State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2026
Exam number: 36371
Attachment: Formula and data sheets for physics
English translation (3)

Physics
Electricity

Instructions

א. <u>Duration of the exam</u>: Two hours.

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

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

ד. <u>Special instructions</u>:
(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 that you chose.
(2) When solving questions that require calculations, structure your answer as follows:
Write down the mathematical expression as it appears in the attached formulas and data sheets; write down all derivations and change in 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 significant figures, and suitable units of measurement.
(3) Use at least half a page for drawing graphs.
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 formulas 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 pencil for sketches and graphs only.
(7) If you make a mistake, it is sufficient to cross out the incorrect words or sentences with a double line.

Write <u>in the answer booklet only</u>. 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"ו, 2026
מספר השאלון: 36371
נספח: נוסחאות ונתונים בפיזיקה
תרגום לאנגלית (3)

פיזיקה
חשמל

הוראות

א. <u>משך הבחינה</u>: שעתיים.

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

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

ד. <u>הוראות מיוחדות</u>:
(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 שבחרתם ואת הסעיף.
(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 המידה.
(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 <u>במחברת הבחינה בלבד</u>. 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. A group of students researched the motion of oil droplets in an electric field. The research was conducted using an artificial intelligence (AI) generated computer simulation of an experiment conducted on Earth's surface.
In the simulation, the effect of Earth's gravity on an oil droplet is **not negligible**, while the effect of air resistance on the droplet is negligible.
In the simulation, an oil droplet of mass m and positive charge q moves in a region where there is a uniform electric field E between two charged planar plates that are parallel to the ground.
The direction of the electric field is upward, perpendicular to the plates.
The droplet was released from rest at some point between the plates, as depicted in Figure 1.
The positive direction of the position axis is defined as upward.

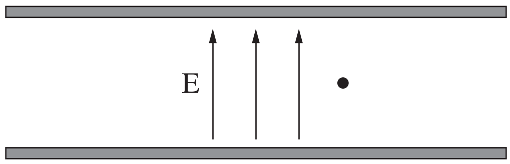


Figure 1

א. **(1)** Draw the free-body diagram of the forces acting on the droplet.
(2) Show that the expression for the droplet's acceleration a is: $a = \frac{q}{m}E - g$.
(7 points)

The students varied the magnitude of the electric field in the simulation and observed the acceleration values shown in the table below:

$\mathbf{E}\left(10^4 \frac{V}{m}\right)$	5	10	15	20	25
$\mathbf{a}\left(\frac{m}{s^2}\right)$	–9.5	–5	–0.5	2.5	6.5

ב. **(1)** Draw a scatter diagram of the acceleration a as a function of the magnitude of the electric field E .
(2) Add the best fitting line (trend line) to the scatter diagram.
(9 points)

ג. Calculate the ratio $\frac{q}{m}$ of the oil droplet. (6 points)

ד. AI is known to give results that sometimes disagree with scientific consensus.
In your opinion, did this happen in this simulation? Explain your answer.
(6 points)

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

/Continued on page 3/

Next, using the simulation, the students studied a system that charges and sorts oil droplets.
Figure 2 depicts oil droplets moving inside a metal tube and being sprayed (ejected) from it in the direction of a ball that is positively charged.
We know that during this process, some of the droplets become positively charged and the rest of the droplets remain neutral.
In Figure 2 we see that the charged droplets were repelled from the ball, and that the neutral droplets were attracted to it.

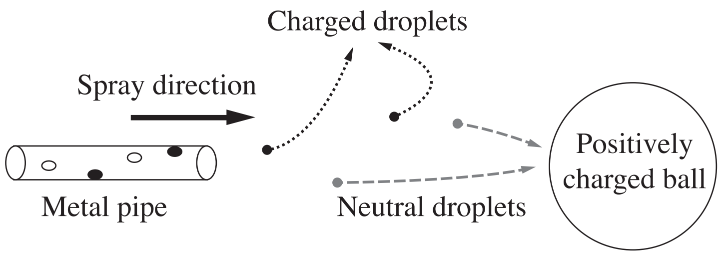


Figure 2

ה. Explain why the charged droplets were repelled from the charged ball, and why the neutral droplets were attracted to it. ($5\frac{1}{3}$ points)

/Continued on page 4/

2. Consider a metallic spherical shell A of radius $R_1 = 10$ cm . The shell has an electric charge Q_1 of uniform density and unknown magnitude and sign.

Figure 1 depicts a midsection of the spherical shell, and a contour line representing an equipotential surface with a value $V = 120$ V at a distance of 5 cm from the spherical shell.

We know that: The potential at infinity is zero.
The effect of gravity is negligible.

Note: The figures in this question are qualitative and are not drawn to scale.

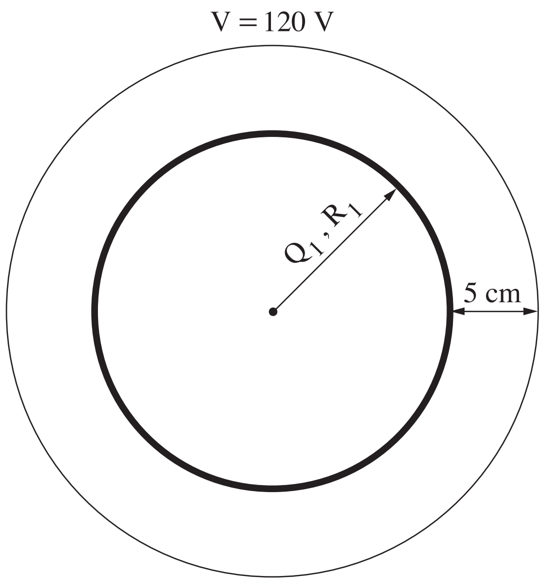


Figure 1

א. Calculate the electric charge Q_1 (magnitude and sign) on the spherical shell.
(6 points)

To move one proton from a very large distance (infinity) to a point on the spherical shell in Figure 1, it must be given an initial velocity v_0 .

ב. Calculate the minimum magnitude of the initial velocity, v_0 , that must be given to the proton at infinity for it to reach the spherical shell. (8 points)

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

/Continued on page 5/

A metallic spherical shell B is located at a very large distance from Shell A . The radius of Shell B is $R_2 = 60$ cm , and it had a positive electric charge $Q_2 = 10$ nC , of uniform density.
Both shells were then connected with a conducting wire of negligible resistance, as depicted in Figure 2.

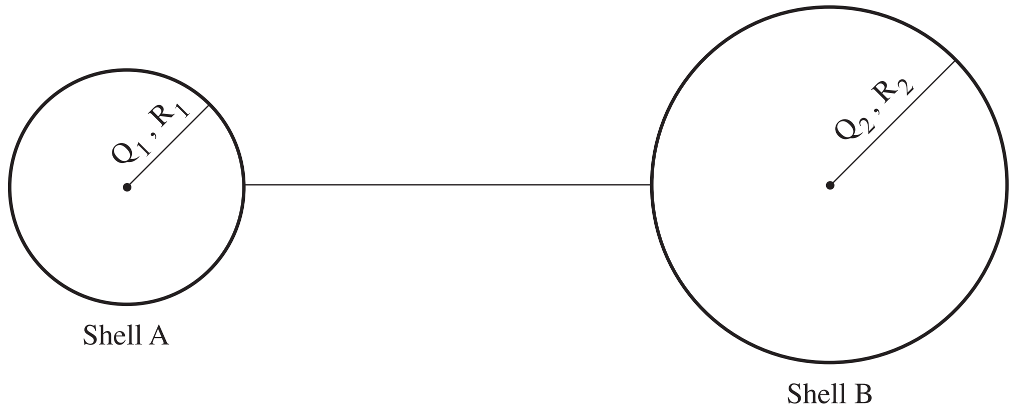


Figure 2

ג. Calculate the charge (magnitude and sign) on each of the spherical shells a long time after the connection was made. (8 points)

The connection caused the movement of **electrons** between the two spherical shells.

ד. Determine whether electrons moved from Shell A to Shell B or vice versa, and calculate how many. (6 points)

ה. Explain why it is necessary to assume a very large distance between the shells. ($5\frac{1}{3}$ points)

/Continued on page 6/

3. Consider two unknown electrical components A and B . The current versus voltage graph (I–V characteristic) for each of the two components is depicted in Figure 1.

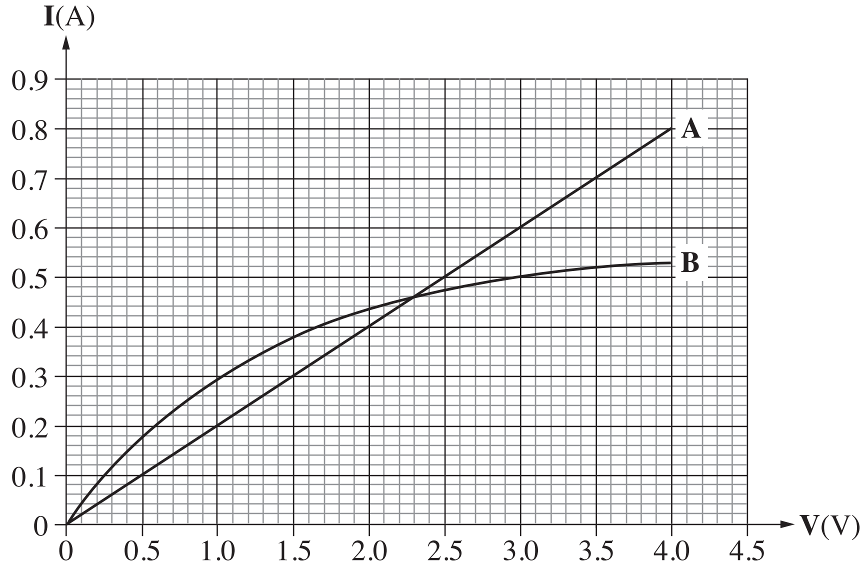


Figure 1

Answer the items below using the graph.

א. Determine which component A or B has a constant resistance. Explain your answer. (5 points)

We know that the component with constant resistance is a conducting wire with the following dimensions:
length $\ell = 2$ m , cross-sectional area $A = 0.45\ \text{mm}^2$.

ב. Calculate the resistivity [התנגדות הסגולית] of the wire. (7 points)

A group of students assembled two different circuits. In each of the circuits they used the following components: A and B , a voltage source of emf ε and internal resistance r , and measuring instruments (the instruments are not shown in the figures).
The <u>first circuit</u> the students assembled is depicted in Figure 2.
The students used an ideal voltmeter to measure the voltages on Component A and on Component B , and observed that the two measured voltages were equal.

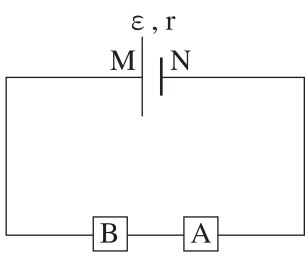


Figure 2

ג. Calculate the source's terminal voltage V_{MN} . (6 points)

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

/Continued on page 7/

The second circuit the students assembled is depicted in Figure 3.
The students used an ideal voltmeter to measure the voltage on Component A, and observed that the voltage was $V = 3.5 \text{ V}$.

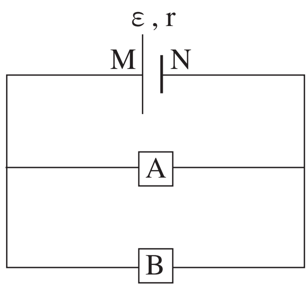


Figure 3

ד. Calculate the current flowing through the voltage source in this circuit. (4 points)

ה. Calculate the emf ε and internal resistance r of the voltage source. (6 points)

The students reassembled the first circuit, depicted in Figure 2.
The students used a non-ideal voltmeter to measure the voltage on the component of constant resistance.

ו. Determine whether the voltage measured here was greater than, less than, or equal to the voltage measured on this component when it was measured using the ideal voltmeter in the first circuit. Explain your answer. ($5\frac{1}{3}$ points)

/Continued on page 8/

4. A physics student assembled a simple electric circuit which included a non-ideal voltage source whose emf (ε) and internal resistance (r) parameters are unknown, a variable resistor MN , and an ideal ammeter (see Figure 1).

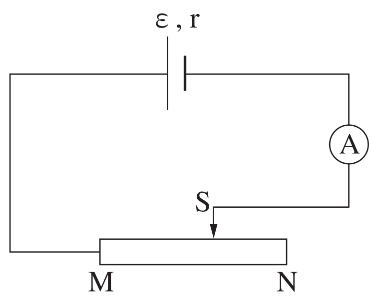


Figure 1

By changing the position of the slider S , the student changed the current several times, each time measuring the resistance of the active part, R_{MS} , in the variable resistor.
The purpose of the student's measurements was to calculate the voltage source's emf ε and internal resistance r .

א. Develop an expression for the resistance of the active part in the variable resistor, R_{MS} , as a function of the value of the electric current I and the parameters ε and r .
(7 points)

Based on the measurement results, the student drew a scatter diagram (Figure 2) and added a regression line (trend line).

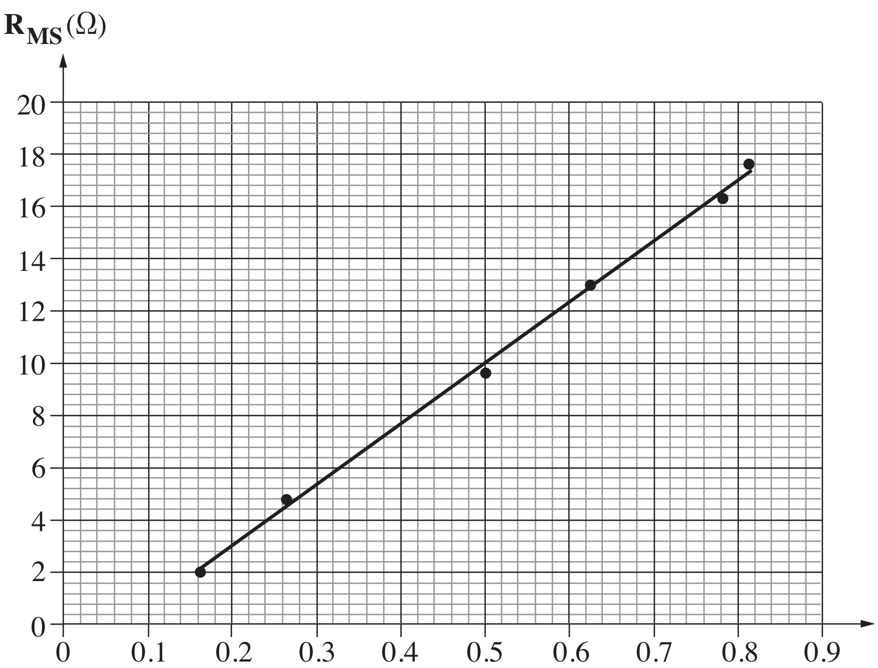


Figure 2

The student did not label the horizontal axis or specify its units.

ב. Label the horizontal axis and specify its units. Explain your answer. (5 points)

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

/Continued on page 9/

ג. Based on the given scatter diagram and the expression that you developed in Item א:

(1) Calculate the voltage source's emf, ε .

(2) Calculate the internal resistance, r .

(10 points)

ד. Calculate the electrical power dissipated in the variable resistor when its resistance is $R_{MS} = 10\Omega$. (6 points)

We know that the power you calculated in Item ד can also be dissipated in the resistor at a higher current.

ה. Determine for which of the two current values (the higher or the lower), the circuit's efficiency will be greater. Explain your answer (no calculations required). ($5\frac{1}{3}$ points)

/Continued on page 10 /

5. Scientists researched the motion of protons in a magnetic field.
The effect of gravity on the motion of protons is negligible.
In the first experiment, a uniform magnetic field B_1 was applied, directed downward, perpendicular to the ground.
A proton entered the region of the magnetic field B_1 in a leftward horizontal direction, at a velocity v (see Figure 1).
We know the magnitude of the magnetic field $B_1 = 0.02T$, and the magnitude of the proton's velocity $v = 10^6 \frac{m}{s}$.

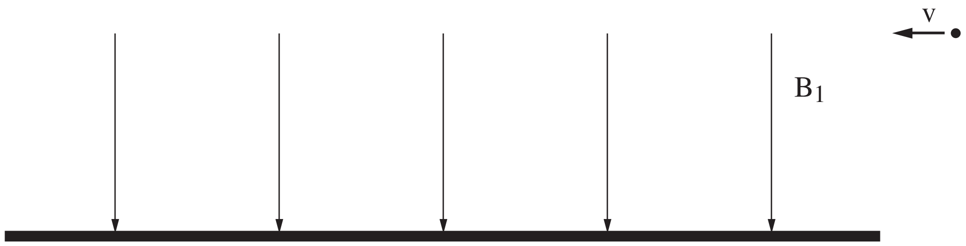


Figure 1

א. Calculate the force (magnitude and direction) acting on the proton as it entered the magnetic field. (6 points)

ב. **(1)** Calculate the radius of rotation R_1 of the proton in the magnetic field.
(2) Calculate the period T_1 of the proton's motion in the magnetic field.
(10 points)

The scientists applied an electric field E in addition to the magnetic field B_1, and the proton moved in a straight line.

ג. Calculate the electric field E (magnitude and direction) which the scientists applied. (7 points)

In a second experiment, the electric field E and the magnetic field B_1 were turned off, and a different magnetic field B_2 was applied, at an acute angle relative to the ground, as depicted in Figure 2.
The magnetic field B_2 is uniform in magnitude, and its field lines are parallel to one another.
The strength of the magnetic field is unknown.
A proton entered the region of the magnetic field B_2 in a leftward horizontal direction, at a velocity v (see Figure 2).

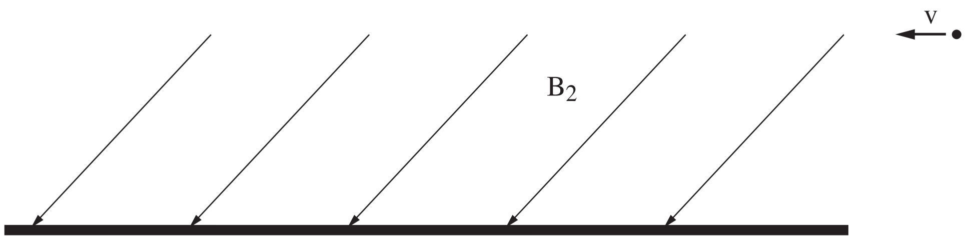


Figure 2

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

/Continued on page 11/

After it entered the magnetic field the proton executed helical motion (circular motion in the plane perpendicular to the field lines while advancing at a constant velocity in the direction of the field lines).

ד. Explain why the proton executed helical motion. (5 points)
Hint: Separate the velocity vector into a perpendicular component and a component parallel to the field lines.

In order to find the magnitude and direction of the magnetic field B_2, the scientists placed a magnetic field sensor on the ground, such that the angle α between the sensor's axis and the ground was variable, as depicted in Figure 3.
We know that the sensor measures the magnitude of the magnetic field component whose direction is parallel to the sensor's axis.

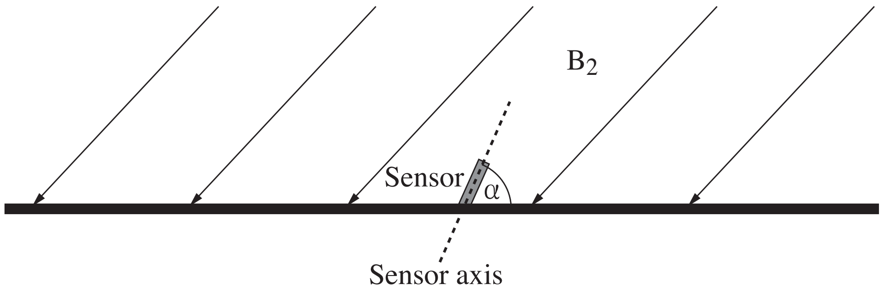


Figure 3

Using the sensor, the scientists took several measurements of the strength of the magnetic field as a function of the angle α of the sensor axis relative to the ground (see Figure 3). The results of the measurements are shown in Figure 4.

Strength of magnetic field as a function of sensor angle

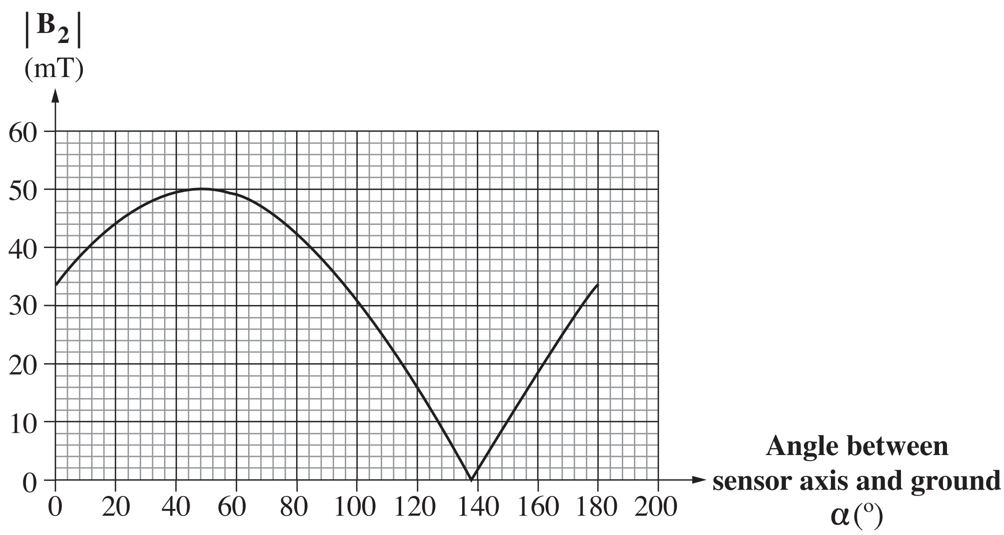


Figure 4

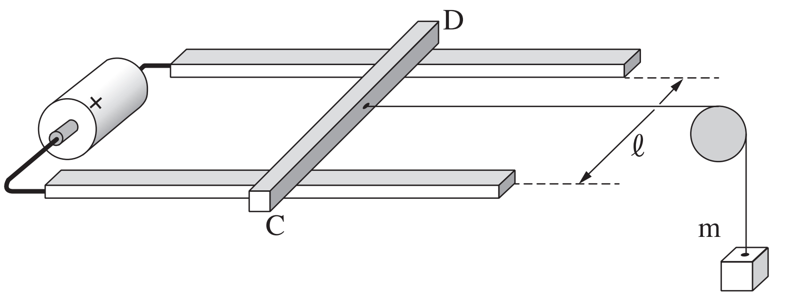
ה. Use Figure 4 to find the magnitude of the magnetic field B_2 and its direction (the angle of the field relative to the ground). Briefly explain your method of solution. ($5\frac{1}{3}$ points)

/Continued on page 12/

Induction

6. Consider a system consisting of conducting Rod CD that is able to move along a very long track composed of two parallel conducting rails.
The distance between the rails is ℓ .
A battery of emf ε and internal resistance r is attached between the ends of the rails.
There is a uniform magnetic field of magnitude B perpendicular to the plane of the track.
Connected to the rod is a horizontal string wound around a pulley, and at the other end of the string hangs a weight of mass m (see figure).

All frictional forces and resistances of the rails and Rod CD are negligible.



We release Rod CD from rest, and the rod remains in its place without moving.

א. Determine the direction of the magnetic field of magnitude B . Explain your answer. (6 points)

ב. Express the mass m of the weight using the data provided in this question (ε , r , ℓ , B) and known physical constants. (7 points)

We replace the battery with a lamp whose resistance is R . We release Rod CD from rest, and the rod begins to move.

ג. Explain in detail the process that causes a current in the lamp when the rod is in motion. (8 points)

After some time, the rod attained a constant speed.
We know that: $B = 1.8$ T , $m = 0.05$ kg , $\ell = 0.8$ m , $R = 7.2\ \Omega$.

ד. Calculate the constant speed of Rod CD . (7 points)

ה. Determine the direction of the current in Rod CD . Explain your answer. ($5\frac{1}{3}$ points)

Good Luck!

בהצלחה!

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זכות היוצרים שמורה למדינת ישראל
אין להעתיק או לפרסם אלא ברשות משרד החינוך