

Hybrid Automobiles

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



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

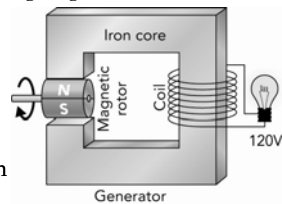
- A coil of wire forms a closed circuit with a lightbulb. If you sweep the north pole of a bar magnet past the coil of wire, the lightbulb will
 - A. blink once.
 - B. blink twice.
 - C. not blink at all.

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.

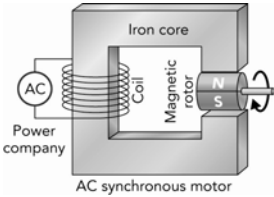


Question 3

- 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.



Generators = Motors

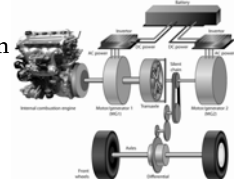
- If generators and motors look similar,
 - that's because they're basically the same device!
 - they differ only in the direction of power flow
- If you twist it forward, it acts as a generator
 - You do work on it and transfer power to it
 - Lenz's law: magnetic effects twist you backward
- If you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

A Different Point of View

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

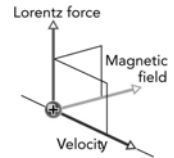
The Lorentz Force

- 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:

$$\text{Lorentz force} = \text{charge} \cdot \text{velocity} \cdot \text{magnetic field} \cdot \sin(\text{angle})$$

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