

Name \_\_\_\_\_

**SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.**

1) What are the advantages and disadvantages of using hydrogen as a fuel?

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2) How does a fuel cell work?

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3) What are the uses of the various types of fuel cells?

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4) What are the advantages and disadvantages of fuel cells?

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5) How does an ultracapacitor work?

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## Answer Key

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1) Advantages of using hydrogen include zero emissions, quiet operation, and ability to generate hydrogen using renewable energy sources. Disadvantages of using hydrogen include limited vehicle range, perceived safety issues, a lack of fueling infrastructure, and low well-to-tank efficiency.

Page Ref: 715-716; 722-723

2) A fuel cell generates electricity by harnessing the energy that is released when hydrogen combines with oxygen. Hydrogen is fed to one side of a catalyst-coated membrane, while oxygen is fed to the other side. The proton from the hydrogen is allowed to pass through the membrane, but the electron must follow a path external to the fuel cell to combine with the oxygen on the opposite side. This electron flow is converted into usable power by sending it through an electrical load such as a motor.

Page Ref: 716

3) Uses of the various types of fuel cells include:

PAFC (Phosphoric Acid Fuel Cell) – used for stationary power applications

PEM (Proton Exchange Membrane Fuel Cell) – used in vehicles, portable power, small stationary power

MCFC (Molten Carbonate Fuel Cell) – used in industrial and institutional power

SOFC (Solid Oxide Fuel Cell) – used in stationary power and military vehicle applications

DMFC (Direct Methanol Fuel Cell) – used in small portable power applications

Page Ref: 716

4) The advantages of a fuel cell include zero emissions (only water and heat), high efficiency relative to an internal combustion engine, and no moving parts. The disadvantages of a fuel cell include high cost, lack of refueling infrastructure, perceived safety issues, lack of vehicle range, lack of durability, freeze starting problems, and insufficient power density.

Page Ref: 715

5) Ultracapacitors can be used in hybrid-electric vehicle applications to store electrical energy during regenerative braking, and then discharge that energy as the vehicle accelerates. Ultracapacitors lack energy density, but can charge and discharge very rapidly and are sometimes used in place of the battery pack in fuel cell hybrid vehicle designs.

Page Ref: 719