OPEN SCHOOL BC

Physics 11
Introduction Assignment

This assignment is intended to familiarize you with some of the basic concepts and skills related to *Physics 11*. This is the first meaningful assignment for *Physics 11,* so complete it with care.

Student Name _____

Student No. _____ **Date** _____

Address _____ **Postal Code** _____

_____

Complete the following *Physics 11* Assignment independently and return it to your teacher based on the instructions provided by your school.

You will need a scientific calculator and a pencil to complete this assignment. No other external resources are required.

There are two parts to this assignment:

Part A: Physics Matching	8 marks
Part B: Rollercoaster design	17 marks

Assignment time:

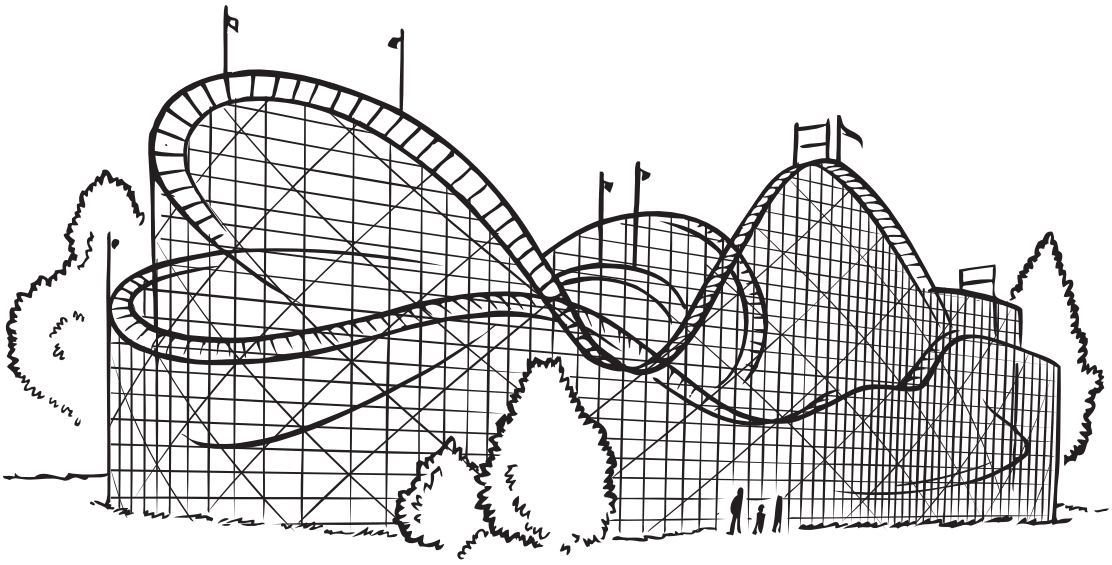
2 hours

Before you start, read these important tips.

1. Read each question carefully before answering.
2. Answer all questions to the best of your ability.
3. Take your time. Check your work before handing in the test.
4. Write neatly and watch your spelling.

The Physics of Roller Coasters

Roller coasters are a common sight at most amusement parks. If you've ever ridden a roller coaster, you probably didn't have time to think about the physics involved while you plunged 60 metres, twisted 90°, flipped upside down, and experienced a moment or two of free-fall. Well, now's the time to think about the physics behind the ride.



Designing safe and fun roller coasters depends heavily on science. Designers and engineers must carefully balance the thrills and excitement with a concern for safety. Many principles of physics are used to make riders feel like they are experiencing a thrilling and dangerous ride, when really they're quite safe.

The thrills of a roller coaster ride come from the forces the rider feels. A force, in physics, is something that acts on an object causing a change in the object's velocity. When you accelerate quickly you feel like you're being pushed into the back of your seat. When you experience a sudden drop, you feel lighter –weightless if you're in free-fall. Going around a horizontal loop pushes you to the side. Incorporating several of these forces causes the rider to feel pushed, pulled, and jerked around, all of which add to the feeling of danger and excitement.

Roller coaster designers want to maximize fun and minimize danger. They must be aware of the limitations of the human body. For example, if the upward force (making you feel very heavy in your seat) is too large, your body

will have trouble circulating blood to your upper body and head causing light-headedness or fainting. Whiplash is another concern because our muscles need time to adjust to changes in the forces they are experiencing. Knowledge of what forces cause us to feel thrills and how much our bodies can endure are crucial components of roller coaster design.

Kinematics (the study of motion) and dynamics (the study of how forces influence the motion of objects) play an important role in rollercoaster design. You may not know this, but many coasters are driven by the force of gravity – they have no engine! The coaster is pulled to the top of the first hill. During the first drop, acceleration due to gravity causes the coaster to speed up enough to make it over the next hill and through the remaining twists, turns, and loops until it returns to its starting point. The *potential*, or stored, energy the coaster has at the top of the first hill is all the energy it will need for the entire trip. As the coaster begins to fall, the stored energy is converted into the energy of motion, or *kinetic* energy. In Physics 11, you'll learn all about potential and kinetic energy and how energy is transformed. For now, just know that a roller coaster depends on this transformation between potential and kinetic energy.

Since coasters have no engines, designers must carefully select the heights and shapes of the hills and loops to ensure the coaster can safely complete its circuit. Not only do they need to take into account the force of gravity, but the other forces as well. For example, there's friction between the wheels and the track, air resistance on the coaster, and centripetal forces (the force that acts on an object travelling in a circular path) when the coaster goes through a loop. All of the forces acting on the roller coaster must be considered—and their effects calculated—to ensure a safe, yet thrilling ride!

Part A: Physics Matching

Match the term to the correct definition. (8 marks)

_____ 1. the study and description of motion

_____ 2. acts on an object causing a change in the object's velocity

_____ 3. rate of motion

_____ 4. energy stored within a physical system

_____ 5. the study of matter, forces, energy, and motion

_____ 6. rate of change of motion

_____ 7. the study of how forces influence motion

_____ 8. the energy an object possesses due to its motion

A. dynamics

B. acceleration

C. physics

D. velocity

E. kinetic energy

F. force

G. potential energy

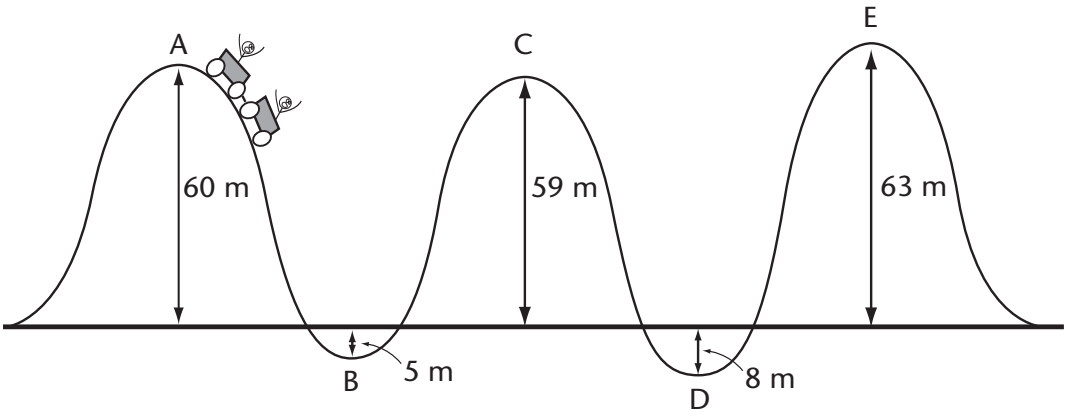
H. kinematics

Part B: Roller Coaster Design

An amusement park owner has hired someone to design a roller coaster for her theme park. The owner listed the following requirements for this roller coaster:

- there must be three hills.
- there cannot be any loops.
- the first hill must be at least 60 m high.
- the coaster must begin and end at the same elevation.

The designer came up with the design shown below. The coaster is lifted from the starting point to point A. Once it drops from its resting position at point A, it is powered by gravity only. Gravity causes the coaster's speed to increase until it reaches the bottom of the hill. The coaster then continues to travel up the next hill slowing down as it heads toward the top.



The designer is sure that his design is perfect, but the owner isn't so sure. She hires a physicist (you) to analyse and evaluate the design. Complete the following questions.

Note: Since you haven't yet studied forces or energy, we'll use a simplified model based on kinematics (This model does not take into account forces of friction or air resistance acting on the coaster.). You will be asked to consider forces and energy, but you will not be doing any calculations related to these concepts.

To find the coaster's velocity at points B, C, D, and E, you can use the formula

$$v_y^2 = v_x^2 + 2gh_{xy}$$

where v_y is the velocity at point y.
v_x is the velocity at point x.
g is acceleration due to gravity (–9.8 m/s^2).
h_{xy} is the difference in height from point x to point y.

Remember, acceleration due to gravity is negative because it acts in the downward direction. Note also, that h_{xy} may be positive or negative, depending on the direction of the coaster's travel (For example, if the coaster travels up 5 m, h_{xy} will be 5 m; if it travels down 5 m, h_{xy} will be –5 m.).

Answer the following questions, and be sure to show all your work. (17 marks)

1. What is the coaster's velocity at

   a. point B? (2 marks)

b. point C? (2 marks)

c. point D? (2 marks)

d. point E? (2 marks)

Now it's time to analyse the results of your calculations.

2. It can be difficult to relate to velocities given in metres per second. From driving or riding in cars, we are used to seeing velocities in kilometers per hour. To get a better idea of how fast you'd travel on the initial drop, convert your answer from (a) to km/h. (1 mark)

3. Have a look at your answer in 1(d). What do you think happened to the coaster (Hint: will the coaster make it to point E?)? (1 mark)

4. Remember that roller coasters are all about balancing excitement and safety. Look at your answer in 1(b). The velocity of the coaster at point C is quite low. List at least two possible reasons why this is not a very good design feature. (2 marks)

5. Now it's time to evaluate the design of this rollercoaster. Based on your answers in questions 2–4, you should make two changes to the design of this rollercoaster. Make sure your new design still meets the requirements listed in the original description.

   a. Outline the changes you would make (Clearly describe these changes and/or provide a sketch of your new design.). (2 marks)

b. The amusement park operator doesn't want to have any safety issues, or any complaints of a boring ride. The original designer doesn't believe your changes will make the roller coaster a better design. Briefly outline why you made the changes you did. Support your argument with relevant calculations. (3 marks)

/8	Part A: Physics Matching
/17	Part B: Rollercoaster Design
/25	**Total**