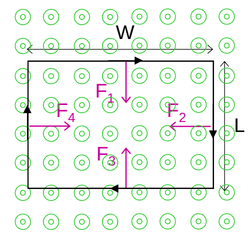
Torques

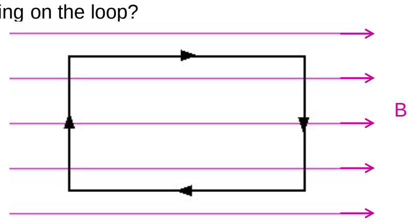
The force on a current-carrying loop II

As shown below, $|F_1| = |F_3| = BIW$ and $|F_2| = |F_4| = BIL$. The net force is always zero when a current-carry loop is <u>completely</u> inside a uniform field.



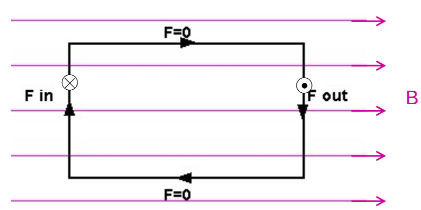
Is there a net anything on the loop?

Let's change the direction of the uniform magnetic field as shown below. Is the net force on the loop still zero? Is there a net anything on the loop?



Is there a net anything on the loop?

Let's change the direction of the uniform magnetic field. Is the net force on the loop still zero? Is there a net anything on the loop?



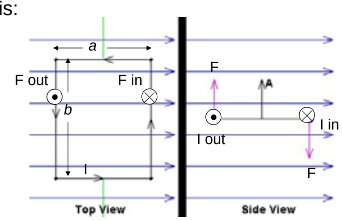
The net force is still zero, but there is a net torque that tends to make the loop spin.

The torque on a current loop

The magnetic field is in the plane of the loop and parallel to two sides. If the loop has a width *a*, a height *b*, and a current I, then the force on each of the left and right sides is $F = IbB$. The other sides experience no force because the field is parallel to the current in those sides. Simulation

The torque ($\tau = rF\sin\theta$) about an axis running through the center of the loop is:

$$\tau = \frac{a}{2}F + \frac{a}{2}F$$
$$= aF$$
$$= IabB$$



The torque on a current loop

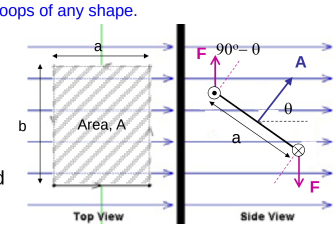
The above shows that $\tau = IabB$, where *ab* is the area of the loop, so the torque here is $\tau = IAB$.

This is the maximum possible torque, when the field is in the plane of the loop. When the field is perpendicular to the loop the torque is zero. (Why?) In general, the torque is given by:

$$\tau = IAB\sin\theta$$

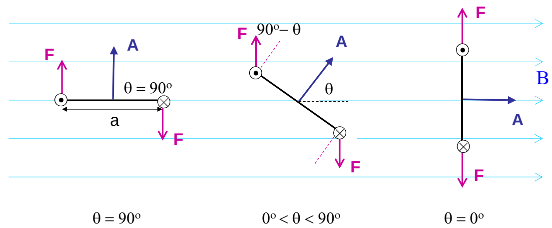
N.B. This applies to loops of any shape.

where θ is the angle between the area vector, ***A***, (which is perpendicular to the plane of the loop, see side-view at right) and the magnetic field, ***B***.



The torque on a current loop I

The pictures below explains the reason for the factor of sinθ in the expression for the torque, $\tau = IAB\sin\theta$



Note that *F* = *BIb* in all three orientations shown above, but the torque decreases from *Fa* to Fasinθ to 0.

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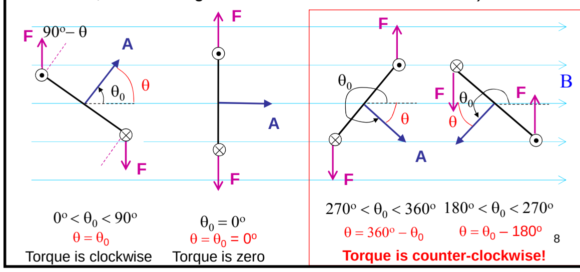
The torque on a current loop II

When the current loop has rotated by more than 90°, the direction of the forces acting on the two perpendicular arms does not change, but the arms have switched to the opposite sides of the rotational axis, causing the torque direction to reverse. (Below, θ_0 is the angle measured from vector **B** to vector **A**; θ is the angle to be inserted in τ = IABNsinθ.)



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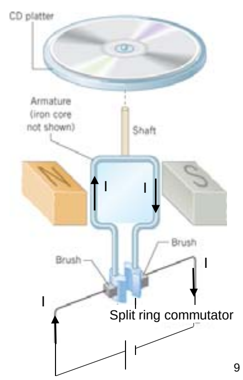
A DC motor

A direct current (DC) motor is one application of the torque exerted on a current loop by a magnetic field. The motor converts electrical energy into mechanical energy.

If the current always went the same way around the loop, the torque would be clockwise for half a revolution and counter-clockwise during the other half. To keep the torque (and the rotation) going the same way, a DC motor usually has a "split-ring commutator" that reverses the current every half rotation.
Simulation



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