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ABSTRACT

In the present document the effectiveness of a student team teaching technique is evaluated in comparison with the lecture method. The team teaching technique, previously used for upper division and graduate physics courses, was, for this study, used in a sophomore physics, electricity and magnetism course for engineers, mathematicians, chemists, and physicists. The result is that student team teaching is less effective and much less popular than the lecture method for students in this engineering physics course. (Author/HS)

Final Report

Project No. 1-J-046
Grant No. OEC-X-71-0043(057)

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AN EVALUATION OF STUDENT TEAM TEACHING IN SOPHOMORE PHYSICS CLASSES

April, 1972

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

ABSTRACT

The effectiveness of student team teaching technique is evaluated in comparison with the lecture method. This method, which has been used before for upper division and graduate physics courses, is used in a sophomore physics electricity and magnetism class for engineers, mathematicians, chemists, and physicists. The result is that student team teaching is less effective and much less popular than the lecture method for students in this "engineering physics" course.

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The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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INTRODUCTION

This project was initiated and executed to investigate an alternate to the lecture method of presentation. The lecture technique is widely used and criticized. Its defects are well known. These include a tendency for the students to lose interest and for the student-teacher interaction to be quite small.

The lecture technique is nevertheless quite resistant to change. One reason for this is the enthusiasm that the teacher generates within himself when he is preparing the lectures. A failure of the technique often occurs when the teacher tries to communicate this enthusiasm to the students; a catastrophe all too often occurs when the teacher doesn't realize that his enthusiasm has not been transferred.

A fairly common method of involving the students in the enthusiasm generated by lecture preparation is to assign the presentation of a lecture to a student. This technique often benefits one student but leaves the other students without either an interest in the lecture or a unified presentation.

Another approach is to use the student team teaching technique. This is described by David S. Folk and N.S. Wall in "An Experiment in Undergraduate and Graduate Teaching and an Evaluation", American Journal of Physics, 38, No. 12, 1485-1486 (1970). In this technique, teams of students prepare topics for presentation to the class. All of the team members thus have the experience of preparing a lecture and share in the resulting enthusiasm. As an additional benefit, the students interact with each other; they help, criticize, and encourage each other and gain proficiency in group work activities.

The purpose of this project was the evaluation of the student team teaching technique. To acquire significant statistics, a class of over one hundred students was used. This necessitated the use of a sophomore physics class.

PROCEDURES

The experiment was performed during the first semester of the 1971-1972 school year. The class involved was Physics 221: Engineering Physics II--Electricity and Magnetism.

On the first day of class pretests A, B, and C were given. These pretests, reproduced in Appendix A, were used in the evaluation to account for variations in the students' initial mathematics manipulation ability, mathematics formulation ability, and association of physical quantities.

Also at the beginning of the semester, information forms D and E were completed by the students. Information from these forms, reproduced in Appendix B, was used to: (1) schedule meeting times with the students and (2) evaluate the results of the experiment in manner acknowledging variations in the students' sex, age, major, physics course background, and mathematics course background.

The total class of 130 students was split into two sections. These two sections met at 2:00 p.m. and 3:00 p.m. on Monday, Wednesday, and Friday. Due to scheduling difficulties, equal section sizes were not possible; there were 71 students in the 2:00 section and 59 in the other.

During the first five week experimental session. standard lectures were presented to the 2:00 section and student team teaching was used in the later section; during the second five week session, this procedure was reversed. Since there was no time lapse between the two sections, common hour exams were given to the two sections and used to evaluate the effectiveness of student team teaching as compared to the lecture method.

The topics discussed in the course are listed in Appendix C. The background topics were presented to both sections by the course instructor using standard lectures. Electricity was the subject discussed in the first five week session; the second session was devoted to magnetism. After the second session, a brief review was presented before final examinations.

The homework problems in the course are listed in Appendix D. All of these are from the text, Physics, by Halliday and Resnick. This text was used because it is the most widely used book for engineering physics courses. During the student team teaching sessions, when students were presenting the problems in class, the homework was not collected. During the lecture sessions, the homework was collected weekly.

Each five week experimental session was divided into two phases in the student team teaching section. During the first phase, the students presented all of the topics to the class. Three students each presented one topic or homework problem at each class meeting. During the second phase, the course instructor presented two topics and two students each presented one homework problem at each class meeting.

All students who presented topics or homework problems to the class were prepared before the presentation. Two days (or one weekend) before a presentation, a group of 10 students met with the course instructor and the topic or problem was assigned. At this time, all necessary background material was discussed. On the morning before the presentation, the students met again with the instructor. At this time, a student was selected to make the presentation and he or she practiced presenting the topic. In addition to making sure that the topic or problem was thoroughly understood, the instructor made suggestions regarding the use of the blackboard, clarity of speech, and time limitations.

The tests which were used in this project are reproduced in Appendix E. Tests 2 and 3 were given in the first five week experimental session and tests 4 and 5 were given in the second. Tests 2 and 4 terminated the first phases and tests 3 and 5 concluded the second phases of the two sessions. Due to scheduling difficulties, the two sections could not take a common final examination. It, therefore, could not be used as an evaluation instrument. Test 1 and the two final examinations are reproduced in Appendix E only to present the entire scope of the course.

As soon as the students completed phase two of their student team teaching session, they were asked to complete parts A, B, and C of the questionnaire reproduced in Appendix F. This was done to get their personal opinion of student team teaching. Part D of the questionnaire was distributed at mid-semester of the semester following the experiment. This was done to gather information concerning the change of major.

The final test of the students' opinion of student team teaching was made with the questionnaire reproduced in Appendix G. The students were given the opportunity to take part in another student team teaching class.

Finally, the students who were involved in the student team teaching experiment in Physics 221 were observed in Physics 222. Their performance on the first Physics 222 hour examination was compared with that of the students who had no experience with student team teaching.

RESULTS

The effectiveness of student team teaching as compared to the lecture method was determined by two statistical analyses. The first was used to determine the overall effect of the teaching method for the entire class. The second was used to investigate the response of various types of students to student team teaching.

To find the overall effect, a least squares analysis of variance for unequal subclass numbers was used to obtain unbiased estimates for the effects of teaching method, physics course background, mathematics course background, major, sex, and age and pretest partial regression coefficients. The least squares maximum likelihood general purpose program for the IBM 360/40 was used to analyze the data from tests 2, 3, 4, and 5. A total of 64 problems and problem combinations were analyzed.

In the comparison of the two teaching methods only 9 of the 64 categories were significant at the 10% level. The lecture method surpassed the student team teaching technique in effectiveness by an 8 to 1 margin. To give perspective to these results, all of the significant results from this first analysis are listed in Table I and Table II. Age and pretest score appear to be the most influential factors.

To investigate the response of different types of students to student team teaching models containing the effects of teaching method, a_i, and the interaction of teaching method with a_i were fit separately for each of the 64 questions and question combinations. Several type classifications, a_i's, were investigated. Only results which were significant at the 10% level are reported in Table III. Variables of a_i which did not lead to any significant results were pretest A score, pretest B score, combined scores of pretests A and B, combined scores of pretests A, B, and C, whether or not the student returned the questionnaire of Appendix F, the final course grade in Physics 221, the students' grade point average for the semester of the experiment, and whether or not the student changed major during the semester of the experiment.

The popularity of student team teaching was measured by the questionnaires of Appendix F and Appendix G. Both indicate that the students strongly favor the lecture method. The response to the first questionnaire is reported in Appendix H. The second questionnaire drew votes of approval for student team teaching from only 5% of the students who had been in the experiment. Over a third, 37% , of these students rejected the call for volunteers by refusing to return the questionnaire while 58% returned it with a negative response.

The student team teaching method appears to have no residual effect on students' performance. On the first hour examination in Physics 222, the course which formerly followed Physics 221 in the prerequisite sequence, the average grades and standarddeviations were as follows: 69.4 ± 13.1

for students with no student team teaching background, 72.2 ± 13.2 for students who attend topic conferences but did not present topics, and 74.6 ± 12.4 for students who did not attend topic conferences. Clearly these results show no significant differences.

TABLE I--OVERALL TEST RESULTS

These results were obtained from a least squares analysis of variance for unequal subclass numbers which considered the effects listed in this appendix and in Appendix I.

EFFECT	SIGNIFICANCE LEVEL	PROBLEM NUMBER	RESULT
Teaching Method	1%	5-10	L > STT
	5%	4-8	L > STT
		4-7+...+11	L > STT
		4-1+...+11	L > STT
		5-6+10	L > STT
	10%	2-1+...+6	L > STT
		2-7	STT > L
		4-10	L > STT
		5-3	L > STT
Physics Course Background	1%	NONE	
	5%	2-8	220 > NONE
		4-11	220 > NONE
		3-7+...+10	220 > NONE
	10%	5-10	220 > NONE
		5-9	220 > NONE
		3-7A	220 > NONE
		3-8B	220 > NONE
		3-9	220 > NONE
		3-1+...+10	220 > NONE
Math Course Concurrent	1%	5-7B	180 > 190 > 200
	5%	2-2	200 > 190 > 180
		2-4	190 > 180 > 200
	10%	3-8A	190 > 200 > 180
		5-7+...+9	190 > 180 > 200
Major	1%	NONE	
	5%	2-1+...+6	Phys & Chem > Other > Math > Eng
		5-2	Other > Eng > Math > Phys & Chem
		5-1+...+5	Other > Eng > Phys & Chem > Math
	10%	2-3	Other > Phys & Chem > Eng > Math
		2-1+...+11	Phys & Chem > Other > Math > Eng
		5-10	Phys & Chem > Eng > Other > Math
		5-6+10	Phys & Chem > Eng > Other > Math
Sex	1%	4-1	F > M
	5%	2-7	M > F
		4-1+...+6	F > M
	10%	2-1	F > M
		4-4	F > M
		5-3	F > M
		5-8A	M > F

ABBREVIATIONS: L = Lecture Presentation, STT = Student Team Teaching, 220 = Physics 220 (which was not a prerequisite for Physics 221 for the first time in the semester of this experiment), 180 = Calculus I, 190 = Calculus II, 200 = Calculus III

TABLE II--REGRESSION COEFFICIENTS

These results were obtained from a least squares analysis of variance for unequal subclass numbers which considered the effects listed in this appendix and in Appendix H. The results are listed in units of % increase in problem score per year for the age effect and % increase in problem score per unit increase in pretest score for the pretest effects.

EFFECT	SIGNIFICANCE LEVEL	PROBLEM NUMBER	RESULT
Age	1%	2.2	+0.6
		2.6	+6.2
		4.5	+5.8
		4-1+...+6	+2.4
		4-7+...+11	+1.8
		4-1+...+11	+1.9
		3-6	+2.9
	5%	2-1+...+6	+1.5
		2-7	+2.5
		2-1+...+11	+1.1
		4-7	+3.1
		4-8	+1.9
		3-8B	+2.9
		3-4	+1.8
		3-1+...+10	+1.3
		5-5	+3.8
	10%	2-7+...+11	+1.1
		4-4	+3.0
		3-7+...+10	+0.9
		5-7B	+2.5
		5-7+...+9	+1.0
Pretest A	1%	2-8	+.4
		2-9	+.4
		2-11	+.4
		2-7+...+11	+.3
		2-1+...+11	+.3
		4-9	+.6
		4-10	+.6
		4-11	+.6
		4-7+...+11	+.5
		4-1+...+11	+.4
		3-9	+.4
		3-10	+.5
		3-7+...+10	+.3
		3-1+...+10	+.4
		5-7A	+.8
		5-7B	+.7
		5-8A	+.5
		5-7+...+9	+.4
	5%	4-7	+.5
	10%	3-2	+.6
		3-1+...+5	+.3
		3-6	+.3
		5-6	+.3
		5-6+10	+.3

TABLE II
(Cont'd.)

EFFECT	SIGNIFICANCE LEVEL	PROBLEM NUMBER	RESULT
Pretest B	1%	2-7	+.5
		2-8	+.5
		2-7+...+11	+.3
	1%	2-7+...+11	+.3
		5-8B	+.7
	5%	5-7+8+9	+.2
	10%	2-5	+.7
		2-1+...+6	+.2
		4-9	+.4
		4-7+...+11	+.2
		4-1+...11	+.2
		5-2	+.5
		5-8A	+.4
Pretest C	1%	4-7+...+11	+.3
		4-1+...+11	+.2
	5%	2-5	+.4
		2-7+...+11	+.2
		2-1+...+11	+.2
		4-8	+.3
		3-6	+.8
		5-7A	+.4
	10%	2-8	+.2
		2-9	+.2
		4-2	+.4
		4-1+...+6	+.2
		4-7	+.3
		4-11	+.2
		5-5	+.5
		5-1+...+5	+.2

TABLE III--INTERACTION RESULTS

These results were obtained by fitting models containing the effects of teaching method, a_i, and the interaction of a_i and teaching method to the 64 categories. Only results at the 10% level of significance are reported.

a_i	INTERACTION	NUMBER OF MAJORITY INDICATIONS	NUMBER OF MINORITY INDICATIONS
Pretest C	Low or High C → STT >L	6	2
Pretests B& C	Low B x C → STT > L	5	2
Pretests A&C	High A x C → STT > L	3	1
Topic	Presented Topic → L > STT	3	0
School History	Transfer Student → L > STT	7	3
Sex	Female → L > STT	4	1
Major	Phys. or Chem. → STT > L	5	1
Previous GPA	High GPA →L > STT	8	2
Previous GPA	Low GPA → STT > L	9	3
Volunteer for more STT	No Response → STT > L	4	2

ABBREVIATIONS: L = Lecture, STT= Student Team Teaching

CONCLUSIONS

The primary conclusion of this report must be that student team teaching, as it was used in this project, is quite inferior to the lecture method. The main reason for this conclusion is the students' personal feeling about the method. Their rejection of student team teaching is evidenced by: (1) the response to the questionnaire of Appendix F which is reported in Appendix H, (2) the low percentage, 5, of students who volunteered to work in another student team teaching class after they had completed the experiment, and perhaps less reliably but more dramatically, (3) the indication of the interaction analysis, reported in Table III, that the students who said no to the volunteer option by refusing to return the questionnaire actually scored higher on the hour examinations when they were involved in student team teaching. The secondary, but quite persuasive, reason for favoring the lecture method is that the student team teaching technique, as used and evaluated in this project, is less effective than the lecture method. This is evidenced by the results listed in Table I.

The results of this project differ quite markedly from those reported by Folk and Wall; this difference may be due to a variety of effects. They report in the December, 1970 issue of the American Journal of Physics that their junior, senior, and graduate students prefer student team teaching. Although they did not have any control sections, it appears that they had much better response than was obtained in this project. Upper division students may perform better than sophomores when using an innovative method. Physics majors may respond better than engineers to this treatment; in fact, this is suggested by the interaction results of Table III. Perhaps most important was the difference in the length of the students' presentations. Folk and Wall had small classes and let each student have an entire class period; in this project students were limited to 15 or 20 minutes in order to increase the number of students who actually presented topics. Although no measurements were taken, it was observed that the students had difficulty following the train of thought when three or four people presented information in one class period. The topics were well prepared and most were presented in an organized and audible manner; but the listeners still had difficulty in quickly adjusting to different styles. Finally, many of the students objected to performance of any type of experiment. One conclusion of this report is that any innovative teaching method should be discussed with and accepted by the students before it is implemented.

APPENDIX A--PRETESTS

The three pretests reproduced below were given at the beginning of the experiment to all involved students. Pretest A was intended to test the manipulation of mathematics. Pretest B was intended to test the formulation of mathematics. Pretest C was intended to test the association of physical quantities. Times of 25, 9, and 7 minutes were allowed for pretests A, B, and C respectively.

<u>Pretest A</u>.

1. Given: $x^2 + a = b$
   Find: x

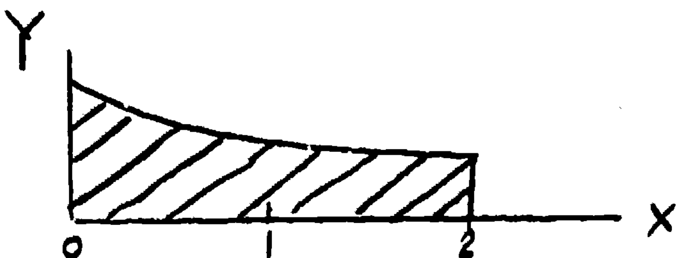
2. Given: $\sin^2 (ax) + 2 \sin (ax) - 3 = 0$, a is a real number
   Find: $\sin (ax)$

3. Given: $y = e^{-x}$

   Find: Area of shaded region (which extends from $x = 0$ to $x + \infty$)

4. Given: $y = 1/(x+a)^2$
   Find: $\int_{x=0}^{x\to\infty} y\,dx$

5. Given: $y = 1/(x+1)$



   Find: Volume of solid formed by rotating shaded area 360° about the X axis

6. Given: $\log_4 2 = a$
   $(2)^4 = 16$
   Find: $\log 16$

7. Given: $y = A(x^B + C)^{10}$
   Find: dy/dx

8. Given: $dV = r^2 \sin (\theta)\, dr\, d\theta\, d\phi$
   Find: $\int_{r=0}^{r=R} \int_{\theta=0}^{\theta=\pi} \int_{\phi=0}^{\phi=2\pi} r\,dV$

9. Given: $y = x^4 - (4/3)\, x^3$
   Find: Finite value (or values) of x that makes y either a <u>maximum</u> or <u>minimum</u>

10. Given: $y = ax + 2bx^3$
    Find: $\int_{x=-1}^{x=+1} y\,dx$

11. Given: $x + 5y = 4$
$7x - 3y = -10$
Find: x

12. Given: $y = x\ e^{(x/a)^2}$
Find: $\int y dx$

13. Given: $y = 1/x$
Find: $y dx$

14. Given: $y = \tan x$ (You <u>may</u> use $\tan x = \frac{\sin x}{\cos x}$)
Find: dy/dx

15. Given: $y = (x^4/4) - 2x^2$
Find: Finite value (or values of x that make y a <u>maximum</u>)

<u>Pretest B</u>.

1. The altitude of a rectangle is h units long. The base is three units longer than the altitude. Write an algebraic expression which represents the area of the rectangle.

(1) (h^2+h^3) (2) $(2h+h^3)$ (3) $(2h+3)$ (4) $(2+3h^2)$ (5) (h^2+3h)

2. The larger of two weights is four pounds less than twice the smaller. How heavy is the larger weight if the smaller weighs x pounds?

(1) $(2x+4)$ (2) $(\frac{x}{2}+4)$ (3) $(x-4)2$ (4) $(x-4)$ (5) $(2x-4)$

3. Because of its weight the atmosphere exerts a force at sea level of approximately 15 pounds for each square inch. What is the total force on the lid of a box x inches long and y inches wide?

(1) $\frac{xy}{15}$ (2) $\frac{15}{xy}$ (3) $\frac{x^2y^2}{15}$ (4) $15xy$ (5) $(15xy)$

4. A submarine, propelled by Diesel and electric motors crosses a larger body of water. The Diesel motors drive the craft y miles and the electric the remainder of the distance. If the electric motors operate 500 miles less than the Diesels, how wide is the body of water?

(1) $(500y+y^2)$ (2) $(2y+500)$ (3) $(2y-500)$ (4) (y^2+500) (5) $(y+500y)$

5. The drag of a sliding object is defined as its time rate of change of momentum per unit velocity. Letting D represent the drag of the sliding object, M its time rate of change of momentum and V its velocity, express the above relationship in equation form.

(1) $D = \frac{M}{V}$ (2) $D = \frac{V}{M}$ (3) $V = DM$ (4) $V = \frac{D}{M}$ (5) $D = MV$

6. Three times the volume occupied by a gas molecule ($1/N_v$) is equal to the ratio of the product of the mass m of a molecule and the square of its mean velocity V to the gas pressure P. Express this as a formula.

(1) $3/N_v = VP$ (2) $3/N_v = \frac{mP^2}{V}$ (3) $3/N_v = \frac{mV^2}{P}$ (4) $V = \frac{3/N_v}{P^2}$ (5) $3/N_v = mV^2P$

7. The force P exerted upon a large piston is as many times the force p applied to a small piston as the area of the cross-section of the large piston A is times that of the small piston a. Express this statement in a formula.

(1) $PA = pa$ (2) $pP = Aa$ (3) $\frac{P}{p} = \frac{a}{A}$ (4) $\frac{P}{p} = \frac{A}{a}$ (5) $P = \frac{a}{A} P$

8. The ratio of resistance as a function of pressure (R) to resistance at zero pressure (R_o) increases exponentially with the product of a positive constant (C) and the pressure (P). Which formula could possibly apply?

(1) $\frac{R}{R_o} = CP$ (2) $\frac{R}{R_o} = e^C e^P$ (3) $\frac{R}{R_o} = e^{CP}$ (4) $\frac{R}{R_o} = eCP$ (5) $\frac{R}{R_o} = e^{-CP}$

9. How many kilowatt-hours of energy can be bough for D dollars if each kilowatt-hours costs c cents?

(1) 100 Dc (2) $\frac{100D}{c}$ (3) $\frac{D}{100c}$ (4) $\frac{D}{c}$ (5) $\frac{c}{D}$

Pretest C.

IF YOU WANT TO ESTIMATE A WITHOUT ACTUALLY OBSERVING IT, YOU WOULD MOST WANT TO KNOW B.

1. A is the temperature in Moscow, Idaho on a windless day. B is:
(a) humidity in Moscow, Idaho
(b) barometric pressure in Moscow, Idaho
(c) temperature 1000 ft. above Moscow, Idaho
(d) temperature in San Francisco, California

2. A is the height of waves on a rectangular lake. B is the velocity of the wind and the:
(a) barometric pressure
(b) length of the lake
(c) width of the lake
(d) distance across the lake in direction of the wind

3. A is the probability that a glass top coffee table will break when a croquet ball is dropped on it. B is:
(a) the mass of the ball
(b) the speed of the ball just before it hits
(c) the momentum of the ball just before it hits
(d) the kinetic energy of the ball just before it hits

4. A is the fraction of the total volume of a submarine that is above the water. (The submarine has all hatches closed and it is floating freely.) B is the density of the water and the:
(a) mass of the submarine
(b) average density of the submarine
(c) density of the most dense part of the submarine
(d) density of the underwater part of the submarine

5. A is the time a frisbee takes to stop spinning after it is thrown into a waveless, currentless lake. B is a measure of the frictional drag of the water, the frisbee's moment of inertia, and the frisbee's:
(a) angular velocity as it left the thrower's hand
(b) kinetic energy as it left the thrower's hand
(c) kinetic energy as it hit the water
(d) linear velocity as it hit the water

6. A is the weight that the rear tire of a very long but very light non-symmetrical bicycle must support when it is ridden by an average sized 16 year old boy. B is:
(a) the exact weight of the boy
(b) the maximum force the boy exerts on the pedals
(c) the average force the boy exerts on the pedals
(d) the ratio of the distances from the rear axle to the boy and from the rear axle to the front axle

7. A is the increase in probability that a hiker will slip on the snow when he puts on a back pack. B is:
(a) the weight of the pack
(b) the ratio of the weight of the pack to the weight of the hiker
(c) the vector distance from the normal center of mass of the hiker to the center of mass of the pack
(d) the vector distance from the normal center of mass of the hiker to the center of mass of the hiker plus the pack

APPENDIX B--INFORMATION FORMS

The two information forms reproduced below were distributed to all involved students at the beginning of the course. Information from the forms was used to schedule meeting times for the student team teaching conferences and to analyze the results of the experiment.

Form D.

NAME:______________________________ CLASS:____________ MAJOR:__________

AGE:________ MINOR:_________________

Complete the following table with course numbers. If you are in Math 200, indicate section A or B.

TIME	MONDAY	TUESDAY	WEDNESDAY	THRUSDAY	FRIDAY
8:00 a.m.					
9:00 a.m.					
10:00 a.m.					
11:00 a.m.					
1:00 p.m.					
2:00 p.m.					
3:00 p.m.					
4:00 p.m.					
5:00 p.m.					
7:00 p.m.					
8:00 p.m.					

If you work, commute, etc., indicate times.

Form E.

NAME________________________________

Section: A ________
B ________

This course is a: Requirement______
Elective ______

U of I Courses Completed

MATH		PHYSICS		ELEC. ENG.	
Course #	Grade	Course #	Grade	Course #	Grade

(If you are a transfer student, fill out the above table with course names.)

APPENDIX C--COURSE TOPICS

The topics listed below were the ones considered in the course. Topics in Section I were presented in lectures before the start of the experiment. Topics in Sections II and IV were presented by the student team teaching technique in phase one of the electricity and magnetism portions respectively. Topics in Sections III and V were presented by short lectures, interspersed with student team teaching presentation of related problems, in phase two of the electricity and magnetism portions respectively. All symbols used are defined in PHYSICS by Halliday and Resnick; this standard text was used in the experiment because it is the most widely used introductory physics text.

I. Background
   A. Description of Course and Experiment
   B. Nature of Charge, Current, and Single Loop Circuits
   C. Kirchoff's Laws
   D. Current Density, Continuity, and Examples

II. Electricity - Phase One
   A. Coulomb's Law and "Sizes" of Forces
   B. Electric Field
   C. Calculation of $\vec{E}$ (a)
   D. Calculation of $\vec{E}$ (b)
   E. Point charge in Electric Field
   F. Dipole in Electric Field
   G. Electric Field Flux
   H. Gauss' Law, Gauss' Law → Coulomb, Gauss' Law → $Q = 0$ Inside a Conductor
   I. Coulomb's Law → Gauss' Law
   J. Experiment Proof of Gauss' Law and σ on a Conductor
   K. Line Charge and Sheet Charge
   L. Spherical Charge Distribution

III. Electricity - Phase Two
   A. V and Constant V Situations
   B. $dV = -\vec{E} \cdot d\vec{\ell}$
   C. $dV = (1/4\pi\varepsilon_o \; dz/r)$
   D. V for Dipole and a Special Quadrupole
   E. $W = V q_2 = q_1 q_2 / 4\pi\varepsilon_o r_{12}$
   F. $E = -dV/d\ell$
   G. $C \equiv Q/V = f_{(\varepsilon + \text{geometry})}$
   H. Parallel Plate and Cylindrical Capacitors
   I. Series and Parallel Capacitors
   J. $K = \varepsilon/\varepsilon_o$
   K. $W = (1/2)\, QV$ and $u = dW/dvol = (1/2)\, K\varepsilon_o E^2$
   L. Force and Energy
   M. Rewrite Gauss' Law
   N. 3 Electric Vectors: $\vec{D}$, $\vec{E}$, and $\vec{P}$

IV. Magnetism - Phase One

A. Existence of the $\vec{B}$ Field
B. Definition of $\vec{B}$
C. $dF = i\, d\ell \times \vec{B}$
D. Torque on Current Loop
E. Circulating Charge
F. Ampere's Law
G. $\vec{B}$ Near a Long Wire
H. Use of Ampere's Law
I. Biot-Savart Law
J. Toroid and Solenoid

V. Magnetism - Phase Two

A. Faraday's Law and Lenz' Law
B. Examples of Faraday's Laws
C. Time Varying $\vec{B}$ Fields
D. Inductance
E. $E = (1/2)\, Li^2$ and $u = (1/2)\, (1/\mu_o) B^2$
F. Magnetic Dipoles
G. Paramagnetism
H. Diamagnetism
I. Ferromagnetism
J. Three Magnetic Vectors: $\vec{B}$, $\vec{H}$, and $\vec{M}$

APPENDIX D--COURSE PROBLEMS

The problems listed below were considered in the course. The Roman numbers designate the section of the course; I refers to the preliminary section. II and IV refer to phase one of the electricity and magnetism sections repsectively, and III and V refer to phase two of the electricity and magnetism sections respectively. The number before the dash identifies the chapter in PHYSICS by Halliday and Resnick; the number after the dash identifies the problem in that chapter.

I.	II.	III.
26-1	26-3	29-10
26-16	26-4	29-18
31-1	27-5	29-19
31-12	27-15	29-27
31-16	27-25	29-33
31-24	28-3	30-3
	28-4	30-7
	28-9	30-8
	28-14	30-14
	28-20	30-24
		30-25
		30-26
		30-28

IV.	V.
33-3	35-5
33-11	35-9
33-15	35-15
33-25	35-16
34-4	36-2
34-6	36-4
34-18	36-20
34-23	37-1
	37-3
	37-5
	37-12
	37-13
	37-14

APPENDIX E--TESTS

The seven tests reproduced below were given to the class and used for grading purposes. Test 1 was given before any student teaching was done. Test 2 and test 4 were given at the end of phase one of the student team teaching experiment. Test 3 and test 5 were given at the end of phase two of the student team teaching experiment. These first five tests were given to the entire class. There are two final tests because the two sections of the class could not be scheduled for a common final.

Test 1.

Physics 221

Put name on back of test. Include your section also.

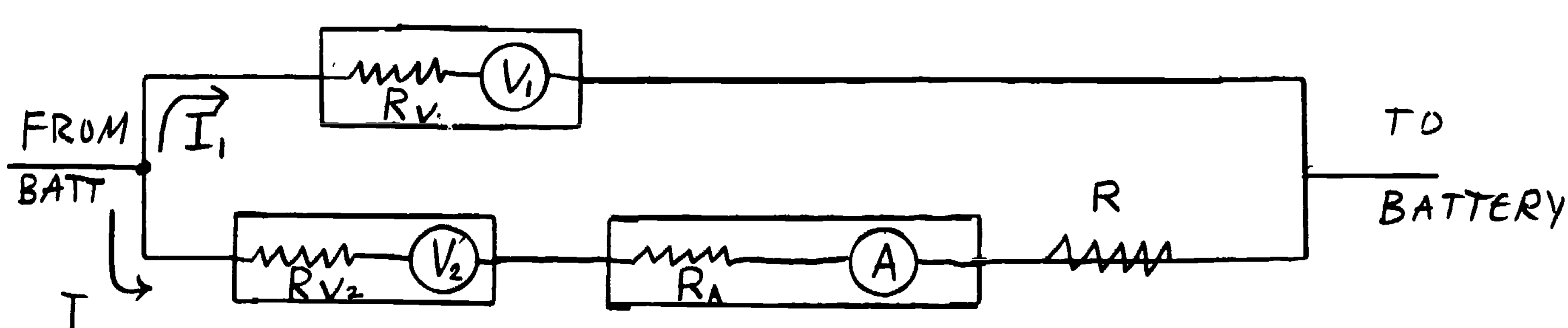
Points: 1. /18, 2. /14, 3. /17, 4. /17, 5. /17, 6. /17

1. (a) Why is electric current defined as dq/dt instead of q/t?
   (b) What charge, Δq, is involved in the definition of "electromotive force?
   (c) What is Ohm's law?
   (d) Kirchoff's _______ law and the continuity equation both are statements of the conservation of ________.
   (e) Kirchoff's other law is a statement of the conservation of __________.
   (f) What charge, Δq, is involved in the definition of charge density, ρ?

2. If an ammeter reads 20 amp, how much time is required for 5 electrons to go past the ammeter terminal post? ($e = 1.6\ (10)^{-19}$ coul/electron)

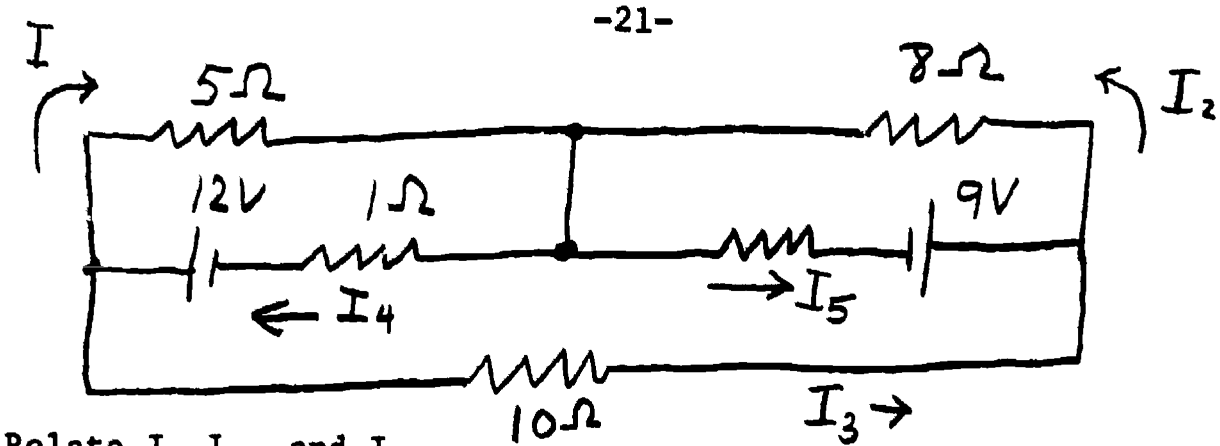
3. In a certain α-particle plasma, each positive charged particle has a charge of $3.2\ (10)^{-19}$ coul, a mass of $6.68\ (10)^{-27}$kg, and a constant drift velocity of 3.1 m/sec. Assume the current density, 600 amp/m^2, is constant. Find both densities (the number per unit volume and the mass per unit volume) of the plasma.

4. Given the meter resistances, R_{V1}, R_{V2}, and R_A, and the meter readings V_1, V_2, and I_2, find R.



(Yes, electrical engineers, no one in their right mind would measure R this way!)

5.

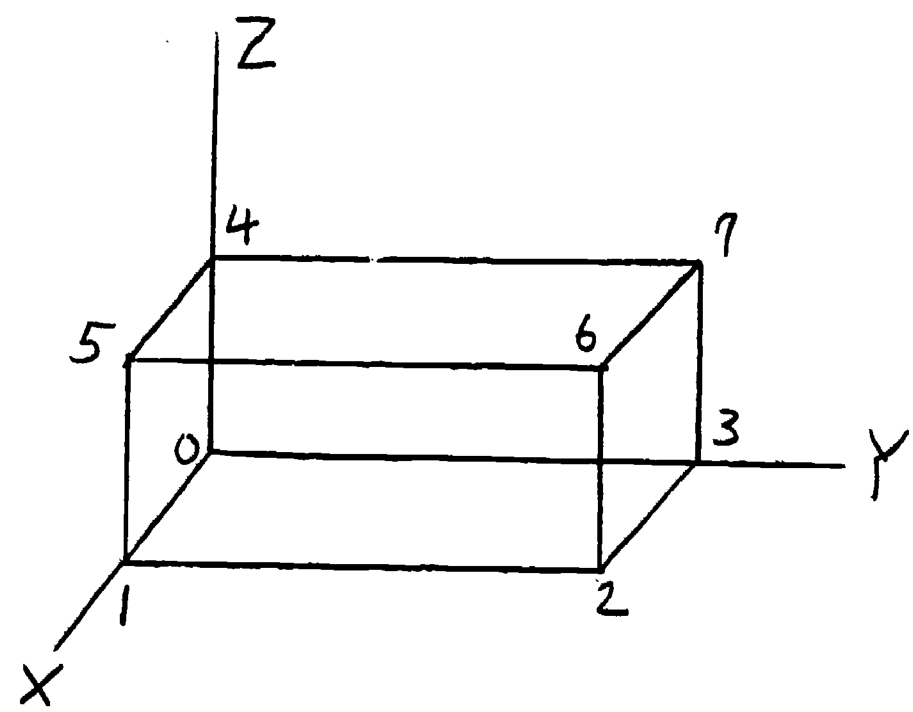


(a) Relate I, I_3, and I_4.
(b) Relate I_2, I_3, and I_5.
(c) Use Kirchoff's second law to write down enough equations (but not more) to use the two relationships from (a) and (b) and find all five currents. (Do not do the arithmetic.)

6. The coordinates of point 6 are (X_m, Y_m, Z_m).
$\vec{J}$ is always parallel to Z axis and is always directed upward.
$J_{(x,y,z)}$ is not constant

$J_{(x,y,0)}$ is constant

$J_{(x,y,Z_m)}$ is constant



(a) Find I going out of box through
(b) Find I going out of box through
(c) Find I going out of box through
(d) Find I going out of box through
(e) Find I going out of box through
(f) Find I going out of box through
(g) Find $\int_0^{Z_m}\int_0^{Y_m}\int_0^{X_m} \frac{\partial \rho}{\partial t}\, dx\, dy\, dz$

Note: In the above problem, put J on the left of $\iint$ if possible.

Test 2.

PLEASE PUT YOUR NAME AND SECTION ON BACK.

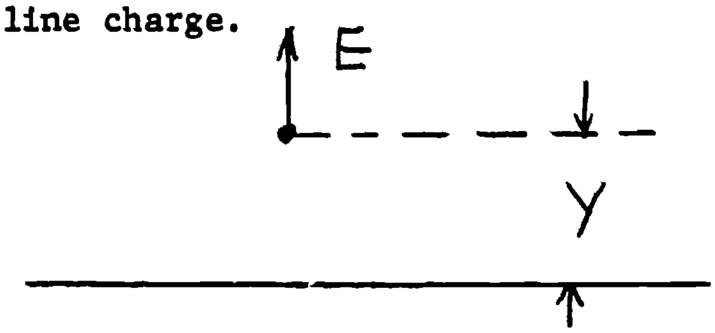
POINTS: M.C. /18, 7. /14, 8. /17, 9. /17, 10. /17, 11. /17

Information that may be useful:

$\int d\theta = \theta$
$\int \sin\theta\, d\theta = -\cos\theta$
$\int \cos\theta\, d\theta = \sin\theta$
$\int \sin\theta \cos\theta\, d\theta = 1/2 \sin^2\theta$

$\sin^2\theta\, d\theta = (1/2)\theta - 1/4 \sin 2\theta$
$\cos^2\theta\, d\theta = (1/2)\theta + 1/4 \sin 2\theta$
$\frac{1}{4\pi\varepsilon_0} = 9\,(10)^9$ (MKS UNITS)
$e = -1.6\,(10)^{-19}$ coul/electron

1. Concerning the problem of finding the electric field at a point a distance y from the midpoint of a finite line charge.



(a) The charge per unit length MUST be constant in order to conclude that E is perpendicular to the line charge.
(b) There is enough symmetry to USE Gauss' law.
(c) The result MUST approach $\lambda/2\pi\varepsilon_0 y$ as y approaches 0.
(d) None of the above.

2. Concerning Gauss' law,
(a) the Gaussian surface must be symmetrical for the law to be valid.
(b) the electric field at points on the Gaussian surface is physically produced by the charges inside the surface.
(c) if the Gaussian surface contains no charge, the electric field at all points on the Gaussian surface must be zero.
(d) None of the above.

3. Concerning an electric dipole,
(a) in a uniform electric field, the dipole is forced in the direction of the field.
(b) there is no torque on a dipole whose vector p is perpendicular to the electric field.
(c) there is no net force on a dipole in a uniform electric field regardless of its orientation.
(d) none of the above.

4. The electric field is defined as $d\vec{F}/dq_0$ instead of $\vec{F}/q_0$ because
(a) an instantaneous rather than an average value is desired.
(b) an exact rather than an average value is desired.
(c) the ratio of the changes of $\vec{F}$ and q_0 rather than the ratio of $\vec{F}$ and q is desired.
(d) the charge q_0 should be as small as possible to avoid disturbing the field producing charges.

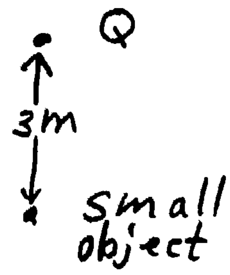
5.(a) The acceleration of a charge particle in an electric field is independent of the particle's velocity and dependent on the particle's charge to mass ratio.
(b) To a real metal, the time required for charges to reach the surface is entirely too long to use Gauss' law results based on E being zero inside the metal.
(c) An experimental proof that all of the charge from a metal ball is transferred to the outside of a closed can (when the ball touches the inside of the can) proves Gauss' law but does NOT prove Coulomb's law.
(d) None of the above are true.

6.(a) We normally don't "feel" electrical forces because electrical interactions are much smaller than gravitational interactions.
(b) Coulomb's law is a proportionality relation and the proportionality constant, $1/4\pi\varepsilon$, characterizes the medium in which the charges are placed.

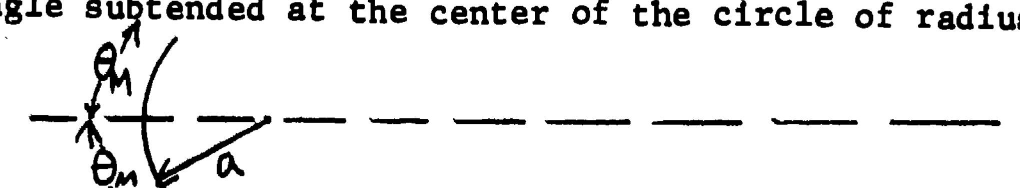
(c) The $\Sigma\vec{E}\cdot\vec{\Delta S}$ must be written as $\oint\!\!\oint \vec{E}\cdot\vec{dS}$ to have Guass' law stated as an equality rather than an approximation because $\vec{\Delta S}$ must shrink to zero in order to obtain a closed surface.
(d) All of the above are true.

7. Consider two metal spherical shells of equal radii (1 meter) whose centers are 4 meters apart. If the charge on one is 4 $(10)^{-9}$ coul and the other's charge is 16 $(10)^{-9}$ coul, what is the magnitude of the electric field at the midpoint of the line connecting the two centers?

8. A small object carrying a charge of -5 $(10)^{-9}$ coul experiences a downward force of 20 $(10)^{-9}$nt when placed 3m below a point charge Q.
(a) What is the electric field at the location of the small object? (State direction and magnitude.)
(b) What is Q? (State sign and magnitude.)
NOTE: (b) can be done independently of (a).
(c) If the small object is removed and replaced by an electron, what will be the force (magnitude and direction) on the electron?

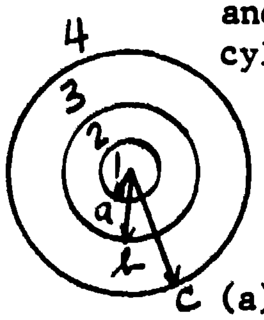


9. Consider a positive charge Q which is distributed with a constant charge per unit length on a line forming part of a circle. Let 2 θ_M be the angle subtended at the center of the circle of radius a.



(a) What is the charge per unit length? (Remember θ = (arc length/radius)
(b) What is the direction of $\vec{E}$ at the circle center?
(c) What is the magnitude of $\vec{E}$ at the circle center?
(d) What does E approach as 2 θ_M approaches 2π radians = 360°?
NOTE: (d) can be done independently of (c).

10. A long (infinite) coaxial cable consists of an inner cylindrical conductor of radius a and an outer coaxial cylinder of inner radius b and outer radius c. The outer cylinder has no net charge. The inner cylinder has a uniform positive charge per unit length λ.

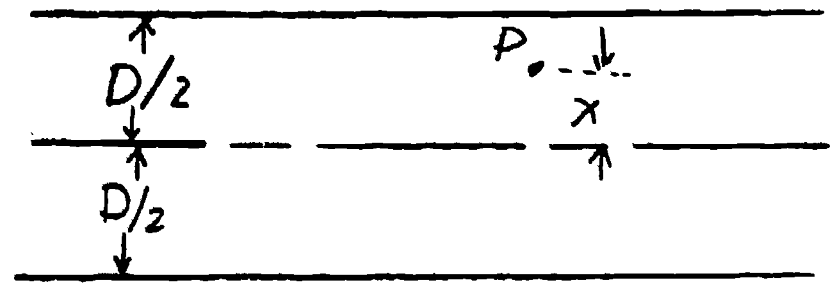


Region 1 & 3: Metal
Region 2 & 4: Vacuum

(a) What is the magnitude of E_1, E_2, E_3, and E_4 as a function of r?
(b) What is the charge per unit length on the surface at radius b?
(c) What is the charge per unit length on the surface at radius c?

11. Consider a charge distribution bounded by two parallel infinite planes separated by a distance D. (This is not a metal.) The charge per unit volume between these two planes, ρ, is a positive constant. (There is no charge in the space which is not between the two planes.) Consider a point P which is a distance x from the midplane of the

charge distribution where $x < D/2$.



(a) What is the direction of the electric field at P?
(b) What is the magnitude of the electric field at P?

Test 3.

PLEASE PUT YOUR NAME AND SECTION ON THE BACK.

M.C. /20, 6. /16, 7. /16, 8. /16, 9. /16, 1 /16

1. When a dielectric is inserted between the plates of a capacitor (which is connected to a constant voltage supply)
(a) the capacitance decreases
(b) the energy stored in the electric field (between the plates) decreases
(c) the free charge on the positive plate decreases
(d) None of the above are true

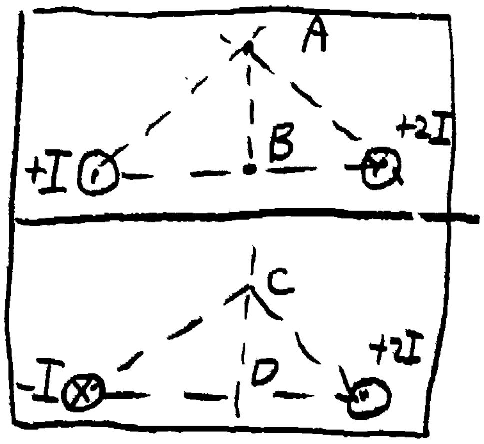
2. The dielectric constant of any dielectric (considering vacuum not to be a dielectric)
(a) is positive (in MKS units)
(b) is dimensionless (in MKS units)
(c) is greater than one (in MKS units)
(d) all of the above are true

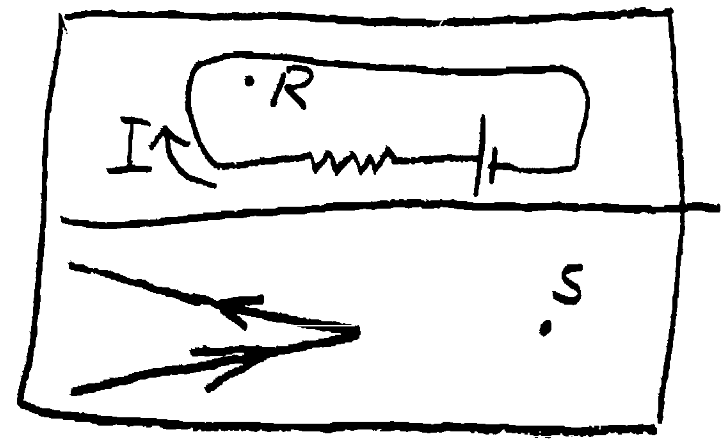
3. Two equipotential surfaces (with $V_1 \neq V_2$) never intersect because
(a) the electric field lines lie in the equipotential surfaces
(b) a perpetual motion machine could be constructed using two such surfaces
(c) both of the above are true
(d) none of the above are true because they can intersect

4. The three electric vectors, $\vec{E}$, $\vec{P}$, & $\vec{D}$ (electric field, electric polarization, & electric displacement)
(a) are independent of each other
(b) are all needed to describe the electrical properties of vacuum
(c) both of the above are true
(d) none of the above are true

5. If you are told the electrostatic potential at a point, you should be able to find
(a) the electric field at that point
(b) the potential energy that a charge of $-1.6(10)^{-19}$ coul would have at that point
(c) both of the above are true
(d) none of the above are true

6. At points A, B, C, D, R, S, & T in the three separate charge distributions below, use an arrow to indicate the direction of the electric field and a + or - sign to indicate the sign of the electrostatic potential. (Use $\vec{0}$ to indicate zero electric field and 0 to indicate zero potential.) (Use ⊙ and ⊗ to indicate fields out of and into the paper respectively.)

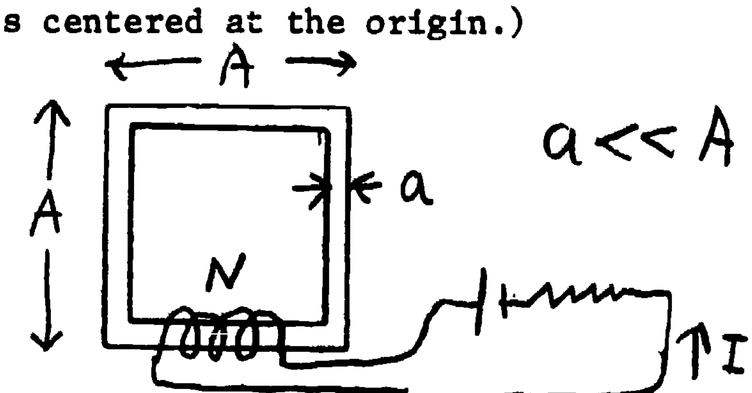




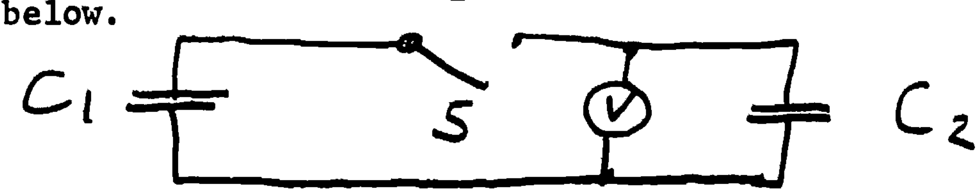
7. The electric field at all points on the positive X axis is pointed in the positive X direction and the potential is $V = A/x^3$ where x is the normal distance along the X axis from the origin and $A = 16$ volt-meter^3.
(a) What is the magnitude of the electric field at $x = 2$ meters?
(b) What is the work necessary to move a test charge of $(10)^{-9}$ coul from $x = 2$m to $x = 1$m? NOTE: (b) can be done independently of (a).

8. A positive charge q is located at the origin and a positive charge Q is uniformly distributed on 1/4 of a circle between the positive Y and Z axes. (The circle has radius R and is centered at the origin.)
(a) How much energy could be obtained by removing the charge q to infinity?
(b) What is the potential at point P? NOTE: (b) can be done independently of (a).

Q is linearly distributed



9. Two capacitors, $C_1 = (10)^{-6}$f and $C_2 = 3(10)^{-6}$f, are initially charged such that $Q_1 = 1200(10)^{-6}$ coul and $Q_2 = 3600(10)^{-6}$ coul. They are connected as shown below.



(a) What will the voltmeter reading be after switch S is closed?
(b) When the switch S is closed, how much energy will leave C?

10. Two parallel metal plates, each with area A, are separated by a distance d. (d << A so the infinite plate assumption is good.) The dielectric between the plates is a partially "settled out solution" so the dielectric "constant" is not constant but is

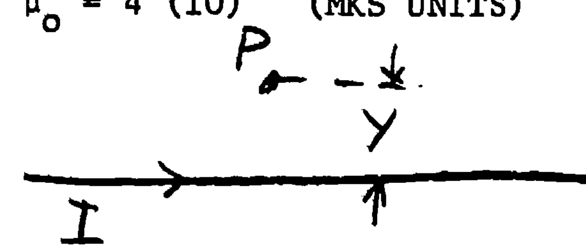
$K = K_o(1 + bx)$ where K_o and b are constants and x is the distance from the plate with +0.
(a) Starting with $D \cdot ds = q_{in}$ (FREE), the assumption that $D = K\,_oE$, and a Guassian surface that you draw, find the capacitance C. NOTE: You can get a little credit by just indicating the order in which things must be calculated.
(b) Is most of the "electric field energy" stored in he half of the dielectric next to the positive plate or the half next to the negative plate? Why?

Test 4.

PLEASE PUT YOUR NAME AND SECTION ON BACK.

POINTS: M.C. /18, 7. /14, 8. /17, 9. /17, 10. /17, 11. /17

General Information: $e = 1.6(10)^{-19}$ coul/electron, $\mu_o = 4\ (10)^{-7}$ (MKS UNITS)



1. Consider the problem of finding $\vec{B}$ field at a point a distance y from the midpoint of a finite wire carrying current I:
(a) This is easily solved using Ampere's law.
(b) Ampere's law is not usable because there is not enough symmetry to find the direction of B due to I in the straight wire shown
(c) Ampere's law is not usable because a current source must be connected to the two ends of the wire shown and this ruins the symmetry.

2. Concerning Ampere's law,
(a) the Amperian line must be symmetrical for the law to be valid
(b) the magnetic flux density at points on the Amperian line is physically produced by the currents which pass through the area bounded by the line
(c) if the Amperian line encloses no current, the magnetic flux density at all point on the Amperian line must be zero
(d) none of the above are true

3. Concerning a magnetic dipole:
(a) the equation $\vec{T} = \vec{\mu} x \vec{B}$ is valid only for a rectangular coil
(b) two physical magnetic poles are located at opposite ends of the dipole
(c) a dipole has one stable and one unstable equilibrium orientation in a uniform $\vec{B}$ field.
(d) none of the above are true

4. A small test charge with a small velocity should really be used in the operational definition of a $\vec{B}$ field because,
(a) an instantaneous rather than an average value is desired
(b) an exact rather than an average value is desired
(c) the source currents should not be disturbed
(d) none of the above are true

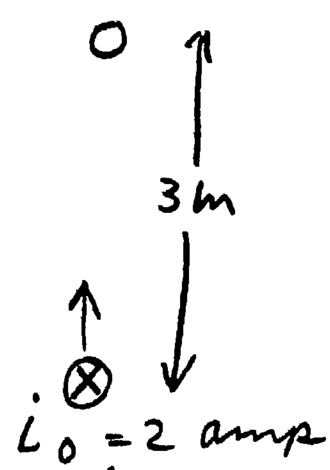
5. Concerning moving charged particles in a uniform constant $\vec{B}$ field (and assuming no $\vec{E}$ or gravitational field):
(a) they all move in circular paths
(b) none ever move in a straight line
(c) none ever gain energy from the $\vec{B}$ field
(d) all have zero acceleration

6. (a) Direct currents (DC) normally flow only on the surface of conductors.
(b) The $\Sigma\vec{B}\cdot\Delta\ell$ must be written as $\oint\vec{B}\cdot d\ell$ to have Ampere's law stated as an equality because $\Delta\ell$ must shrink to zero in order to form a continuous Amperian line.
(c) Magnetic forces and/or torques rarely occur in modern technical devices.
(d) None of the above are true.

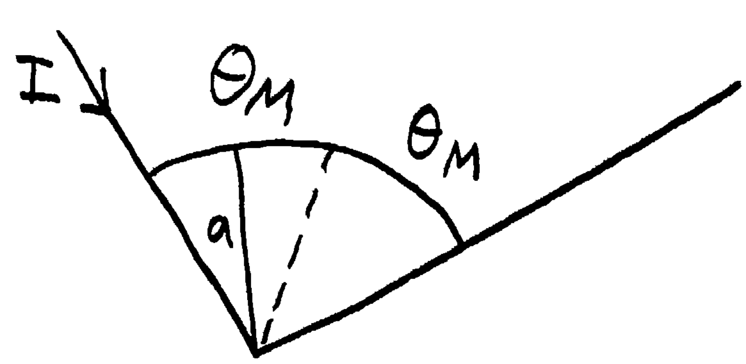
7. Consider two parallel copper wires of equal radii (1 meter) whose centers are 4 meters apart. If the current in one is 4 amperes toward you and the other's current is 16 amp away from you, what is the magnitude of the magnetic flux density on the line which is midway between the two centers?

8. Two parallel infinite wires are separated by 3 meters. The bottom one has a current of 2 amp into the plane of the paper and experiences an upward force per unit length of 12 $(10)^{-7}$ nt/m.
(a) What is the magnetic flux density at the location of the bottom wire? (State magnitude and direction.)
(b) What is the current in the top wire? (State magnitude and direction.)
(c) If the bottom wire is replaced by an electron moving with a velocity (out of the plane of the paper) of $(10)^5$ m/sec, what will be the force on the electron? (State magnitude and direction.)

$$\frac{F}{\ell} = 12\times10^{-7}\,\frac{nt}{m}$$

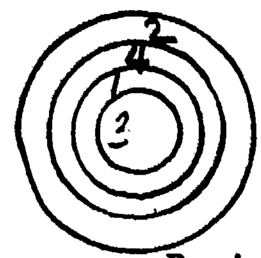


9. Consider a current I which comes in from infinity radially, goes around part of a circle of radius a, and goes back to infinity radially as shown below. Let 2 θ_M be the angle subtended at the center of the circle.
(a) What is the direction of $\vec{B}$ at the circle center?
(b) What is the magnitude of $\vec{B}$ at the circle center due to the two straight wires?
(c) What is the total magnitude of $\vec{B}$ at the circle center?
(d) What does $\vec{B}$ approach as 2 θ_M approaches 2π radians = 360°? (Let the straight wires stay perpendicular to the circle.)



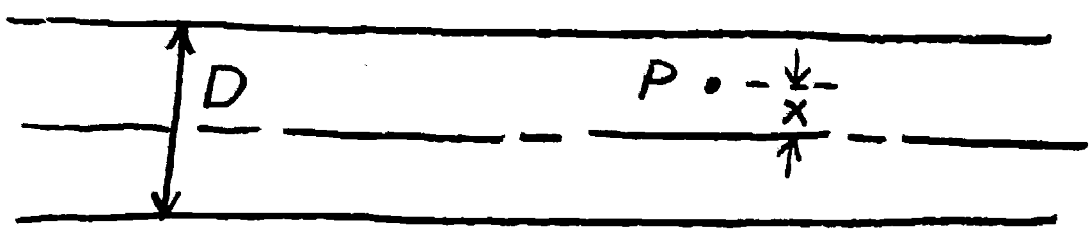
10. A strange long (infinite) coaxial cable consists of (1) an inner hollow cylinder of inner radius a and outer radius b and (2) a coaxial hollow cyliner of inner radius c and outer radius d. The inner piece, (1), carries a current I_1 toward you and the outer piece, (2), carries a current I_2 away from you. ($I_2 > I_1$)

(a) What is the magnitude of $\vec{B}$ as a function of r in regions 3, 1, 4, and 5 (omit 2)? Draw all Amperian lines that you need!
(b) At what radius, R, is $\vec{B} = 0$



Regions 1 & 2 are copper
Regions 3, 4, & 5 are vacuum

11. Consider a large flat strip of copper of thickness D which is carrying a current straight toward you (perpendicular to the paper). The current per unit area, J, is a constant. Consider a point P which is a distance x from plane in the middle of the copper strip. (Let x be less than D/2.)



(a) Draw an arrow to show the direction of the magnetic flux density at P. (Use ⊙ or ⊗ is $\vec{B}$ is straight out or straight into the plane of the paper.)
(b) What is the magnitude of $\vec{B}$ at P?

Test 5.

PLEASE PUT YOUR NAME AND SECTION ON THE BACK.

M.C. /20, 6. /16, 7. /16, 8. /16, 9. /16, 10. /16

1. If the current is increased in a solenoid shaped coil,
(a) the $\vec{B}$ field (magnetic flux density) at the solenoid center decreases
(b) the self inductance decreases
(c) the self inductance increases
(d) none of the above are true

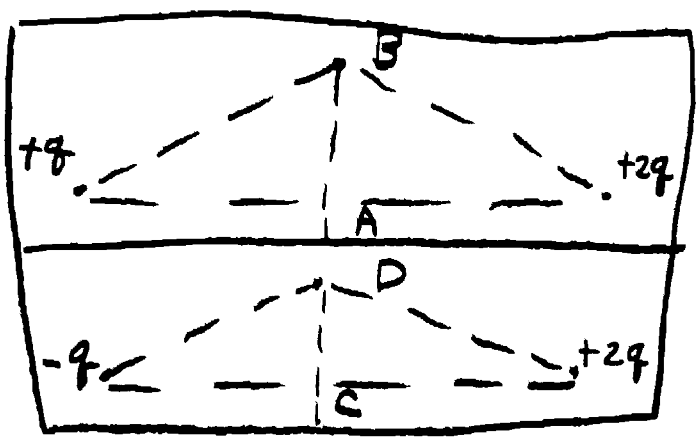
2. The relative magnetic permeability of any material
(a) is always negative (in MKS units)
(b) is always dimensionless (in MKS units)
(c) is always greater than one (in MKS units)
(d) all of the above are true

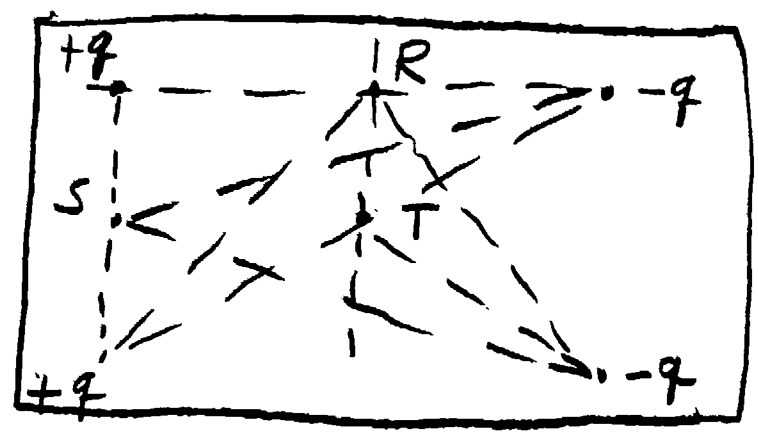
3. Two magnetic flux lines never intersect because
(a) a stationary charged particle at the intersection point could have either of two forces on it so causality would fail
(b) a moving charged particle at the intersection point could have either of two forces on it so causality would fail
(c) both of the above are true
(d) none of the above are true because they can intersect

4. The three magnetic vectors, $\vec{B}$, $\vec{M}$, & $\vec{H}$, (magnetic flux density, magnetization per unit volume, and magnetic intensity)
(a) are independent of each other
(b) are all needed to describe the magnetic properties of vacuum
(c) both of the above are true
(d) none of the above are true

5. If you are told a number (and a unit) for the magnetic flux through a single loop of wire (an are also told the number of amperes which are flowing in the loop and producing the magnetic flux), you should be able to find
(a) the induced emf in that loop
(b) the self inductance of that loop
(c) both of the above are true
(d) none of the above are true

6. At points A, B, C, D, R, & S in the 4 separate current distributions below, use an arrow to indicate the direction of the magnetic flux density. (Use 0 & ⊗ for directions out of & into the paper respectively.)





(b) At points T, U, V, W, X, Y, Z, & Z' in the two B field distributions below, use an arrow to indicate the direction of the force on infinitesimal lengths of the current carrying wires (or moving point charges) (Note: $\vec{B}$ is supplied by currents NOT shown and is constant.) (Use 0 & ⊗ for directions out of and into the paper respectively.) (Use 0 for zero.)

7. The magnetic flux through a loop of wire is $\phi_B = A/t^3$ where t is time and $A = 16$ weber-sec^3.
(a) What is the magnitude of the induced emf at $t = 2$ sec?
(b) What is the self inductance of this single loop at $t = 2$ sec (if $i = 4$ amp is the current in the loop producing ϕB at this time)?

8. (a) Consider a "square" toroid which is wrapped with N turns of a wire carrying a current I. The material inside the toroid has a relative permeability, k_m, which is not equal to one but is constant. Find $\vec{H}$ and $\vec{B}$ (omit directions).

(b) An iron magnet has a total dipole moment of 7.5 amp-meter^2. It is split into two pieces, each of which is a single domain, which have total dipole momenta of 10 amp-meter^2 and 2.5 amp-meter^2. Was the initial piece a single domain? Why or why not?

If the volume and number of alligned individual Fe dipoles in the 10 amp-meter^2 piece are $(10)^{-5}$ meter and $(10)^{24}$ respectively, what is the magnetization per unit volume, $\vec{M}$, of the 10 amp-meter^2 piece and what is the individual dipole moment, $\vec{\mu}$, of each Fe dipole in this 10 amp-meter^2 piece? (omit directions)

9. A special coaxial cable is made of vacuum and <u>two</u> concentric cylindrical metal shells. The inner one, of radius a, carries a current I straight toward you and the outer one returns this current I. Find the self inductance per unit length.

(a) From the definition of self inductance.

(b) From energy considerations.

10. At the center (or nearby) of each of the 5 separate wire loops below, place a O or a ⊗ to indicate the direction of the $\vec{B}$ field <u>produced by</u> the induced current. On each of the 5 wires, place an arrow to indicate the direction of the induced current.

(a) B is coming straight toward you and <u>decreasing</u>.

(b) B is coming straight toward you and <u>constant</u>. The <u>area</u> enclosed by the wire is being <u>decreased</u>.

(c) B is pointed away from you and <u>increasing</u>.

(d) B is pointed away from you and is <u>constant</u>. The wire loop is rotating about the axis toward a zero flux position (i.e. flux is decreasing).

(e) B is pointed away from you and is <u>constant</u>. The area is <u>increasing</u>.

<u>Final Test for Section A.</u>

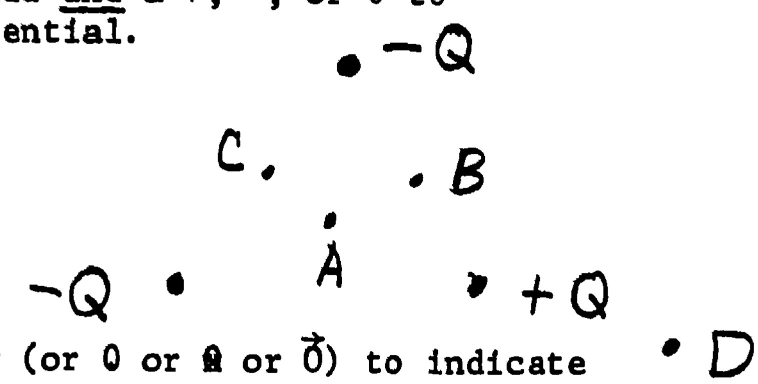
1. In each blank on the left, place <u>one</u> letter from the list on the right so that each quantity is matched with its MKS unit. (Letters <u>may</u> be repeated.)

____ p = electric dipole moment	(a) coul/m^2
____ E = electric field	(b) weber/amp-m
____ L = self inductance	(c) joule/m^3
____ σ = area charge density	(d) volt-meter
____ μ_o = permeability	(e) none
____ R = electrical resistance	(f) coul-meter
____ M = magnetization	(g) henry
____ k = dielectric constant	(h) amp/meter
____ u_E = electric energy per unit volume	(i) nt/coul
	(j) ohm

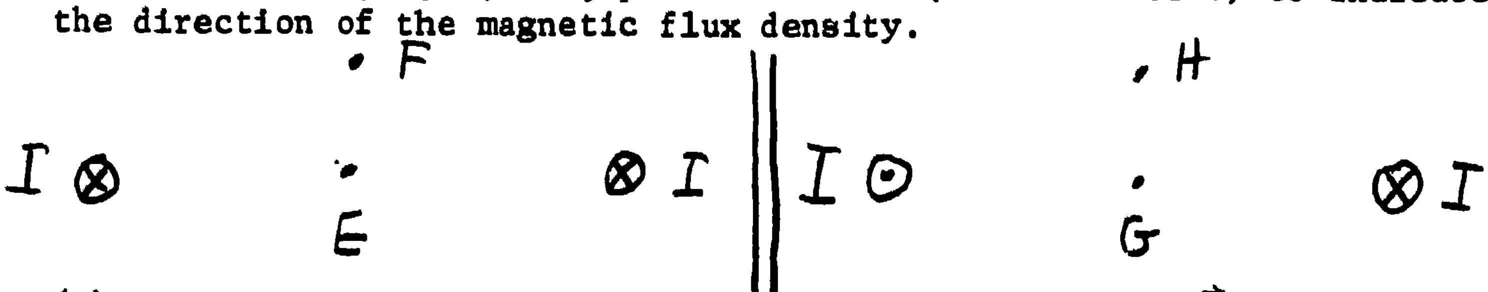
2. The magnetic flux through a single loop of wire is given by $\Phi_B = a\,t^5$ where a is a constant and t is the time.
(a) What is the magnitude of the induced EMF at time t = 2T?
(b) What is the self inductance of the loop at time t = T if the current flowing in the loop at this time is I?

3. The electrostatic potential in a region of space is given by $V(x) = a\,x^3$ where a is a constant and x is the distance from the origin along the x-axis.
(a) What electric field exists in this region?
(b) How much work would have to be done to move a particle of charge +Q from the point x = X to the point x = 3X?
(c) If a particle of charge +Q is released from rest at the point x = 3X, with what speed will it be moving when it reaches the origin?

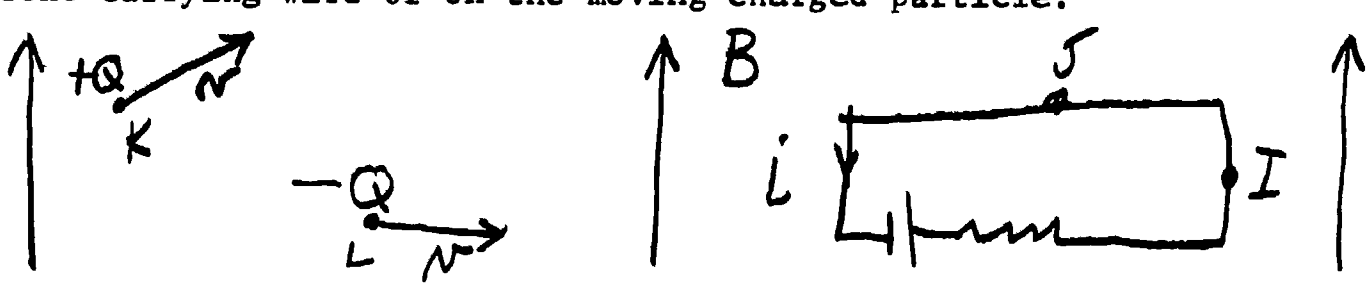
4. (a) At points A, B, C, & D, place an arrow (or 0 or ⊗ or $\vec{0}$) to indicate the direction of the electric field and a +, -, or 0 to indicate the sign of the electrostatic potential.



(b) At points E, F, G, & H, place an arrow (or 0 or ⊗ or $\vec{0}$) to indicate the direction of the magnetic flux density.



(c) At points I, J, K, & L, place an arrow (or 0 or ⊗ or $\vec{0}$) to indicate the direction of the magnetic force on the infinitesimal lengths of the current carrying wire or on the moving charged particle.

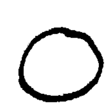


(d) On each of the four wire loops, place an arrow to indicate the direction of the induced current and place a 0 or ⊗ in the center of each loop to indicate the direction of the induced $\vec{B}$ field.

$\vec{B}$ is away from you and increasing.

$\vec{B}$ is toward you and decreasing.

$\vec{B}$ is constant away from you but the shape is being changed to a rectangle.

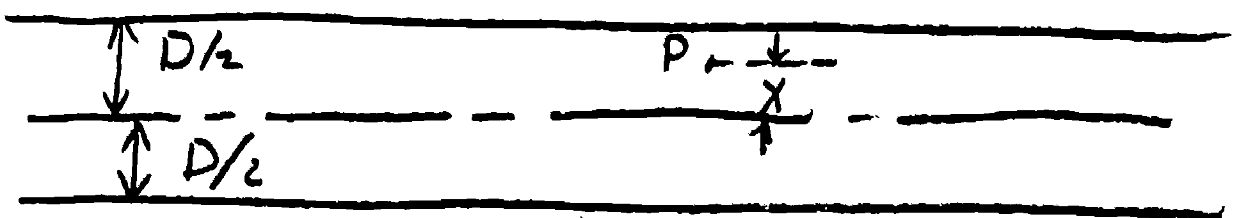


$\vec{B}$ is constant away from you but the shape is being changed to a circle.

5. A system consists of two infinite planes of charge separated by a distance D. The planes have equal, but opposite, charge densities of magnitude σ.
(a) Determine the electric potential function for this system. Be sure to clearly define your coordinate system, reference point, for potential, etc.
(b) A particle located outside the region between the planes and having charge +Q is projected toward the plane having charge density $-\sigma$. What is the minimum velocity which the particle can have if it is to pass through the two planes and emerge on the other side?

6. A system consists of two point charges lying on the x-axis. A charge -Q is at the origin and a charge +Q is at the point $x = +a$. What electric field is present at the point with coordinates (x, y)?

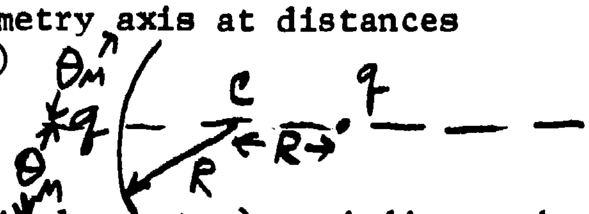
7. Consider a large flat strip of copper of thickness D which is carrying a current straight toward you (perpendicular to the paper). The current per unit area, $\vec{J}$, is a constant.



(a) Place an arrow (or 0 or ⊗ or $\vec{0}$) at P to indicate the direction of the magnetic flux density, $\vec{B}$, at that point.
(b) State your reasons for picking this direction.
(c) Find the magnitude of $\vec{B}$ at P. (Clearly indicate the reasons for setting any quantitites equal to zero.)

8. An infinite cylinder of a magnetic material (permeability k_m) has a radius R and a wire carrying a current I running along its axis.
(a) Determine the magnetic induction ($\vec{B}$) as a function of the distance r from the wire both inside and outside the cylinder.
(b) What induced current flows on the surface of the cylinder?

9. Consider a positive charge, Q, which is uniformly distributed on a circular arc which subtends an angle of $2\theta_m$ at the circle center. Let the circle radius be R. (The only other charges in the problem are two equal point charges, q, located on the symmetry axis at distances R to the left and right of the circle center.)



(a) Place an arrow or 0 or ⊗ or $\vec{0}$ at C (the circle center) to indicate the direction of the electric field, $\vec{E}$, at that point.
(b) State your reasons for picking this direction.
(c) Find the magnitude of $\vec{E}$ at C. (Clearly indicate the reasons for setting any quantitites equal to zero.)

10. A spherical hole of radius R is cut out of a very large block of dielectric material (dielectric constant K). A point charge of magnitude +Q is at the center of the spherical hole.
(a) Determine the electric field ($\vec{E}$) as a function of the distance from the point charge both inside and outside the sphere.
(b) What is the induced charge density on the surface of the spherical cavity?

Final Test for Section B.

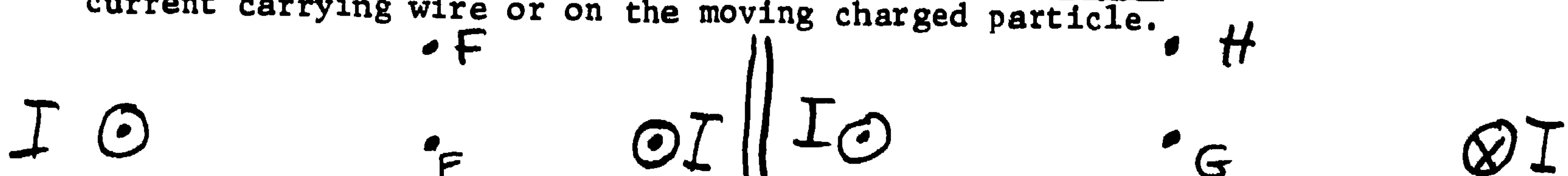
1. In each blank on the left place one letter from the list on the right so that each quantity is matched with its MKS unit (letters may be repeated).

____ μ = magnetic dipole moment	(a) amp/m^2
____ C = capacitance	(b) joule/m^3
____ B = magnetic flux density	(c) weber/m^3
____ μ_B = magnetic energy per unit volume	(d) none
____ P = polarization	(e) weber
____ ε_o = permitivity	(f) weber/m^2
____ ϕ_B = magnetic flux	(g) coul/m^2
____ J = area current density	(h) $coul^2$/nt-m^2
____ k_M = relative permeability	(i) farad
	(j) amp-m^2

2. The magnetic flux through a single loop of wire is given by $\phi_B = a\,t^3$ where a is a constant and t is the time.
(a) What is the magnitude of the induced EMF at time t = T?
(b) What is the self inductance of the loop at time t = 2T if the current flowing in the loop at this time is I?

3. The electrostatic potential in a region of space is given by $V(x) = -ax^5$ where a is a constant and x is the distance from the origin along the x-axis.
(a) What electric field exists in this region?
(b) How much work would have to be done to move a particle of charge -Q from the point x = X to the point x = 2X?
(c) If a particle of charge -Q is released from rest at the point x = 2X, with what speed will it be moving when it reaches the origin?

4. (a) At points A, B, C, & D place an arrow (or ⊙ or ⊗ or $\vec{0}$) to indicate the direction of the electric field and a +, -, or 0 to indicate the sign of the electrostatic potential.
(b) At points E, F, G, & H place an arrow (or ⊙ or ⊗ or $\vec{0}$) to indicate the direction of the magnetic force on the infinitesimal lengths of the current carrying wire or on the moving charged particle.



(d) On each of the four wire loops, place an arrow to indicate the direction of the induced current and place a ⊙ or ⊗ in the center of each loop to indicate the direction of the induced $\vec{B}$ field.
$\vec{B}$ is toward you and increasing.

$\vec{B}$ is away from you and decreasing.

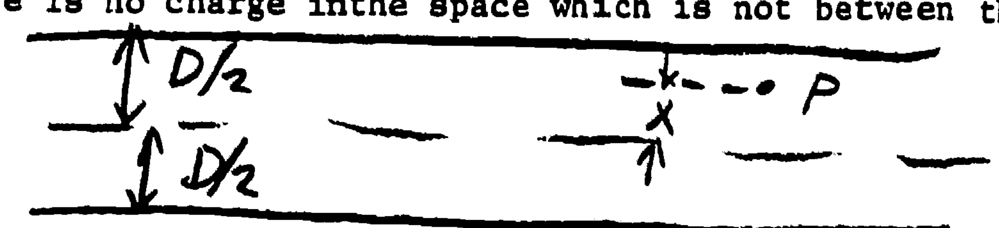
$\vec{B}$ is constant toward you but the shape is being changed to a rectangle.

$\vec{B}$ is constant toward you but the shape is being changed to a circle.

5. A system consists of three infinite planes of charge. Two planes, each having charge density $+\sigma$ are separated by a distance 2D and the third plane, having charge density -2σ, is midway between them.
(a) Determine the electric potential function for this system. Be sure to clearly define your coordinate system, reference point for potential, etc.
(b) If a particle having charge -Q is released from rest near the central plane, how fast will it be moving when it passes the positively charged plane?

6. A system consists of two point charges lying on the y-axis. A charge +Q is at the origin and a charge -Q is at the point y = +a. What electric field is present at the point with coordinates (x, y)?

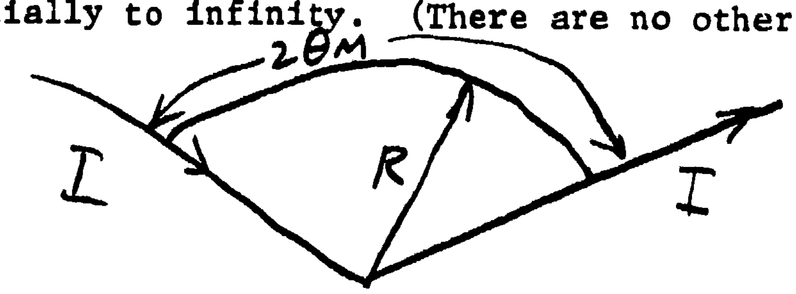
7. Consider a charge distribution bounded by two parallel infinite planes separated by a distance D. (This is not a metal.) The charge per unit volume between these two planes, ρ, is a positive constant. (There is no charge inthe space which is not between the two planes.)



(a) Place an arrow (or O or ⊗ or O) at P to indicate the direction of the electric field, $\vec{E}$, at that point.
(b) State your reasons for picking this direction.
(c) Find the magnitude of $\vec{E}$ at P. (Clearly indicate the reasons for setting any quantities equal to zero.)

8. A long cylindrical hole of radius R is cut out of a very large block of magnetic material (permeability constant K_m). A wire carrying a current I runs along the axis of the cylindrical hole.
(a) Determine the magnetic induction ($\vec{B}$) as a function of the distance r from the center of the wire both inside and outside the cylinder.
(b) What induced current flows on the surface of the cylindrical cavity?

9. Consider a wire carrying a current, I, which comes in radially from infinity, goes around a circular arc which subtends an angle $2\theta_M$ at the circle center, and goes out radially to infinity. (There are no other currents in the problem.)



(a) Place an arrow (or 0 or ⊗ or $\vec{0}$) at C (the circle center) to indicate the direction of the magnetic flux density $\vec{B}$ at that point.
(b) State your reasons for picking this direction.
(c) Find the magnitude of $\vec{B}$ at C. (Clearly indicate the reasons for setting any quantities equal to zero.)

10. A sphere of a dielectric material (dielectric constant K) has a radius R and a point charge of magnitude +Q imbedded at its center.
(a) Determine the electric field ($\vec{E}$) as a function of the distance from the point charge both inside and outside the sphere.
(b) What is the induced charge density on the surface of the sphere?

APPENDIX F--OPINION QUESTIONNAIRE

The questions reproduced below were used to obtain the opinions of the students involved in the experiment. Sections A, B, and C were distributed to all involved students immediately following phase two of the experiment. Section D was distributed at mid-semester of the semester following the experiment.

NAME:______________________________ SECTION:________________________

Answer all questions on an A, B, C, D, & F scale using A for definite yes and F for definite no.

A. Everyone answer these questions:

1. Could you hear the presentations of the students as well as those of the regular lecturer?
2. Could you understand the content of the presentations of the students as well as those of the regular lecturer?
3. Did the students' lack of understanding of their topics prevent you from absorbing the material as they presented it?
4. Do you feel that your understanding of the material increased when the students began to present problems only instead of all the material?
5. Do you feel that your understanding of the material would have been greater if there had been no student persentations?
6. Did you feel any sense of partnership with other members of your team?

B. Answer only if you presented a topic to the class:

1. Did student team teaching increase your enthusiasm for the course?
2. Did your presentation increase your understanding of your topic?
3. Do you feel that too much time was required for your preparation for your presentation?
4. Would you have preferred not to have presented a topic?
5. Would you have been agreeable to presenting one topic:
   (a) once every 2 weeks all semester?
   (b) once every 4 weeks all semester?
   (c) once every 8 weeks all semester?
6. Would you have been willing to present one topic:
   (a) once every 2 weeks all semester?
   (b) once every 4 weeks all semester?
   (c) once every 8 weeks all semester?

C. Answer only if you did not present a topic:

1. Did student team teaching decrease your enthusiasm for the course?
2. Do you think that presenting a topic would have increased your understanding of that topic?
3. Do you think that too much time would have been required to prepare for teaching?

4. Would you have preferred to present a topic?
5. Would you have been <u>agreeable</u> to presenting one topic:
   (a) once every 2 weeks all semester?
   (b) once every 4 weeks all semester?
   (c) once every 8 weeks all semester?
6. Would you have been <u>willing</u> to present one topic:
   (a) once every 2 weeks all semester?
   (b) once every 4 weeks all semester?
   (c) once every 8 weeks all semester?

D. <u>Answer only if you have changed your major since September, 1971</u>:

1. Old major:
2. New major:
3. Did the coure material in Physics 221 influence your decision to change majors?
4. Did the education experiment in Physics 221 influence your decision to change majors?

APPENDIX G. --PHYSICS 222 QUESTIONNAIRE

The form reproduced below was used to ask for volunteers to extend the experiment. It was distributed to all students in the course, Physics 222, which followed the course used in the experiment.

PHYSICS 222 QUESTIONNAIRE

NAME: ______________________________ DATE RECEIVED: February 16, 1972
DATE RETURNED: February 18, 1972

( ) I volunteer to work in the student team teaching class described below.

( ) I am going to remain in the regular lecture class taught by Dr. Geiger.

If, and only if, 25% of the total class volunteers, a student team teaching class under the direction of Paul Thrasher will be held. There are two reasons for requiring a minimum number. First, there would be a disproportionate amount of work required of the volunteers, if less than 30 students participated. Second, for the results to be statistically valid, a significant number is necessary.

In the student team teaching technique, teams of students prepare and present the majority of the topics discussed in class. These teams are aided by the course coordinator.

If it is held, the student team teaching session will (1) be held at the same times as the regular lectures and recitations, (2) begin on February 23, 1972, (3) last until the next hour examination on March 15, 1972, (4) cover topics selected by Dr. Geiger from Chapters 43,44 and 45 of Physics by Halliday and Resnick, (5) cover problems assigned by Dr. Geiger, and (6) have no examinations other than the one at the end of the session. The terminating test will be constructed by Dr. Geiger and will be given concurrently to the students in the student team teaching and regular sections.

Physical optics is the subject that will be discussed during this time interval. The primary topics are interference and diffraction; the secondary topics of gratings and spectra will be studied only as time and progress allow. This material is not easy; Halliday and Resnick present one of the more sophisticated discussions of physical optics at the introductory level.

Each student has complete freedom to select the class of his choice; but every student must state his or her choice on this form. Once the selection is made, it cannot be changed.

APPENDIX H. --QUESTIONNAIRE RESULTS

These are the results to the questionnaire reproduced in Appendix F. Although 80 students responded only 6 of these responses were applicable to section D. For all questions other than B5, B6, C5, and C6, the results are listed as average ± standard deviation; absolute no corresponds to 0.0 and absolute yes corresponds to 4.0. The majority of the students interpreted B5, B6, C5, and C6 as multiple choice questions, the results are listed in terms of percentages.

QUESTION	RESULT
A1	1.3 ± 1.3
A2	1.8 ± 1.3
A3	1.9 ± 1.4
A4	1.4 ± 1.4
A5	2.4 ± 1.4
A6	0.6 ± 1.0
B1	1.0 ± 1.2
B2	3.0 ± 1.1
B3	1.2 ± 1.2
B4	2.1 ± 1.3
B5(a)	28
(b)	17
(c)	55
B6(a)	35
(b)	15
(c)	50
C1	2.2 ± 1.6
C2	2.1 ± 1.5
C3	2.3 ± 1.5
C4	0.9 ± 1.2
C5(a)	18
(b)	14
(c)	68
C6(a)	19
(b)	15
(c)	16
D3	2.7 ± 1.8
D4	1.0 ± 1.5