A bicycle is a composite of several simple machines.

a. Describe where these simple machines are found on a bicycle: lever, pulley, and wheel-and-axle.

b. Describe how each is used to transfer energy.
The academic expectation addressed by “Bicycle Design” is

2.3 Students identify and analyze systems and the ways in which their components work together or affect each other.

The core content assessed by this item includes

Content

• Objects change their motion only when a net force is applied. Laws of motion are used to predict and/or calculate the effects of forces on motion of objects.

Bicycle Design

Use the illustration of a bicycle below to answer the questions.

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SCORING GUIDE
Grade 11 Science

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>The response is complete and shows a solid understanding of simple machines and how they are used to transfer energy. There is a clear and accurate description of where each of the three simple machines is found on a bicycle and how each transfers energy.</td>
</tr>
<tr>
<td>3</td>
<td>The response shows an understanding of simple machines and how they are used to transfer energy. There is a clear description of where at least two of the simple machines are found on a bicycle and how each transfers energy. The response may lack detail or contain minor errors or misconceptions.</td>
</tr>
<tr>
<td>2</td>
<td>The response shows a limited understanding of simple machines and how they are used to transfer energy. There is a description of where at least one of the simple machines is found on a bicycle and how it transfers energy. The response may contain errors, misconceptions, and omissions.</td>
</tr>
<tr>
<td>1</td>
<td>The response is incomplete and shows a minimal understanding of simple machines and how they are used to transfer energy. There is a description of where the simple machines are found or a description of how they transfer energy, however, the response is mostly incorrect and contains major errors and omissions.</td>
</tr>
<tr>
<td>0</td>
<td>Response is totally incorrect or irrelevant.</td>
</tr>
<tr>
<td>Blank</td>
<td>No response.</td>
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</tbody>
</table>

Science Behind the Question:

Examples of where the simple machines can be found on a bicycle:

- wheel and axle pedals and crank; back wheel and axle
- lever steering; pedals and crank; gear shift; brakes
- pulley, chain and gear

Examples of energy transfer through these simple machines:

- energy on the pedals is transferred to chain
- energy on handlebars used to turn the wheel
- energy on the brake handle transferred to brake pad
- energy of the rear wheel and axle transferred to the road
There are three simple machines found on a bicycle: lever, pulley, and wheel-and-axle. Wheel-and-axle is the most obvious. The bike contains wheels and axles in the front and rear wheels. A wheel-and-axle is simply a wheel that rotates on an axle as shown below.

![Wheel-and-Axle Diagram]

A second machine is the pulley. It is located where the bicycle chain and gears are. The chain is wrapped around the pulley which turns and causes the wheel to turn on its axle.

![Pulley Diagram]

The third machine is the lever. The pedal is a lever. When force is applied to the lever it moves down, and causes the pulley to turn.

![Lever Diagram]

When you ride a bike, energy is transferred from the force of your legs to the lever (pedal). Energy goes from the lever to the pulley (chain and gear), and finally to the wheel and axle, and then to the ground under the wheel, which makes your bike move.

**Student Response**

<table>
<thead>
<tr>
<th>Student clearly and accurately describes where a wheel-and-axle can be found on a bicycle (i.e., in the front and rear wheels) and what a wheel-and-axle does. The drawing clarifies the description and shows the relevant motion.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student clearly and accurately describes where a pulley can be found on a bicycle (i.e., chain and gear) and what this pulley does. The drawing clarifies the description and shows the relevant motion.</td>
</tr>
<tr>
<td>Student clearly and accurately describes where a lever can be found on a bicycle (i.e., the pedals) and what this lever does. Again, the drawing clarifies the description and shows the relevant motion.</td>
</tr>
<tr>
<td>Student clearly and accurately describes how the simple machines transfer energy to make a bicycle move. The description is supported by information provided throughout the response.</td>
</tr>
<tr>
<td>Overall, the response demonstrates a solid understanding of simple machines and how they are used to transfer energy.</td>
</tr>
</tbody>
</table>
Sample 4-Point Response of Student Work

**Student Response**

A. The lever on a bicycle is the brake lever located on the front handle bars. The pulley is the chain and gear that help make the bike run, and the wheel and axle are in the front and back tires.

B. The bike's pulley transfers energy from the person's body to the chain. The chain then sends the energy to the wheel-and-axle which transfers it to the tire and then onto the road causing movement. The lever stops the movement by sending the energy from the tire to the brake pads where it is absorbed and neutralized.

Student clearly and accurately describes where a lever, pulley, and wheel-and-axle can be found on a bicycle (i.e., lever—brake lever on handlebars; pulley—chain and gear; wheel-and-axle—front and rear tires).

The student clearly and accurately describes how the simple machines transfer energy to make a bicycle move.

Overall, the response demonstrates a solid understanding of simple machines and how they are used to transfer energy.
Sample 3-Point Response of Student Work

**Student Response**

The lever is the pedal. The pulley is the chain, sprockets, and gears. And the wheel and axle are in the front and the back where the wheel and axles are.

In the transfer of energy, energy is passed from one’s body through the legs to the pedals. From the pedals, the energy is carried along the chain by means of the pulleys. The energy from the pulleys finally reaches the wheel and axles causing the bicycle to move in a forward motion. That concludes the following energy of a bicycle.

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Student accurately describes where a lever, pulley, and wheel-and-axle can be found on a bicycle (i.e., lever—pedal; pulley—chain, sprockets and gears; wheel-and-axle—front and rear wheels and axles).

Student explains how the simple machines transfer energy, but the explanation lacks some detail (e.g., omits that the wheel and axle transfers energy to the ground which finally moves the bike forward).

Overall, the response demonstrates an understanding of simple machines and how they are used to transfer energy.
Sample 2-Point Response of Student Work

**Student Response**

A lever is the pedal in which you push down on to turn the crankshaft, which is an example of a pulley. The wheel and axle is the handlebars and the shaft that connects it with the wheel to turn.

Energy is transferred when a person pushes on the levers to turn the pulley, which makes the wheels turn and the bike go forward. Energy is spent turning the wheel and axle or handlebars also.

**Annotations**

- Student accurately describes where a lever and pulley can be found on a bicycle (i.e., lever—pedals; pulley—crank), though some details are omitted (e.g., both the crank and the chain are necessary for the pulley to work). The description for the handlebar is incorrect (i.e., the handlebar is a lever, not a wheel).

- Student describes how the simple machines transfer energy, but the description is incomplete and lacks some clarity.

**Overall**

Overall, the response demonstrates a limited understanding of simple machines and how they are used to transfer energy.

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Sample 1-Point Response of Student Work

**Student Response**

On a bicycle there are several simple machines such as: lever, pulley, and wheel-and-axle. Each of these are very important on a bicycle. They are all used to transfer energy. The lever is the bicycle itself. It is used to keep the bicycle up and together. The pulley is the pedal. This is where the rider uses the force of their legs to make the bicycle move. Then there is the wheel-and-axle. This is the Chain and wheel. When the rider is pedaling the chain moves and this causes the wheel to turn, which allows the bicycle to move.

**Annotations**

- The student attempts to describe where the simple machines are found on a bicycle and how they transfer energy, but much of the response is incorrect or lacks clarity. For example, a bicycle itself is not a lever, nor are the pedals by themselves a pulley system. Similarly, while the student does address the concept of energy transfer from the pedal to the wheel, he or she confuses a chain and wheel and a wheel and axle.

**Overall**

Overall, the response demonstrates a minimal understanding of simple machines and how they are used to transfer energy.
The open-response item “Bicycle Design” was designed to assess student’s ability to (1) break down a complex, but very familiar, machine into simple machine components and (2) describe how these simple machine components, in combination, transfer energy as a bicycle operates. The instructional strategies below present ideas for helping students practice and master these skills and concepts.

Discuss the following concepts and skills with students:

- The differences and connections between force, motion, and energy
- Types of simple machines and how they can be coupled to create complex machines
- How to analyze complex machines into component simple parts that transfer force and hence motion and energy

Have students work individually, in pairs, in small groups, and/or as a class to complete any or all of the following activities:

- Identify and obtain detailed drawings or photographs of complex machines (e.g., farm equipment, construction machines). Prepare transparent overlays that identify the components of the machines. Categorize these components into simple machine types. Write descriptions and/or present oral reports on how each part works to change motion and/or transfer energy.
- Construct a “Rube Goldberg” machine to, for example, collect water from a dripping tap and set off an alarm bell and crack a nut when a certain time has elapsed. For each component (step), identify the type of simple machine used and prepare a written description of how the motion/energy is changed and transferred. Give a prize to the group that includes (in their working model) the most simple machines.
- Create a “Name that Simple Machine” game that requires players to identify simple machines, describe their functions, and explain how they help “do work” in commonly-used machines.