

27 Regenerative Braking Systems

? FREQUENTLY ASKED QUESTION

What is the Difference Between Mass and Weight?


Mass is the amount of matter in an object. One of the properties of mass is inertia. Inertia is the resistance of an object to being put in motion and the tendency to remain in motion once it is set in motion. The weight of an object is the force of gravity on the object and may be defined as the mass times the acceleration of gravity.

Therefore, mass means the property of an object and weight is a force.

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FIGURE 27.1 This Honda Insight hybrid electric vehicle is constructed mostly of aluminum to save weight.



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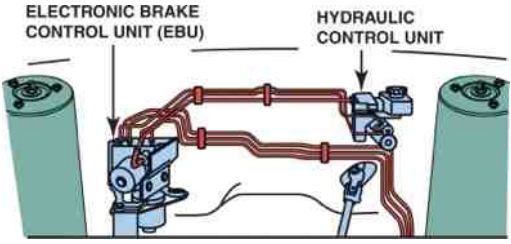
FIGURE 27.2 A Toyota Prius hybrid electric vehicle. This sedan weighs more and therefore has greater kinetic energy than a smaller, lighter vehicle.



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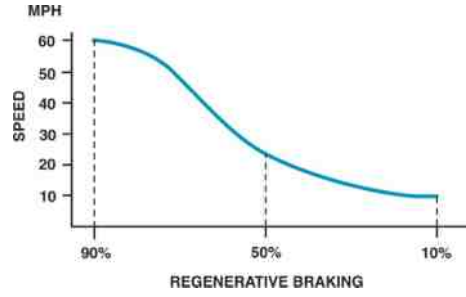
FIGURE 27.3 The electronic brake control unit (EBU) is shown on the left (passenger side) and the brake hydraulic unit is shown on the right (driver's side) on this Ford Escape system.



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FIGURE 27.4 A typical brake curve showing the speed on the left and the percentage of regenerative braking along the bottom. Notice that the base brakes are being used more when the vehicle speed is low.



| Regenerative Braking (%) | Speed (MPH) |
|--------------------------|-------------|
| 90% | 60 |
| 50% | 25 |
| 10% | 10 |

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Are the Friction Brakes Used During Regenerative Braking?

Yes. Most hybrid vehicles make use of the base (friction) brakes during stopping. The amount of regenerative braking compared to the amount of friction braking is determined by the electronic brake controller. It is important that the base brakes be used regularly to keep the rotors free from rust and ready to be used to stop the vehicle. A typical curve showing the relative proportion of brake usage is shown in **FIGURE 27-4**.

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FREQUENTLY ASKED QUESTION

How Does the Computer Change a Motor to a Generator So Quickly?

The controller of the drive motors uses a varying frequency to control power and speed. The controller can quickly change the frequency, and can therefore change the operation of a typical AC synchronous motor from propelling the vehicle (called motoring) to a generator. **SEE FIGURE 27-5**.

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FREQUENTLY ASKED QUESTION

Do Regenerative Brake Systems Still Use a Parking Brake?

Yes. Regenerative braking systems work while the vehicle is moving and supplements but does not replace the conventional brake system including the parking brake system.

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FIGURE 27.5 The frequency ("f") applied to the stator windings of an AC synchronous motor can be varied to create either forward torque ("T") or regenerative braking. If the frequency is changed from point 1 to point 2 as shown on the chart, the torque is changed from motoring (powering the vehicle) to generating and this change can be made almost instantly by the controller.

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FREQUENTLY ASKED QUESTION

What Do Regenerative Brakes Look Like?

Regenerative brakes use the rotation of the wheels applied to the electric traction (drive) motor to create electricity. Therefore the brakes themselves look the same as conventional brakes because the hydraulic brakes are still in place and work the same as conventional brakes. The major difference is that the standard wheel brakes work mostly at low vehicle speeds whereas conventional brakes work at all speeds. As a result, the brakes on a hybrid electric vehicle should last many times longer than the brakes on a conventional vehicle.

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TECH TIP

"B" Means Braking

All Toyota hybrid vehicles have a position on the gear selector marked "B." This position is to be used when descending steep grades and the regenerative braking is optimized. This position allows the safe and controlled descent without having the driver use the base brakes. Having to use the base brakes only wastes energy that could be captured and returned to the batteries. It can also cause the brakes to overheat. **SEE FIGURE 27-8.**

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FIGURE 27.6 The Toyota Prius regenerative braking system component showing the master cylinder and pressure switches.

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FIGURE 27.7 The Ford Escape regenerative braking system, showing all of the components. Notice the brake pedal position sensor is an input to the ECU, which controls both the brake and traction control systems.

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FIGURE 27.8 The "B" position on the shift display on this Lexus RX 400h means braking. This shifter position can be selected when descending long hills or grades. The regenerative braking system will be used to help keep the vehicle from increasing in speed down the hill without the use of the base brakes.

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NOTE: One of the major concerns with hybrid vehicles is rust and corrosion on the brake rotors and drums. This occurs on hybrids because the base brakes are usually only used at low vehicle speeds.

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FIGURE 27.9 The ABS ECU on a Toyota Prius uses the brake switch and pressure sensor inputs to control the regenerative braking system. The circuit includes a voltage signal from the sensor, the regulated 5V supply to it, the input from the brake light switch (12V when the brakes are on), and the ground connection.

The diagram shows an ABS ECU with several electrical inputs. At the top, a 14-V (B+) line is connected to the ECU. Below it, a 5V (V-REF) line is connected through a resistor to the ECU. Further down, there are two inputs labeled 'PRESSURE SWITCH INPUT' and 'BRAKE SWITCH INPUT'. At the bottom, a 'GROUND' connection is shown. The ECU itself is depicted as a rectangular box with a blue component on top and a yellow component on the bottom.

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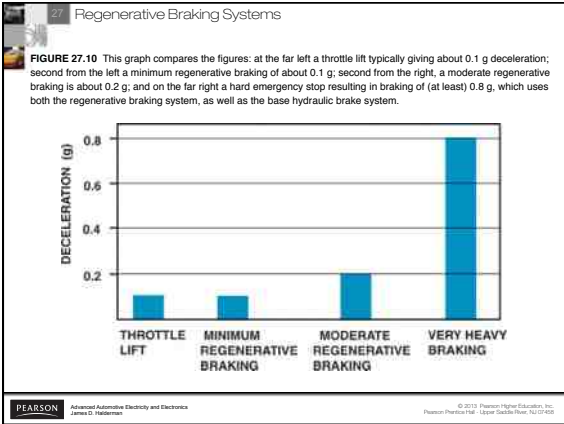
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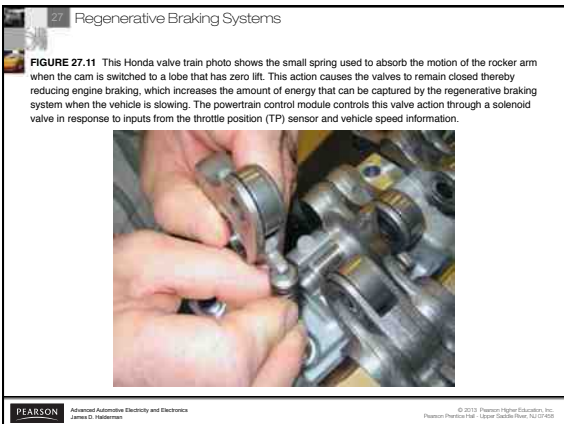
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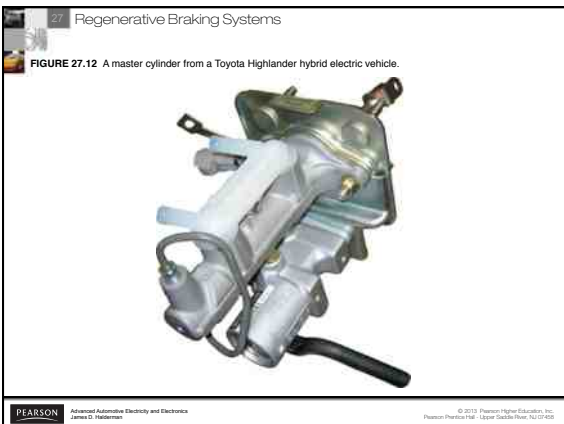
Can an On-Vehicle Brake Lathe Be Used on a Hybrid Electric Vehicle?

Yes. When a brake rotor needs to be machined on a hybrid electric vehicle, the rotor is being rotated. On most hybrids, the front wheels are also connected to the traction motor that can propel the vehicle and generate electricity during deceleration and braking. When the drive wheels are being rotated, the motor/generator is producing electricity. However, unless the high-voltage circuit wiring has been disconnected, no harm will occur.

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When Does Regenerative Braking Not Work?

There is one unusual situation where regenerative braking will not occur. What happens if, for example, the vehicle is at the top of a long hill and the battery charge level is high? In this situation, the controller can only overcharge the batteries. Overcharging is not good for the batteries, so the controller will disable regenerative braking and use the base brakes only. This is one reason why the SOC of the batteries is kept below 80% so regenerative braking can occur.

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FIGURE 27.13 When working on the brakes on a Ford Escape or Mercury Mariner hybrid vehicle, disconnect the black electrical connector on the ABS hydraulic control unit located on the passenger side under the hood.



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CAUTION: To prevent physical harm or causing damage to the vehicle when serving the braking system, the technician should do the following:

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