when your BMR is lowest - overnight.

QUESTIONS

1) Did you gain or lose mass since this morning? If so, about how much?

2) Why should a person's BMR be higher during sleep than during resting?

3) Why would a person's average daily BMR decrease nearly 2 percent per decade throughout life?

4) Why does body surface area affect BMR?

5) Why do males have higher BMR than females?

6) What important roles do fat cells play in maintaining good health?

7) Another way to calculate your total daily energy requirements (in joules) is to multiply your desired mass by 16 (for females) or 18 (for males). How does this compare with your estimate for your total energy requirements? Remember, you did not use a 24-hour period in your calculations!

QUESTIONS

1) List three reasons why you think it is important to have plants in the Park?

2) What do you estimate is the ratio of green space to paved area in the Park?

3) What would be the advantage of installing paved stone instead of using cement to cover the walking area?

4) List the essential elements to maintaining healthy growth of the plants in the Park?

5) How many different types of plants can you find in the Park?

6) How many species of evergreen plants can you find in the Park?

7) What chemical do you think is added to the water in **White Water Canyon**?

8) Why is this chemical added to the water in **White Water Canyon**? What is the effect on the pH value of the water?

9) Name two places you can find the largest volume of water in the Park.

RING TOSS GAME

Number of throws observed ______________________

Number of successful throws observed ______________________
(if zero, assume one)

QUESTIONS

1) Based on the observed data, what is the percentage of successful throws?

2) If it takes one successful throw to win a prize (having one ring caught), how many rings would have to be thrown to win based on the percentage calculated in question #1 and assuming the last throw is the successful one?

3) Assuming the value of the prize is $20.00 and it costs $1.00 for five throws, what is the lowest possible cost per ring to win?

4) List five factors that would affect the percent of successful throws.