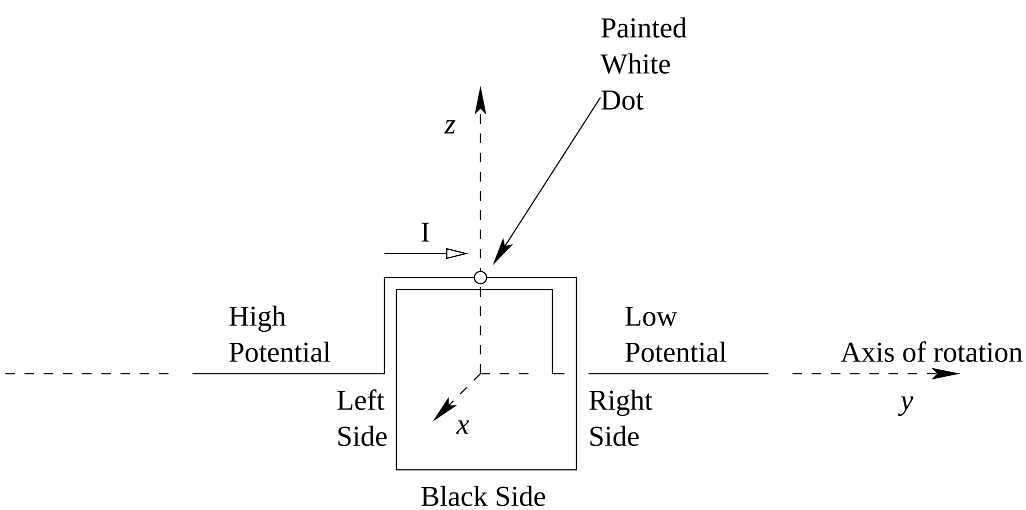
Building a DC Motor

We are going to build a DC motor from scratch.

1 Preparation

Let us think about what happens to a square loop in a magnetic field. Consider a square loop carrying current such as the one in the figure. The loop has four sides, plus the two ends which stick out from the square. The "left side" is the side of the loop near the high potential end of the wire. The "right side" is the side of the loop near the low potential end of the wire. Imagine painting a white dot on the loop for identification purposes. This white dot has no effect on the operation of the loop. We will call the side of the loop with the white dot the "white side" and the opposite side the "black side". You can imagine a black dot painted on the black side.



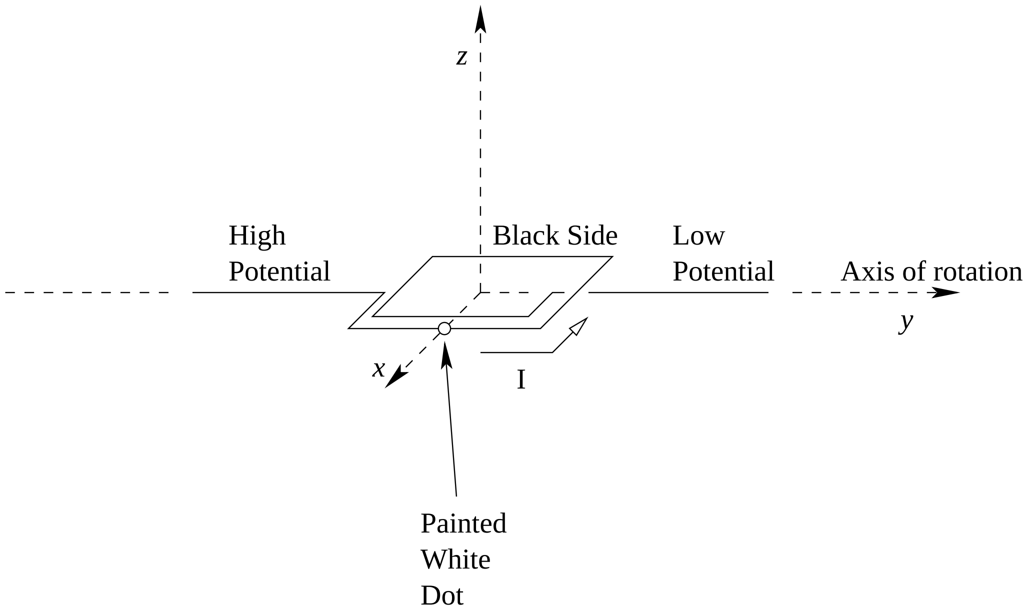
This wire loop is free to rotate about the axis of rotation shown in the figure. Take the center of the loop to be the origin of our coordinate system and suppose that there is a magnetic field in the positive z-direction. Take the axis of rotation of the loop to be along the y-axis. The high potential side of the loop is on the negative y-axis and the low potential side of the loop is on the positive y-axis.

If the loop is oriented so that the white dot is on the positive z-axis, what is the direction of the force on each side of the loop? For each force, what is the direction of the torque with respect to the axis of rotation when viewed from the right (positive y-axis)? You may answer clockwise, counterclockwise, or none.

	Direction of Force	Direction of Torque
Left Side		
Right Side		
White Side		
Black Side		

What will the loop do in this case?

If the loop continues a quarter turn in the direction it should rotate, it will be oriented so that the white dot is on the positive x-axis, as shown below. What is the direction of the force on each side of the loop? For each force, what is the direction of the torque with respect to the axis of rotation when viewed from the right (positive y-axis)?

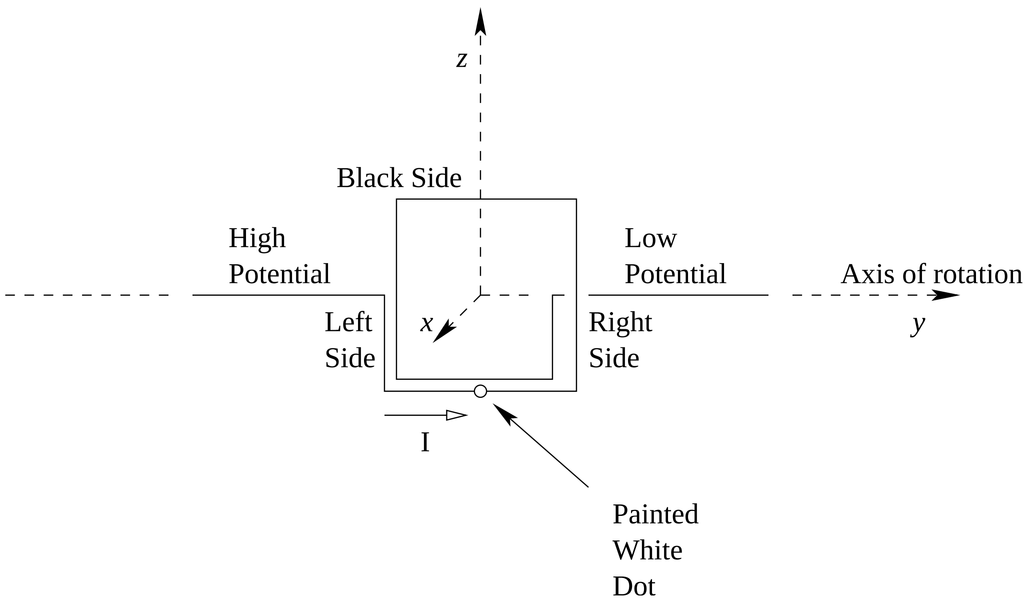


	Direction of Force	Direction of Torque
Left Side		
Right Side		
White Side		
Black Side		

Recall from last semester that an equilibrium position is one in which both the sum of the forces and the sum of the torques is zero. Is this an equilibrium position?

Considering that the loop brings some angular momentum into the quarter-turn rotation, according to Newton's first law, what should the loop continue to do?

If the loop were to continue in accordance with the correct answer to the question above, the loop would be oriented so that the white dot is on the negative z-axis, as shown in the figure below. What is the direction of the force on each side of the loop? For each force, what is the direction of the torque with respect to the axis of rotation when viewed from the right (positive y-axis)?



	Direction of Force	Direction of Torque
Left Side		
Right Side		
White Side		
Black Side		

What will the loop do in this case?

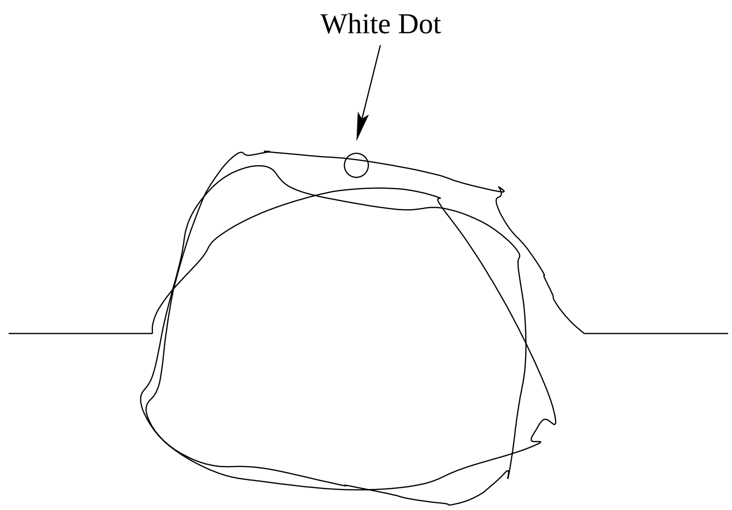
A restoring torque is a torque felt by an object after moving from an equilibrium position that would restore the system to the equilibrium position. Is there a restoring torque on the loop?

Recall from last semester that a position of stable equilibrium is an equilibrium position that is supported by restoring forces and torques on either side of that position. Where does the white dot need to be in order for the loop to be in a stable equilibrium position?

2 Make a Wire Loop

1. Take two paper clips and partially unfold them into an "S" shape. Hang these from a wooden stick about 6 cm from each other to make a cradle for the rotating coil.

2. Make a coil out of insulating wire by wrapping the wire around your finger about 15 times. Your loop will not be a square loop, but that's fine. Strip the insulation from the two ends of the wire (about 2–3 cm) and let the ends stick out like in the figure below. The ends will be the axis of rotation for the loop.



3. Paint a white dot on the appropriate side, as in the figure above. It matters which side you paint. One side is correct, the other side is incorrect. Paint the side on which current will flow from the high potential side to the low potential side.

4. Place the coil in the cradle you made out of paper clips.

5. Turn the DC bench supply to about the half way position. Use alligator clips to apply this DC voltage to the paper clips (black end of DC supply to one paper clip, red end to the other).

6. The magnetic field points from the north pole of the magnet to the south pole. Use a compass to determine which end of the magnet is

the north pole. The compass needle should point toward the north pole. Hold the magnet so that the north pole is on the bottom. In this way you will get a magnetic field that points upward (toward the ceiling).

7. When the loop is in the magnetic field, does it go to the stable position that you predicted? Describe what happens when the loop is in the magnetic field. Where is the white dot?

3 Make a DC Motor

1. So far, we haven't gotten anything to keep rotating. In order for us to call this thing a motor, it needs to keep rotating. The way we have things set up now, it won't keep rotating. Why won't it keep rotating?

2. Here is our plan to make the loop rotate continuously in the magnetic field. We will paint (with white-out, an insulator) one half of each bare end of the wire. When the loop is oriented in such a way that the exposed metal side of the wires ends is in contact with the paper clips, the loop will turn in response to the magnetic field. But, as the loop continues to turn, the side of the wire with the painted insulation will come in contact with the paper clips, no current will flow through the loop, and the loop will not respond to the magnetic field. Instead, it will simply continue to rotate (conserving its angular momentum). The loop will not respond to the magnetic field until it has turned far enough that the bare part of the wire ends is again in contact with the paper clips.

3. It is important which half of the wire you paint. Which half will you paint? Draw a picture of the loop showing which half of the wire ends you will paint. Feel free to check your plan with your instructor before proceeding.

4. Carefully paint half of your wire ends and see if you have a working DC motor.
5. Show your working DC motor to your instructor.