Hybrid Automobiles

Introductory Question

- If you connect an electric motor in a circuit with a lightbulb, is there a chance that spinning the motor will cause the lightbulb to light up?

A. Yes
B. No

Observations about Hybrid Automobiles

- A hybrid car propels itself on fuel or batteries
- It combines electrical and mechanical power
- It switches easily between fuel, batteries, or both
- It can recharge its batteries during braking
- It can turn its engine off when not needed
- It can restart its engine quickly and easily

5 Questions about Hybrid Automobiles

- How does a hybrid car power its wheels?
- How does a hybrid car generate electric power?
- How does a hybrid car use that electric power?
- How does a hybrid car manage that power?
- If magnets don't move, can they affect charge?

Question 1

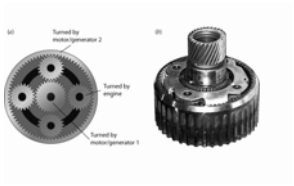
- How does a hybrid car power its wheels?
  - How does it combine engine and battery power?

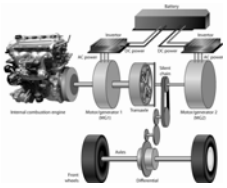
Combining Mechanical Power

- A hybrid automobile uses a machine that blends
  - rotary mechanical power from its fuel-burning engine
  - rotary mechanical power from its electric motors
  - rotary mechanical power from its wheels
- That "transaxle" can transfer mechanical power between any of those devices in either direction!

The Transaxle

- A hybrid car's transaxle is a gear assembly that
  - couples together its engine, motors, and wheels
  - conveys mechanical power between those devices
  - replaces the transmission of a normal car





Clicker Question

- You and a friend are arm wrestling—trying to twist each others arms down to the table. When is your arm doing work on your friend's arm?

A. As you are winning
B. As your friend is winning
C. While your arms are both motionless
D. Throughout the match

Rotary Power

- Recall that to provide rotary power to a machine
  - you must exert a torque on that machine
  - in the direction of its angular velocity.
- The transaxle allows engine, motors, and wheels
  - to exert torques on one another
  - as they turn in various directions at various speeds
  - and thereby transfer rotary power to one another.
- Power can flow in any direction via the transaxle!

Question 2

- How does a hybrid car generate electric power?

Clicker Question

- A coil of wire forms a closed circuit with a lightbulb. If you sweep the north pole of a bar magnet past the coil of wire, the lightbulb will

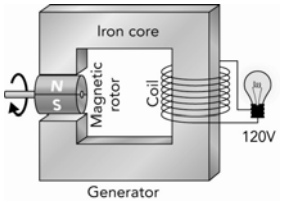
A. blink once.
B. blink twice.
C. not blink at all.

Generating Electricity

- Recall that changing magnetic fields
  - produce electric fields,
  - which propel currents through conductors,
  - which produce magnetic fields.
- Changing magnetic effects *induce* currents
- Moving magnets have changing magnetic fields
  - and can induce currents in coils of wire
  - with magnetic fields that oppose the moving magnets.
- Mechanical power becomes electrical power!

An AC Generator

- An AC Generator resembles a transformer
  - except that it has no primary coil
  - and instead uses a spinning magnet
  - to induce AC current in its secondary coil.
- Magnet rotation speed sets the AC frequency.
- Magnet strength, turns in the coil, and rotation speed set voltage rise.

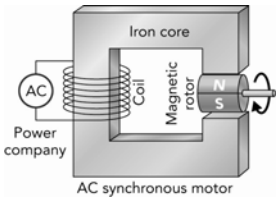


Question 3

- How does a hybrid car use that electric power?
  - Does it need both generators and motors?
  - How different are generators and motors?

An AC Motor

- An AC Motor resembles a transformer
  - except that it has no secondary coil
  - and instead uses a spinning magnet
  - to obtain power from its primary coil.
- AC frequency sets the Magnet rotation speed.
- Magnet strength, turns in the coil, and rotation speed set voltage drop.



Introductory Question (revisited)

- If you connect an electric motor in a circuit with a lightbulb, is there a chance that spinning the motor will cause the lightbulb to light up?

A. Yes
B. No

Generators = Motors

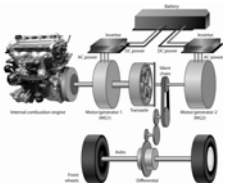
- If generators and motors look similar,
  - that's because they're basically the same device!
  - they differ only in the direction of power flow
- If you twist it forward, it acts as a generator
  - You do work on it and transfer power to it
  - Lenz's law: magnetic effects twist you backward
- If you twist it backward, it acts as a motor
  - You do negative work on it and extract power from it
  - Lenz's law: magnetic effects twist you forward

Question 4

- How does a hybrid car manage that power?
  - How do the batteries, motor/generators, engine, and wheels all act together to propel the vehicle?

Hybrid Propulsion System

- Its electronics transfer electrical power between
  - its batteries, which use direct current,
  - its motor/generators, which use alternating current,
  - with help of AC↔DC invertors (hi-tech switches)
- Its transaxle transfers mechanical power between
  - its motor/generators
  - its engine
  - its wheels



Meeting Every Requirement

- Each rotary device has its own angular velocity
  - Engine operates best at a specific angular velocity
  - Wheels operate best when they roll on the ground
  - Motor/generators can operate at any angular velocity
- Flexibility of the motor/generators makes up for the pickiness of the engine and wheels
- The vehicle can drive fast on level ground, climb hills, and using braking to recharge its batteries.

Question 5

- If magnets don't move, can they affect charge?
  - From the rotor's perspective, what is going on?

Clicker Question

- A coil of wire forms a closed circuit with a lightbulb. If you sweep the coil of wire past the north pole of a bar magnet, the lightbulb will

A. blink once.
B. blink twice.
C. not blink at all.

A Different Point of View

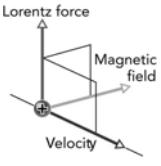
- From rotor's perspective, the poles <u>don't</u> move
  - so there is no electric field to push on charge.
  - How can the motor/generator still work?
- From rotor's perspective, the charges <u>do</u> move
- When a charge moves through a magnetic field, it experience a new force: the Lorentz force

The Lorentz Force

- A charge moving through a magnetic field
  - experiences the Lorentz force,
  - a force that pushes it perpendicular to its velocity
  - and perpendicular to the magnetic field:

  Lorentz force = charge · velocity · magnetic field · sine(angle)

  where the "angle" is that between the velocity and the magnetic field.
- The Lorentz force resolves the apparent paradox



Summary about Hybrid Vehicles

- It uses its motors to convert electrical power from its batteries and generators into mechanical power for its wheels, generators, and engine
- A hybrid vehicle uses its generators to convert mechanical power from its engine and wheels into electrical power for its batteries and motors
- Its generators and motors are the same devices