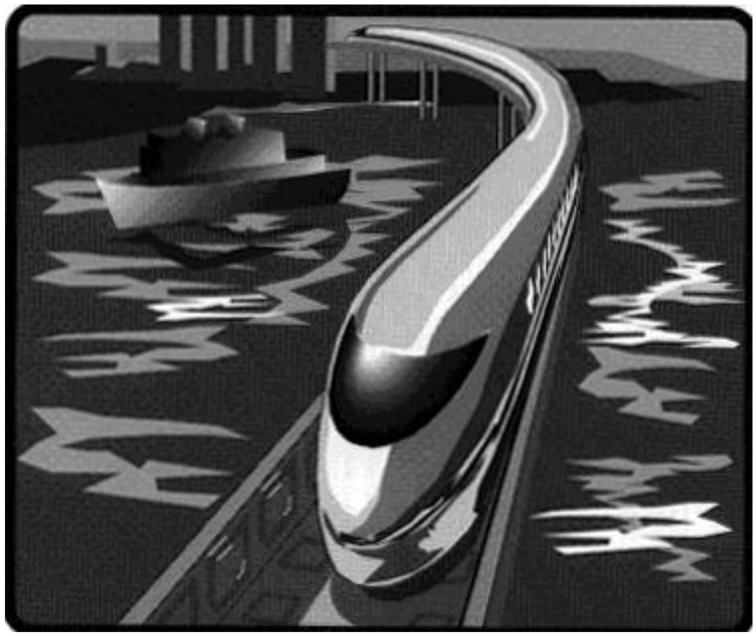
Magnetic Levitation



Answer Key

Answer Sheet:

1. D
2. C
3. D
4. C
5. B
6. B
7. B
8. C
9. D
10. A
11. B
12. E
13. B
14. C
15. D
16. B
17. C
18. B
19. A
20. C
21. C
22. A
23. D
24. D
25. A

Short Answer/ Fill in the blank (20 points):

1. A conductor is poised in a magnetic field produced by a north poled on the left and a south pole on the right. What is the direction of the induced emf when a) the conductor moves down through the field and b) the field moves down across the conductor?

a) The direction of the induced emf is away from the observer (1 point)

b) The direction of the induced emf is toward the observer (1 point)

2. If a charged particle is circulating in a magnetic field and it reflects back and forth between two ends of the field, it is said to be trapped in a(n) **<u>magnetic bottle</u>**. **(1 point)**

3. Briefly describe how a cyclotron works and mention one inherent problem with its operation.

A cyclotron is designed to accelerate a charged particle to high energies (1 point)

It consists of two metal plates with a small gap between them where there is a potential difference. (1 point)

A charged particle passes through the field and is accelerated. It enters the metal plate where there is no electric field but a magnetic field which causes it to circle back around. (1 point)

It then passes back through the gap and accelerates more. The electric field alternates as the particle shifts from side to side. (1 point)

Problems (answers may very): At high energies, the particles have a large radius, the alternating electric field does not account for relativistic effects etc. (1 point max)

4. What is an electrodynamic tether and how can it be used to generate electricity?
It is a large conductor in orbit with its two ends attached to electrodes (one electrode can be the ionosphere). (1 point)

As it moves through the earth's magnetic field in orbit, an emf is induced. OR As it moves through the earth's magnetic field, mechanical energy is converted to electrical energy by induction. (1 point max)

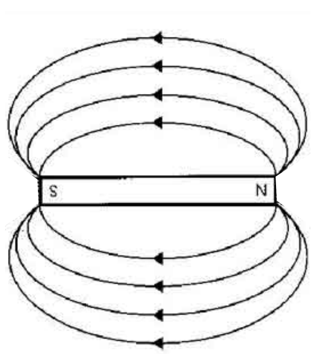
5. Why are rare earth magnets so much stronger than standard ferrite magnets?
Rare earth magnets have unfilled f-orbitals. (1 point)

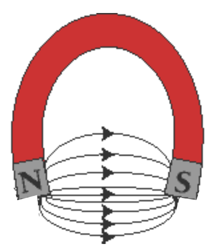
These electrons have aligned spin and are strongly localized. (1 point)

These electrons then provide strong magnetic moments. (1 point)

In regular magnets, the magnetic moments of the electrons in other orbitals may partially cancel out, creating a weaker magnetic moment. (1 point)

6. Sketch magnetic field lines for the following systems (at least 8 of them per diagram). The horseshoe magnetic is weaker than the bar magnet.





3 points for each correct diagram

-2 points if the lines on the bar magnet are not closer together than those on the horseshoe magnet

Problem (30 points): Show all work to get credit.

A square loop of wire with a perimeter of 1.00 m is placed in a magnetic field of strength 10.0 T so that it is parallel to the magnetic field. The loop is then rotated clockwise at a rate of one revolution per minute.

a) What is the flux through the loop at its starting point?

$$\Phi = A * B\sin\theta = (.250m)^2 * 10.0\ T * \sin 0 = \mathbf{0\ Wb}$$

(2 points)

b) What is the maximum flux through the loop?

$$\Phi = A * B\sin\theta = (.250m)^2 * 10.0\ T * \sin 90 = \mathbf{.625\ Wb}$$

(2 points)

c) Sketch a graph of flux versus time for the first minute and complete the following chart. Clearly label points of maximum and minimum flux.

Time (min)	0	0.125	0.300	0.500	0.625	0.750	1.00
Flux (Wb)	0	.442	.594	0	-.442	-.625	0

(9 points for proper table, -1 point per wrong value, no penalty for not using negatives, no credit for no work)

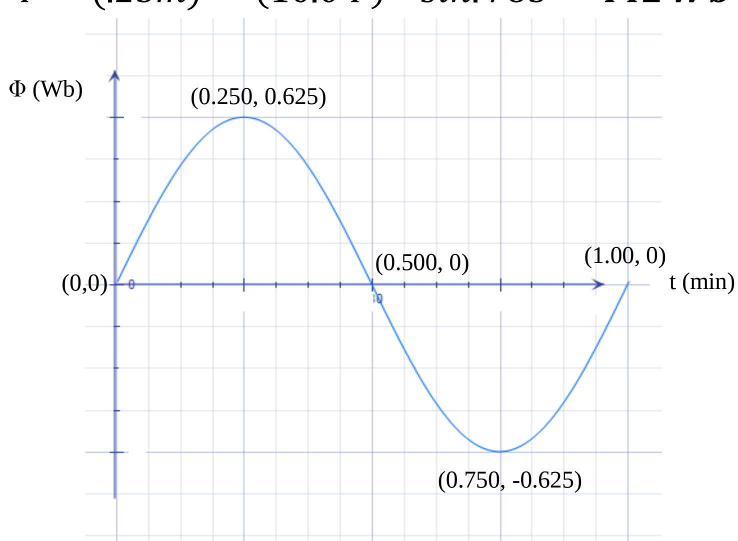
Sample work: $.125\ min$: $\theta = 2\pi * \left(\frac{time}{period}\right) = 2\pi * \left(\frac{.125\ min}{1.00\ min}\right) = .785\ rad$

$$\Phi = (.25m)^2 * (10.0\ T) * \sin .785 = \mathbf{442\ Wb}$$

1 point—shape of curve (must dip below x-axis)

1 point—labeled axes

1 point—labeled maxes, mins, and zeroes



d) What kind of curve is this? Explain the behavior of the curve after 0.500 minutes.

This is a sine curve. (1 point)

The graph drops below the x-axis after .500 min. (1 point) This is a sign convention. Imagine a normal vector to the surface of the loop pointing right at the loop's initial position. After rotating for .500 min it now points in the opposite direction, so flux is negative. (2 points)

e) Using the data points from your chart above, estimate the induced emf at the following times. Note: this does not require calculus, but an exact answer can be given using it and will be accepted.

Time (min)	0.0625	0.213	0.400	0.563	0.688	0.875
Emf (V)—non-calc	.0589	.0145	-.0495	-.0589	-.0244	.0417
Emf (V)—calc	.0605	.0151	-.0530	-.0605	-.0249	.0463

2 points per correct answer, - 2 points for using minutes instead of seconds

Non-calculus solution example: .0625 min.

$$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = \frac{\Phi(.125) - \Phi(0)}{(.125\ min - 0\ min) * \frac{60\ sec}{min}} = \frac{.442\ Wb}{7.50\ sec} = .0589\ V$$

Calculus example solution: .0625 min.

$$\varepsilon = N\frac{d\Phi}{dt} = \frac{d}{dt}(A * B\sin\left(\left(\frac{\pi}{30}\right)t\right) = \left(\frac{\pi}{30}\right) * A * B * \cos\left(\left(\frac{\pi}{30}\right)t\right)$$

$$= \left(\frac{\pi}{30}\right) * (.25m)^2 * 10.0\ T * \cos\left(\left(\frac{\pi}{30}\right).0625\ min * \frac{60\ sec}{min}\right) = .0605\ V$$

f) Write an equation for flux as a function of time in seconds (use radians).

$\Phi(t)=A\cdot B\sin((\pi/30)t)$ (2points)