PHYSICS PRESENTATION

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Does Magnetic force do work?

→ This may be looking simple, but it is a very strange phenomenon. In many situations, it may appear that Magnetic force can't do work. But there are many situations in which it appears that the Magnetic force can do work and is performing work.

If there is a charge Q ~~the~~ moving with velocity $\vec{v}$ and there is a perpendicular Magnetic field $\vec{B}$, then by Lorentz force law, force on (magnetic) charge Q will be

$$\vec{F}_{mag} = Q(\vec{v} \times \vec{B})$$

~~It~~ It is clear that force is ⊥r to both Magnetic field ($\vec{B}$) and velocity ($\vec{v}$).

If we see the displacement of charge particle with charge Q in time t, then it will be

$$\vec{dl} = \vec{v}\, dt$$ (Simply from Kinematics)

Now, the workdone by Magnetic force is

$$W_{mag} = \int F_{mag} \cdot dl = \int Q(\vec{v} \times \vec{B}) \cdot \vec{v}\, dt$$

$$= 0$$ (clearly zero by Property of ~~the~~ Cross product and dot Product)

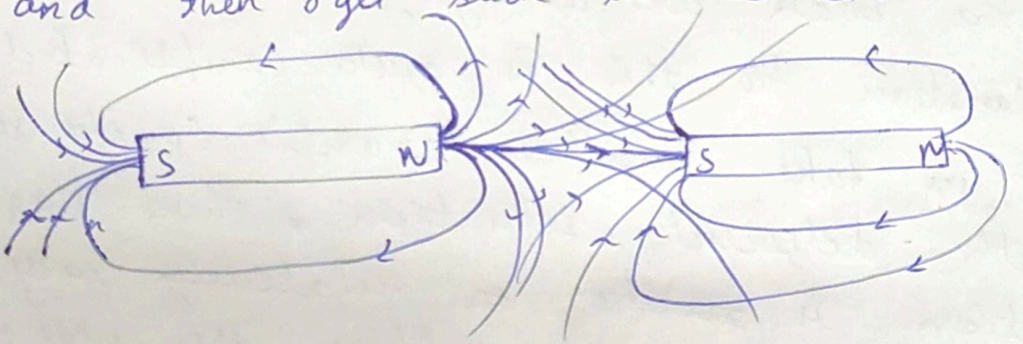
So, we have taken a very general case, and proved that Magnetic force can't do any work.

So, Magnetic can only change the direction of velocity but can't change the Kinetic energy of the Particle.

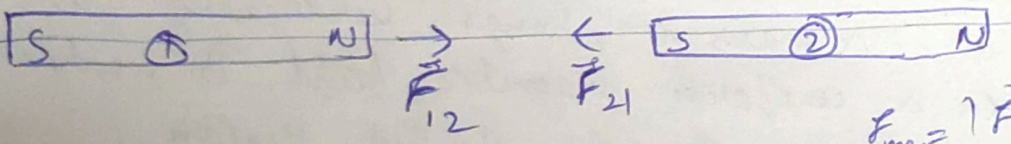
Till now, you must be agreed that Magnetic force can't do any work.

But now, ~~I am~~ I am going to take some situation which can change your perspective about the workdone by Mag. force.

→ If we observe two magnets which north pole facing towards south pole. Then we see that these magnets are atually attracting each other and then they get stick to each other

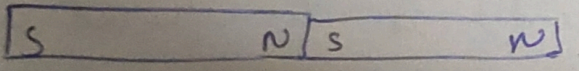


Direction of Magnetic force is clearly along the Magnets



$$F_{mag} = |\vec{F}_{12}| = |\vec{F}_{21}|$$

So, forces are in the direction in which Magnets are going to move and final situation will be



[We are assuming that magnets are only moving in straight line]

So, if we see in horizontal plane only there is no other force other than Magnetic force
So, by looking the case it is too obvious that work done is

$$dW = F_{mag} \, ds \Rightarrow W = F_{mag} \cdot S$$

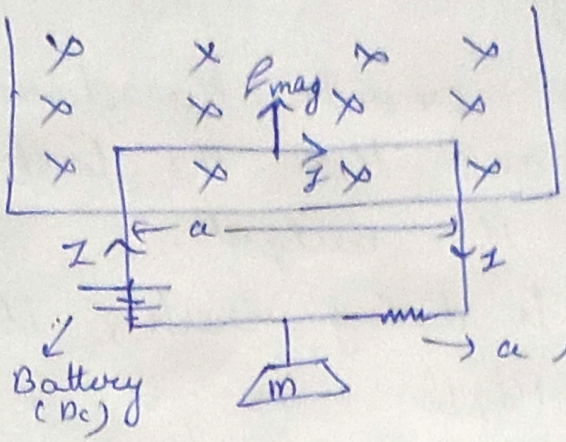
where S is distance b/w the two magnets (centrally)
Distance 'S' is b/w closer North and South Poles.

So, here Magnetic force is doing work? Really?
But we proved by general case that MF can't do any work. How is it happening?
Is all the book are wrong?,
The Explanation to this is quite complicated
So, let us take another Example (quite similar) but with different situation, there the Explanation is relatively easy.
Thus, I am going to explain this new case first and then I will be back to above discussed situation.

New situation: A rectangular loop of wire, supporting a mass m, hangs vertically with one end in a uniform magnetic field $\vec{B}$, which points into the page in the shaded region.

[Reference → Example 3 of Griffith's Electrodynamics]

So, by this situation it is clear that there is magnetic force on current loop (part which is in Magnetic field) is in upward dir^{n}



I want to add a bulb (resistance) to circuit in addition to given situation

$$\vec{F}_{mag} = (\vec{I} \times \vec{B})\, a = BIa\, \hat{k}$$

or

$$\vec{F}_{mag} = \int I\, (dl \times B)$$

$$= BI \int_0^a dl$$

$$\vec{F}_{mag} = BIa\, \hat{k}$$

[Note → we are taking upward direction as $\hat{k}$]

We can easily calculate current in loop which can be able to make $|\vec{F}_{mag.}|$ such that it can cancel the effect of gravity on bar

i.e, $|\vec{F}_{mag.}| = |\vec{F}_{gravity}|$ [As in opp. dir^{n}]

$$BIa = mg$$

$$I = \frac{mg}{Ba}$$

[By this current weight just hangs there, suspended in mid air]

[Note → Now onwards in discussion we are going to assume the current is due to mobile free charges]

Now, what happen if we increase the current beam the above value.

Upward Magnetic force exceeds the downward force of gravity, and thus the loop will rise i.e, it is lifting up the weight.

So, here somebody is doing work, is it Magnetic force? May be as it is in the direⁿ of displacement.

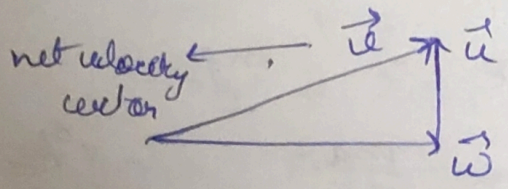
So, one may write that

$$W_{mag} = F_{mag}\, h = BIa\, h$$

[where h is distance through which loop is moved upward]

But, acc. to general case, we know Magnetic force never do any work. So what is happening here?

When the loop start rising, the charge in the wire are no longer moving horizontally- their velocity now acquires an upward component u (speed of loop) in addition to the horizontal component w associated with current, (i.e, $\vec{v} = \vec{u} + \vec{w}$)

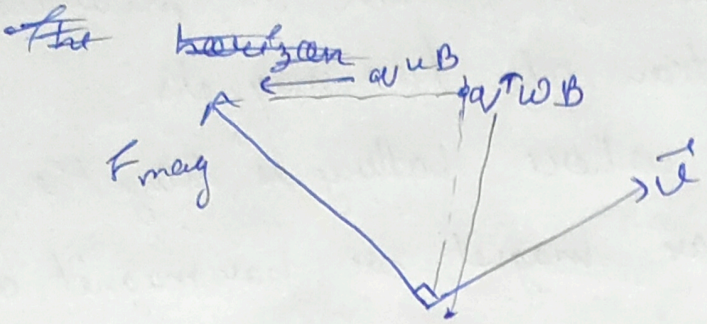


So, the magnetic force, which is ⊥r the velocity, no longer points straight up, but tilts back i.e, force now have both horizontal and vertical component.

And force is ⊥ to net displacement. Thus, it does no work on charge q (inside the wire)

So $|\vec{F}_{vertical}| = qvB = \lambda a v B = IBa$

and $|\vec{F}_{horizontal}| = quB$.



The horizontal component of F_{mag} (quB) opposes the current flow.

So, as the battery is maintaining current, must move push those charges along, ie, again horizontal component of $\vec{F}_{mag}$.

$$\vec{F}_{horizontal} = \lambda a u B$$

displacement in time dt = u dt

So, the workdone must be done by battery, $W_{battery}$

$$W_{battery} = \lambda a B \int u v \, dt$$

$$= I B a h \qquad \left[\because \lambda v = I \text{ and } u\,dt = h\right]$$

This is similar to what we attributed as magnetic force workdone. But by this discussion it is clear that battery is doing the work. And the role of Magnetic force is only redirecting the

horizontal force of the battery into vertical motion of the loop and weight. This work done by Battery can be assumed by discharging of capacitor by Battery
This thing can also be explained by simply mass on slope.

→ Now, I am going back to previous situation of attraction of two magnets.
Like in above case where battery is doing the work, in case of two bar magnet or bar magnet and Magnetic Metal, (i.e., ferromagnetic or Paramagnetic metals) there is another force which is actually doing work
That force is electric force.
If we somehow place two magnet at a distance d apart such that there is no motion of Magnets then, they will stay at their respective position.
But if we have a stationary magnet and we are moving another magnet toward it and if we removed external force even at more the 'd' distance apart then also these magnet get stick to each other. What is happening here?
So, when the magnet is moving there is change in magnetic field and that change in magnetic field creates non Conservative electric field and due to this field these magnet are moving further

towards each other. That is the reason why magnet at rest are not moving toward each other, i.e, we must require some relative motion ~~(or we require some motion maybe not relative)~~

This explanation also have same reason from Quantum Physics like particle spin which I am ~~going~~ going to explain shortly in presentation.

The above explanation is the reason for various Machines like magnetic cranes, etc.

Hence, I can conclude that Magnetic force never do work it can only induce or may produce some other force by changing itself which can perform work.