State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2023
Exam number: 36371
Attachment: Formula and data sheets for 5-point physics
English translation (3)

Physics
Electricity

Instructions

א. Duration of the exam: Two hours.

ב. Exam structure and breakdown of points:
There are six questions in this exam and you are required to answer only three.
Each question is worth $33\frac{1}{3}$ points; $3 \times 33\frac{1}{3} = 100$ points

ג. Material that may be used during the exam:
(1) A non-graphing calculator. You may not use the programming options of a programmable calculator.
(2) Formula and data sheets (attached).
(3) A Hebrew–foreign language / foreign language–Hebrew dictionary.

ד. Special instructions:
(1) Answer three questions only. If you answer more than three questions, only the first three answers in your answer booklet will be graded. Clearly indicate the number of the question and item you chose.
(2) When solving questions that require calculations, you must: Write down the mathematical expression as it appears in the attached formula and data sheets; write down all derivations and change of subject of the formula required by the problem; insert the data in the derived expression; write the results of your calculations in decimal form to a suitable number of decimal places, and note the units of measurement.
(3) When drawing graphs, use at least one half of the page, and use a ruler to draw straight lines.
(4) When asked to express a magnitude using data from the question, write a mathematical expression that includes some or all of the data given in the question. If necessary, you may also use basic constants from the table in the formula and data sheets, or the free-fall acceleration g.
(5) In your calculations, use the value $10\ m/s^2$ for the magnitude of g free-fall acceleration (near the surface of Earth).
(6) Write your answers in pen. You may use a pencil for sketches and graphs only.
(7) If you make a mistake, crossing out the incorrect words or sentences with a double line is sufficient.

Write in the answer booklet only. Write the word "טיוטה" at the top of each draft page. If you write draft material on pages not in the answer booklet your exam may be disqualified.

Good Luck!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשפ"ג, 2023
מספר השאלון: 36371
נספח: דפי נוסחאות ונתונים ל-5 יחידות לימוד
תרגום לאנגלית (3)

פיזיקה
חשמל

הוראות

א. משך הבחינה: שעתיים.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שש שאלות, ומהן יש לענות על שלוש בלבד.
לכל שאלה — $33\frac{1}{3}$ נקודות; $3 \times 33\frac{1}{3} = 100$ נקודות

ג. חומר עזר מותר בשימוש:
(1) מחשבון לא גרפי. אין להשתמש באפשרויות התכנות במחשבון שיש בו אפשרות תכנות.
(2) דפי נוסחאות ונתונים (מצורפים).
(3) מילון עברי–לועזי / לועזי–עברי.

ד. הוראות מיוחדות:
(1) יש לענות על שלוש שאלות בלבד. אם תענו על יותר משלוש שאלות, ייבדקו רק שלוש התשובות הראשונות שבמחברת. יש לציין באופן ברור את מספר השאלה והסעיף שבחרתם.
(2) בשאלות שבפתרון שלהן נדרש חישוב, יש להציג את השלבים האלה: רישום הביטוי המתמטי כפי שהוא כתוב בדפי הנוסחות והנתונים המצורפים, פיתוח מתמטי ושינוי נושא נוסחה בהתאם לבעיה, הצגה מפורשת של הנתונים בביטוי שהתקבל, הצגת תוצאות החישוב באמצעות שבר עשרוני ובו מספר מתאים של ספרות משמעותיות וכן יחידות המדידה.
(3) את הגרפים יש לסרטט בגודל של חצי עמוד לפחות. יש להשתמש בסרגל לסרטוט קווים ישרים.
(4) כאשר נדרשים להביע גודל באמצעות נתוני השאלה, יש לרשום ביטוי מתמטי הכולל את נתוני השאלה או את חלקם; במידת הצורך אפשר להשתמש גם בקבועים בסיסיים מתוך הטבלה שבדפי הנוסחאות והנתונים או בגודל תאוצת הנפילה החופשית g.
(5) בחישובים יש להשתמש בערך $10\ m/s^2$ לגודל של g — תאוצת הנפילה החופשית (בסמוך לפני כדור הארץ).
(6) יש לכתוב את התשובות בעט. מותר להשתמש בעיפרון לסרטוטים וגרפים בלבד.
(7) במקרה של טעות, אפשר להסתפק בהעברת קו חוצה כפול על המילים או המשפטים השגויים.

יש לכתוב במחברת הבחינה בלבד. יש לרשום "טיוטה" בראש כל עמוד המשמש טיוטה.
כתיבת טיוטה בדפים שאינם במחברת הבחינה עלולה לגרום לפסילת הבחינה.

בהצלחה!

Questions

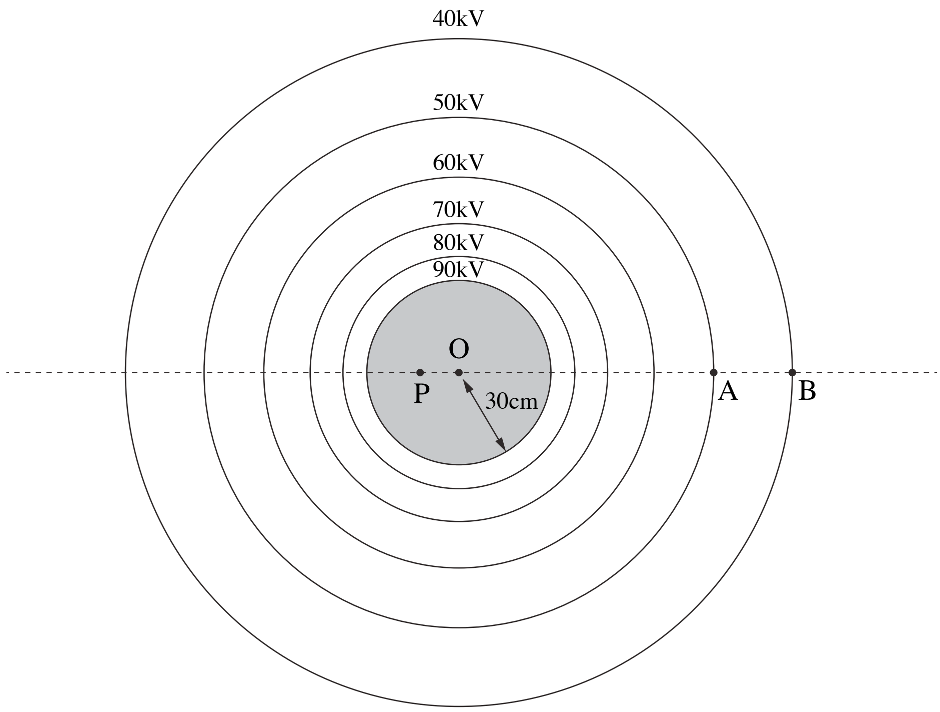
Answer three of the questions 1–6.

(Each question – $33\frac{1}{3}$ points; the point value of each item is given at the end of the item.)

1. The following diagram shows a conductive ball (spherical conductive shell) of positive charge Q and several equipotential lines. Each line is labeled with its potential.

We know that the radius of the ball is $R = 30$ cm, and the potential on its surface is 90,000 V; potential at infinity is set at zero.

Assume throughout this question that the effect of gravitational force is negligible and that the charge remains uniformly distributed on the ball's surface.



Point O is the center of the ball, Point P is located at a distance of 12 cm to the left of the center of the ball, Point A is located on the line whose value is 50,000 V, and Point B is located on the line whose value is 40,000 V (see diagram).

א. Calculate the distance AO. (9 points)

ב. Calculate the electric field at Point A (magnitude and direction). (7 points)

ג. **(1)** What is the magnitude of the electric field at Point P?

(2) What is the potential at Point P?

(5 points)

A small object 1 of mass m_1 and charge q_1 is held at rest at Point A. The object is given a speed of $v = 1.5\frac{m}{s}$ to the right. As Object 1 moves to the right it passes through Point B.

We know that $m_1 = 4 \cdot 10^{-4}$kg, $q_1 = -1.2 \cdot 10^{-8}$C.

ד. Calculate the speed of Object 1 at Point B. (8 points)

(Note: This question continues on the next page.)

/Continued on page 3/

A small object 2 of mass m_2 and charge q_2 is held at rest at Point A . Object 2 is also given a speed of $v = 1.5 \frac{m}{s}$ but to the left. As Object 2 moves to the left it passes through Point C (not marked on the diagram) at the same speed as the speed you calculated in Item ד.

We know that $m_2 = m_1$, $q_2 = -q_1$.

ה. Determine whether the distance AC is equal to, smaller than, or greater than the distance AB . Explain your answer. ($4\frac{1}{3}$ points)

2. Some students built an electric circuit from the following components: a non-ideal voltage source whose emf is ε and internal resistance is r , a fixed resistor R , a variable resistor R_{MK} whose sliding contact is P , ideal measuring instruments—voltmeter V_1 , voltmeter V_2 , and ammeter A , and ideal wires (see Figure 1).

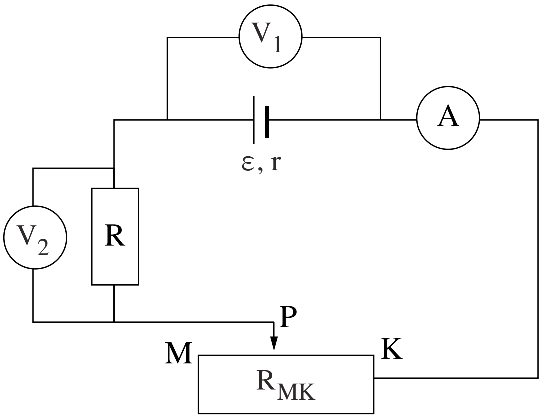


Figure 1

During the experiment the students changed the location of the sliding contact P , and each time they recorded the reading on the ammeter and on each of the voltmeters. Based on their results, they drew Graph א and Graph ב on one coordinate system, as shown in Figure 2 below.

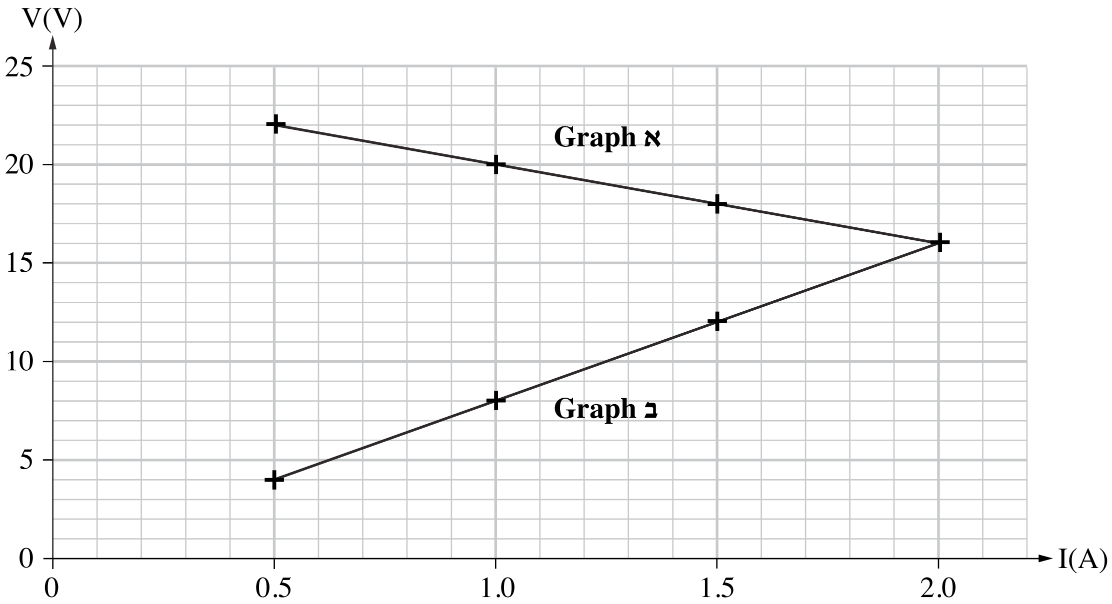


Figure 2

(Note: This question continues on the next page.)

/Continued on page 4/

א. Determine which of the two graphs (א or ב) was drawn from the results obtained on the voltmeter V_1 and which from the voltmeter V_2. Explain your answers. (6 points)

ב. Determine or calculate the emf ε, and the internal resistance r of the voltage source. (7 points)

ג. Calculate the resistance of the resistor R. (5 points)

One of the current values—whose voltage measurements are shown in Figure 2—was measured when the resistance of the variable resistor was at maximum.

ד. Calculate the resistance of the variable resistor in this state. (6 points)

A student moved the sliding contact of the variable resistor toward Point M.

ה. Determine whether the voltage on the variable resistor became higher, lower, or remained unchanged while the sliding contact was moving toward Point M. Explain your answer. (5 points)

A student replaced the ammeter A with the voltmeter V_1, as shown in Figure 3, below.

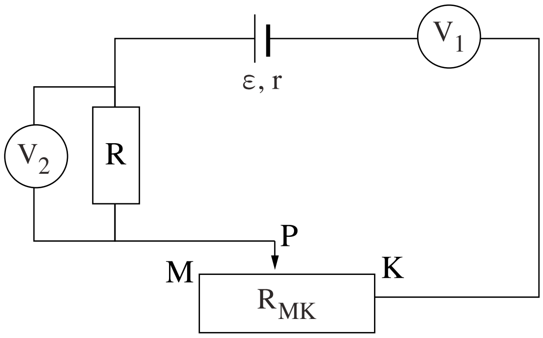
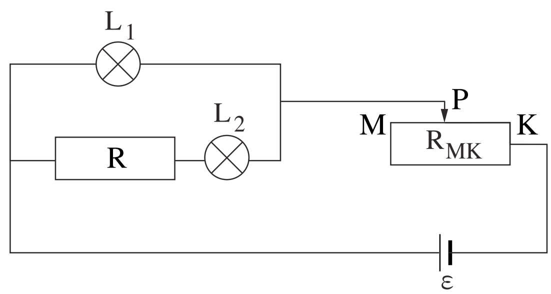


Figure 3

ו. In this arrangement, what will V_1 read and what will V_2 read? Explain your answers. ($4\frac{1}{3}$ points)

/Continued on page 5/

3. The following diagram describes an electric circuit whose components are: an ideal voltage source with an emf of $\varepsilon = 24V$, a fixed resistor R, a variable resistor R_{MK}, a lamp L_1 marked 24 V and 20 W, a lamp L_2 whose voltage is marked 12 V but its power marking has been erased, and ideal wires.



We know that throughout this question the current passing through both lamps is of equal magnitude.

The resistances of the lamps L_1 and L_2 are R_{L1} and R_{L2}, respectively.

א. Calculate R_{L1}. (5 points)

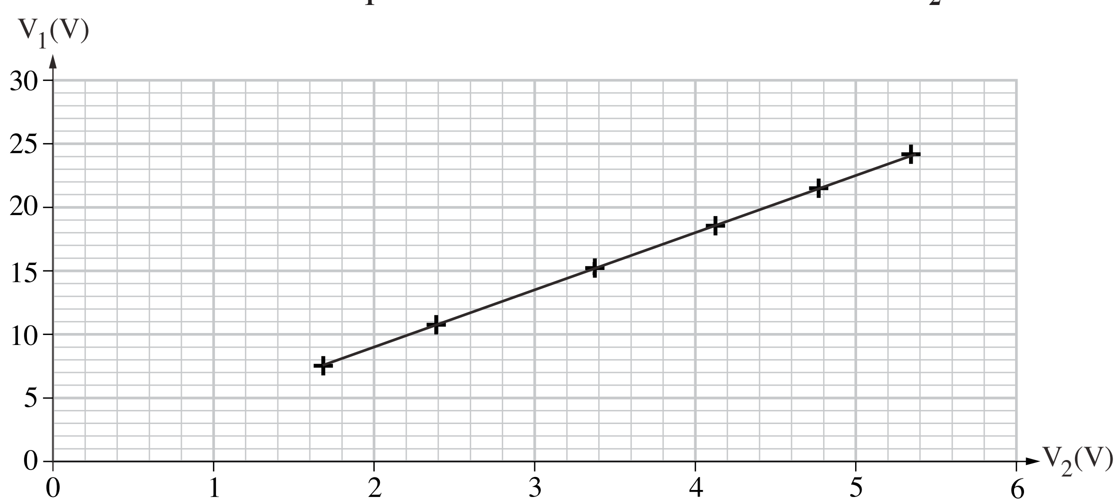
ב. Calculate the intensity of the current passing through the fixed resistor R when Lamp L_1 is <u>fully illuminated</u>. (6 points)

ג. With Lamp L_1 fully illuminated, is the sliding contact of the variable resistor located at Point M, at Point K, or at some point between the two? Explain your answer. (4 points)

ד. Express V_1 (the voltage on Lamp L_1) in terms of V_2 (the voltage on Lamp L_2) and the parameters R_{L1} and R_{L2}. (7 points)

Some high school physics students built the electric circuit described above. They changed the position of the sliding contact of the variable resistor several times, and each time measured the voltage on each of the lamps using a voltmeter. They plotted these measurements on a graph, as shown below.

Voltage on Lamp L_1 as a function of the voltage on Lamp L_2



(Note: This question continues on the next page.)

/Continued on page 6/

ה. Use the slope of the graph to calculate the power of Lamp L_2 (the marking that was erased). (7 points)

The students set the position of the sliding contact of the variable resistor to Point K , and switched the voltage source to a non-ideal voltage source with emf ε_1 and internal resistance r . In this case, Lamp L_1 was fully illuminated and the efficiency of the circuit was 80% .
In this circuit, efficiency is defined as the ratio between the power consumed by the components of the circuit (the lamps and resistor R) and the power delivered by the voltage source.

ו. Calculate the emf of the voltage source, ε_1 . ($4\frac{1}{3}$ points)

/Continued on page 7/

4. A group of students took some measurements to find the horizontal component $B_{E||}$ of Earth's magnetic field in the area where they live.

They placed a small compass on a table and extended a long, straight conductive wire (Wire 1) perpendicular to the plane of the table. The distance between the compass and the wire is labeled x.

The students moved the compass along a line pointing northward from the wire's position.

Figure 1 shows a top view of the wire which is perpendicular to the table, and the deflection of the compass needle when a current I_1 passes through the wire.

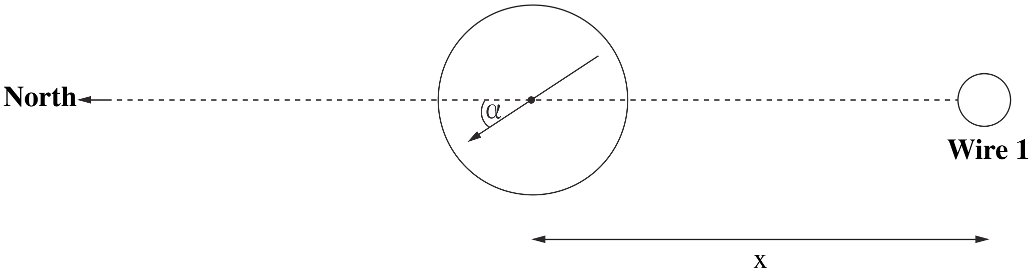


Figure 1

During the experiment, the compass needle deflected by an angle α counterclockwise, as shown in Figure 1.

א. Determine whether the direction of the current I_1 passing through Wire 1 is into the page or out of the page. Explain your answer. (4 points)

ב. Develop an expression for $\tan\alpha$ as a function of the distance x and the parameters $B_{E||}$, I_1, μ_0. (6 points)

The students passed a current of intensity $I_1 = 8A$ through the wire and changed the distance x between the compass and the wire several times. Each time, they measured the angle of deflection α and calculated $\tan\alpha$.

Their measurements and calculations are shown in the following table.

x(m)	0.10	0.15	0.20	0.25	0.30
α^{o}	29	20	16	13	9
tan α	0.55	0.36	0.29	0.23	0.16

To calculate $B_{E||}$, the students drew a graph of $\tan\alpha$ as a function of a new variable, such that they obtained a linear graph.

ג. Determine the new variable and its units. From the table above, copy the row for $\tan\alpha$ to your notebook, add another row below it, and write down the values and units of the new variable. (4 points)

ד. **(1)** In your notebook, draw a scatter chart (dots on a coordinate system) for $\tan\alpha$ as a function of the new variable.

(2) Add the best-fitting line (regression line) to your scatter chart. (8 points)

ה. Calculate $B_{E||}$. (7 points)

(Note: This question continues on the next page.)

/Continued on page 8/

The students extended another long, straight conductive wire, Wire 2, perpendicular to the plane of the table. They placed the compass on the line connecting the two wires, at an equal distance from both wires.

The students passed a current of intensity $I_1 = 5A$ through Wire 1.

When there was <u>no</u> current passing through Wire 2, the compass needle deflected counterclockwise by an angle α relative to the direction south-north (see view from above in Figure 2א).

When a current of intensity I_2 passed through Wire 2, the compass needle deflected by the same angle α , clockwise (see view from above in Figure 2ב).

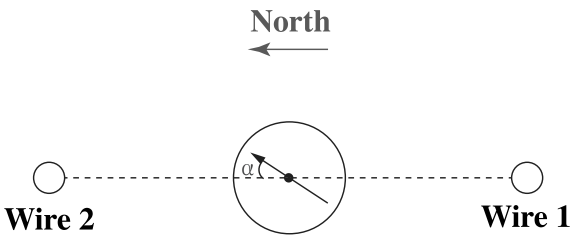


Figure 2ב

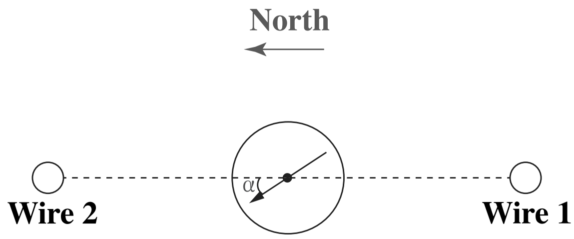


Figure 2א

ו. Determine the direction and intensity (I_2) of the current in Wire 2. Explain your answers. ($4\frac{1}{3}$ points)

/Continued on page 9/

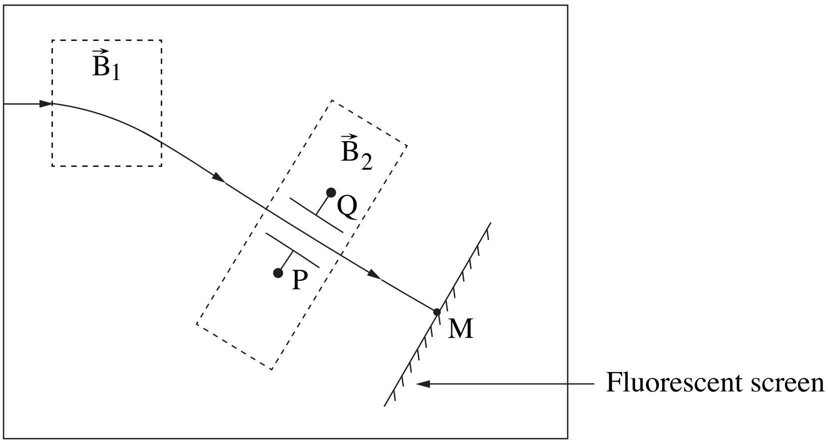
5. The diagram below describes the movement of a beam of protons along a path until it strikes a fluorescent screen on which a point of light then appears.

On its way to the screen, the beam passes through two regions in which there are different fields.

At the start, the beam enters, at speed $v = 10^6 \frac{m}{s}$, a region of uniform magnetic field $\vec{B}_1$ of intensity $0.12T$ whose direction is perpendicular to the plane of the page. The velocity is perpendicular to the direction of the magnetic field. The proton beam exits the region of magnetic field at a certain angle relative to the beam's entry angle (see figure).

On its way to the screen, the beam passes between two parallel metal plates, P and Q, which are connected to a voltage source. There is a uniform electrical field $\vec{E}$ and a uniform magnetic field $\vec{B}_2$ between the two plates. The beam passes between the plates without changing direction, and continues moving in a straight line until it strikes the screen at Point M. The screen is perpendicular to the proton beam's direction of travel as it exits the magnetic field $\vec{B}_1$.

The entire system is located in a chamber that has been emptied of air. Neglect the gravitational force throughout this question.



א. **(1)** Determine whether the direction of the magnetic field $\vec{B}_1$ is into the page or out of the page.

(2) Calculate the radius of the protons' path through the region with the field $\vec{B}_1$.

(8 points)

We know that: the potential difference between the parallel plates P and Q is $\Delta V = 800V$, and the distance between the plates is $\Delta x = 5cm$;

the direction of the magnetic field $\vec{B}_2$ is identical to the direction of the magnetic field $\vec{B}_1$.

ב. Calculate the magnitude of the electrical field $\vec{E}$ between the two plates, and note its direction—from Plate P to Plate Q or in the opposite direction. (8 points)

ג. Calculate the magnitude of the magnetic field $\vec{B}_2$. (8 points)

(Note: This question continues on the next page.)

/Continued on page 10 /

The operation of the magnetic field $\vec{B}_2$ is stopped, and as a result the beam of protons changes its direction. It exits the space between the plates without striking them, and strikes the screen at a different point, not at M .

ד. Determine whether the present speed of the protons when they strike the screen is less than, greater than, or equal to the speed of the protons at the moment they struck the screen at Point M . Explain your answer. (5 points)

ה. Determine whether, after stopping the operation of the magnetic field $\vec{B}_2$, the protons were in motion for less time, more time, or the same amount of time as when the field was in operation. Explain your answer. ($4\frac{1}{3}$ points)

Induction

6. A uniform magnetic field $\vec{B}$ is applied to a square wire frame. This uniform magnetic field is directed into the page and is perpendicular to the plane of the frame (see Figure 1).

We know that: the side length of the frame is $a = 50\text{cm}$;
the resistance of the square wire frame is $R = 2\Omega$.

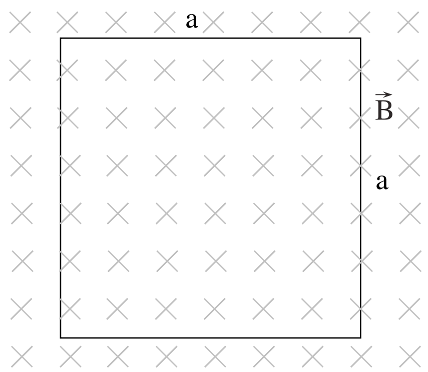


Figure 1

The intensity of the field $\vec{B}$ over three intervals of time I–III is given in the following table and described in Figure 2 (on the next page).

	Time interval	B(T)
I	$0 \le t < 0.2\text{s}$	0.09
II	$0.2\text{s} \le t < 1.0\text{s}$	$-t^2 + 1.2t - 0.11$
III	$1.0\text{s} \le t < 1.2\text{s}$	0.09

(Note: This question continues on the next page.)

/Continued on page 10/

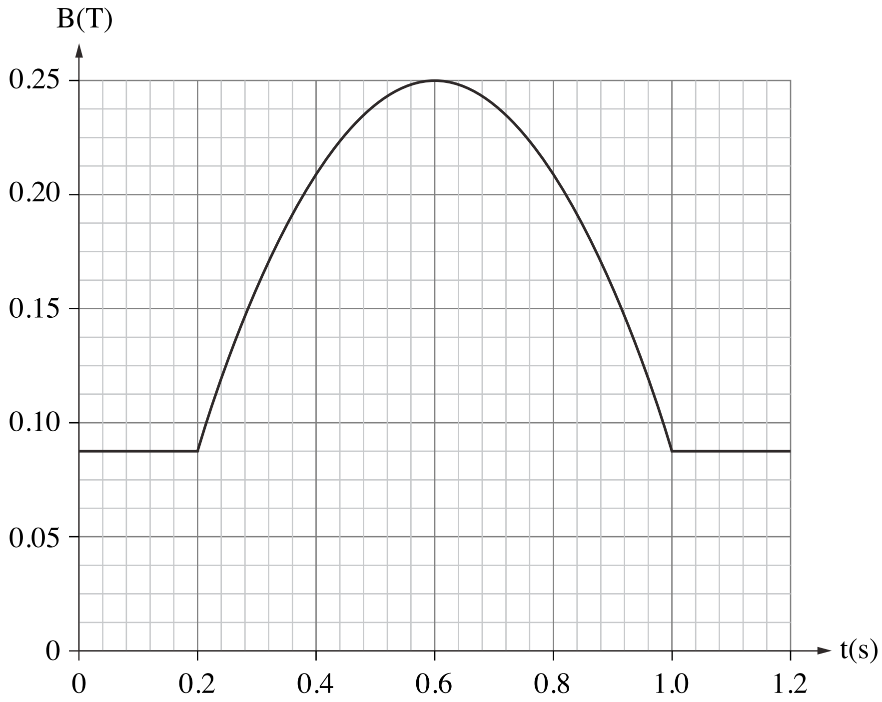


Figure 2

א. For each of the three time intervals I–III , either calculate the following physical quantities or express them in terms of t .

(1) the magnetic flux ϕ_B through the frame

(2) the emf ε in the frame

(3) the intensity of the current I through the frame

(12 points)

ב. Determine whether the direction of the current in the frame at time $t = 0.3s$ is clockwise or counterclockwise. (4 points)

ג. Draw a graph of the current intensity I as a function of time, from the time $t = 0$ until the time $t = 1.2s$. On the graph you drew, determine the positive value of the current when the current in the frame is flowing clockwise. (7 points)

ד. **(1)** Calculate the quantity of electrical charge that passed through the wire between time $t = 0$ and time $t = 0.6s$.

(2) Determine whether the quantity of charge that passed through the wire between time $t = 0.6s$ and time $t = 1.2s$ is greater than, smaller than, or equal to the quantity you calculated in Sub-item ד(1). Explain your answer.

(6 points)

(Note: This question continues on the next page.)

/Continued on page 12/

The wire frame can shrink or expand very slightly because the field $\vec{B}$ exerts magnetic forces on the induced current.

ה. At which one of the time intervals 1–4 below did these forces cause the frame to <u>expand</u>? Explain your answer. ($4\frac{1}{3}$ points)

1. $0 < t < 0.2s$
2. $0.2s < t < 0.4s$
3. $0.8s < t < 1.0s$
4. $1.0s < t < 1.2s$

Good Luck!

בהצלחה!