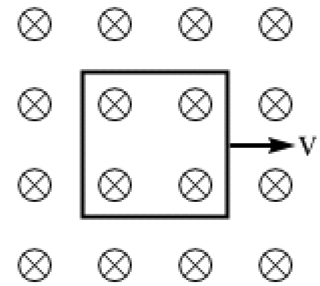
PROBLEM 1 – 16 points

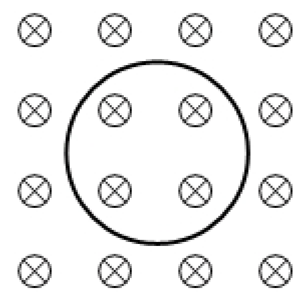
For each situation below determine the direction of the induced current in the loop (if there is one). In each case the multiple-choice part is worth two points, and the justification is worth two points.

(a) A square loop is **moving at a constant velocity to the right through a uniform magnetic field** that is directed into the page and which extends out of the picture to the left and right. In which direction is the induced current in the loop?



[ ] clockwise [ ] counter-clockwise
[X] there is no induced current
Justify your answer: **There is no change in magnetic flux.**

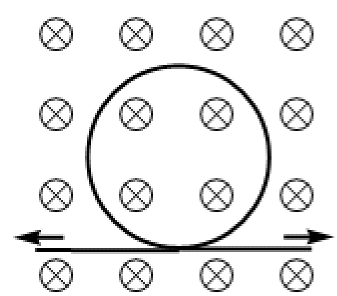
(b) A circular loop is at rest in a magnetic field directed into the page. **The magnetic field is increasing in magnitude.** In which direction is the induced current in the loop?



[ ] clockwise [**X**] counter-clockwise
[ ] there is no induced current

Justify your answer: **If we add more field lines into the page the loop tries to cancel them out (opposing the change) by creating field lines out of the page. It does this via a counter-clockwise induced current.**

(c) A piece of wire is wrapped into a loop and placed in a uniform magnetic field that is directed into the page. You then pull on the ends of the wire so **the area of the loop is decreasing**. In which direction is the induced current in the loop?

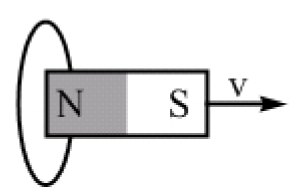


[**X**] clockwise [ ] counter-clockwise
[ ] there is no induced current

Justify your answer: **Decreasing the area of the loop decreases the magnetic flux through the loop. The loop tries to oppose the change by bringing in more field lines into the page, which it does with a clockwise induced current.**

Note that even if there is not a complete circuit (if the wire doesn't touch to get a complete loop) there is still a motional emf effect that would give rise to a deflection of charge clockwise around the loop.

(d) A bar magnet is held near the center of a wire loop. **The magnet is then pulled away from the loop.** The north pole is always closest to the loop. In which direction is the induced current in the loop?



[**X**] clockwise [ ] counter-clockwise
[ ] there is no induced current

Justify your answer: **Initially there are lots of field lines going**

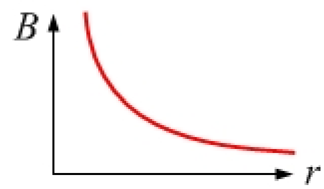
right-to-left through the loop. Moving the magnet to the right reduces the number of these field lines passing through the loop, so to oppose this change the loop sets up its own field, with field lines going right-to-left inside the loop. This requires a clockwise current, as viewed from the perspective shown in the diagram.

PROBLEM 2 – 15 points

Two identical square wire loops are placed near a long straight wire that has a current directed to the right.

[3 points] (a) Sketch a graph showing how the magnitude of the magnetic field produced by the current in the long straight wire changes as a function of *r*, the distance from the wire.

***B* is inversely proportional to *r*, giving the graph shown here.**



[6 points] (b) In what direction is the induced current in loop 1 if …

(i) loop 1 remains at rest and the current in the long straight wire is constant?

[ ] clockwise [ ] counter-clockwise [**X**] neither, there is no induced current
No change in flux

(ii) loop 1 remains at rest and the current in the long straight wire is increasing in magnitude?

[**X**] clockwise [ ] counter-clockwise [ ] neither, there is no induced current

The flux increases out of the page, so the induced current creates a field into the page to oppose the change. A field into the page requires a clockwise current.

(iii) the current in the long straight wire is constant and loop 1 moves toward the wire?

[**X**] clockwise [ ] counter-clockwise [ ] neither, there is no induced current
Moving the loop closer to the wire also increases the flux out of the page, so the induced current creates a field into the page to oppose the change, requiring a clockwise current.

[3 points] (c) At the instant shown in the diagram above, loop 1 and loop 2 are the same distance from the wire, with loop 1 moving at a speed *v* directly toward the wire and loop 2 moving at a speed *v* in a direction 60° to the velocity of loop 1. Which loop has a larger induced current?

[**X**] loop 1 [ ] loop 2 **Briefly justify your answer**

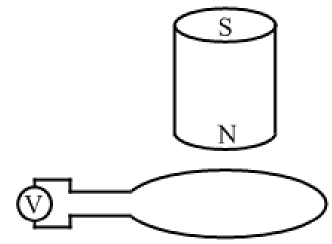
The larger the component of the velocity that is directed toward the long straight wire, the faster the flux through the loop changes and the larger the induced current is. Loop 1 is moving toward the wire faster than loop 2 is, so loop 1's induced current is larger.

[3 points] (d) Returning to the situation described in part (c), with what speed would loop 1 have to move toward the wire to have exactly the same induced current as loop 2, if loop 2 has a speed *v* in the direction shown?

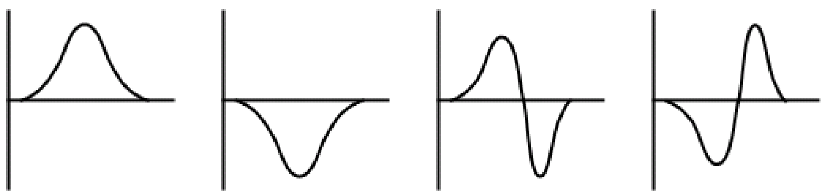
Loop 2's velocity component directed perpendicular to the wire is v cos(60°) = v/2. For loop 1 to have the same induced current, its velocity toward the wire must be the same as loop 2's, so it needs to have a speed of v/2 as it moves toward the wire.

PROBLEM 3 – 10 points

In a Faraday's Law experiment, a magnet is dropped from rest. As shown in the diagram, the north pole of the magnet is at the bottom of the magnet and the south pole is at the top. The magnet accelerates down, passing through the center of a loop of wire connected to a voltmeter. Assume the magnet is always oriented as shown in the diagram, with the south pole at the top of the magnet and the north pole at the bottom.



[3 points] (a) Let us define positive flux as coming from magnetic field lines that are directed up through the loop. Circle the graph below that best represents the graph of **magnetic flux** as a function of time for the magnet passing through the loop.



The field lines are directed down through the magnet at all times, which is the negative direction. Thus, the second graph is the correct choice. (The third and fourth graphs look more like induced emf.)

[2 points] (b) If the magnet is released from rest from a point higher above the loop than it was in part (a), what happens to the height of the peak(s) in the flux vs. time graph? The height of the peak(s) is:

[ ] increased [ ] decreased [**X**] unchanged

Flux is a measure of the number of field lines passing through the loop. The number of field lines is determined by the strength of the magnet, not by its speed. The speed of the magnet changes the peaks on the graph of induced emf, but not on the flux graph.

The two pictures below show two possibilities for the current induced in the loop as the magnet falls through the loop.

Case 1 Case 2

[3 points(c) As the magnet falls, what is the direction of the induced current in the loop?

[ ] as shown in “Case 1” the entire time [ ] as shown in “Case 2” the entire time
[ ] as in “Case 1” initially, then as in “Case 2” after the magnet has passed through the loop
[**X**] as in “Case 2” initially, then as in “Case 1” after the magnet has passed through the loop

As the magnet approaches, the induced current creates an upward magnetic field (as in case 2)to oppose the extra down-directed field lines from the magnet. The current reverses direction when the magnet moves away because now the field is decreasing.

[2 points] (d) Where is the center of the magnet when the induced current in the loop reaches its peak magnitude?

[ ] above the loop [**X**] below the loop [ ] at the center of the loop

The magnet’s speed increases the farther it falls, so the flux chages most rapidly at a point below the loop. At the center of the loop, where the flux is maximum, the induced current is zero.