State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2019
Exam number: 036371
Attachment: Data and formulas for 5-point physics
English translation (3)

Physics
Electricity

Instructions for examinees

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 calculator.
(2) The physics data and formula sheet attached to this exam.
(3) A Hebrew-foreign language / foreign language-Hebrew dictionary.

ד. Special instructions:
(1) Answer the number of questions that you are asked to answer. Answers to additional questions will not be graded. (The answers will be graded in the order they appear in the answer booklet.)
(2) When solving questions that require calculations, write out the formulas that you use. Whenever you use a symbol that does not appear on the formula sheet, write out the meaning of that symbol in words. Before you perform your calculations, substitute the appropriate values into the formulas.
Write your final answer in the appropriate units. If you do not write out the formula, or substitute values, or specify the units, points may be subtracted from your score.
(3) When asked to express a magnitude using data from the question, write a mathematical expression that includes some or all of the data provided in the question. If necessary, you may also use basic constants, such as *g* for free-fall acceleration or *e* for elementary charge.
(4) In your calculations, use the value 10 m/s^2 for the magnitude of free-fall acceleration.
(5) Write your answers in pen. Writing in pencil or erasing with White-Out will preclude any possibility of appealing your score. You may use a pencil for sketches only.

Write in the answer booklet only. Write the word "טיוטה" at the top of each draft page. Writing any sort of draft on pages that are not in the answer booklet may lead to the disqualification of your exam.

Good Luck!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ט, 2019
מספר השאלון: 036371
נספח: נוסחאות ונתונים בפיזיקה ברמה של 5 יח"ל
תרגום לאנגלית (3)

פיזיקה
חשמל

הוראות לנבחן

א. משך הבחינה: שעתיים.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שש שאלות, ומהן עליך 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.
(2) נספח נוסחאות ונתונים בפיזיקה המצורף לשאלון.
(3) מילון עברי-לועזי / לועזי-עברי.

ד. הוראות מיוחדות:
(1) ענה על מספר שאלות כפי שהתבקשת. תשובות לשאלות נוספות לא ייבדקו.
(התשובות ייבדקו לפי סדר הופעתן במחברת הבחינה.)
(2) בפתרון שאלות שנדרש בהן חישוב, רשום את הנוסחאות שאתה משתמש בהן.
כאשר אתה משתמש בסימן שאינו בדפי הנוסחאות, כתוב במילים את פירוש הסימן.
לפני שאתה מבצע פעולות חישוב, הצב את הערכים המתאימים בנוסחאות.
רשום את התוצאה שקיבלת ביחידות המתאימות.
אי־רישום הנוסחה או אי־ביצוע ההצבה או אי־רישום היחידות עלולים להפחית נקודות מן הציון.
(3) כאשר אתה נדרש להביע גודל באמצעות נתוני השאלה, רשום ביטוי מתמטי הכולל את נתוני השאלה או חלקם; במידת הצורך אפשר להשתמש גם בקבועים בסיסיים, כגון תאוצת הנפילה החופשית g או המטען היסודי e.
(4) בחישוביך השתמש בערך 10 m/s^2 לתאוצת הנפילה החופשית.
(5) כתוב את תשובותיך בעט. כתיבה בעיפרון או מחיקה בטיפקס לא יאפשרו ערעור.
מותר להשתמש בעיפרון לסרטוטים בלבד.

כתוב במחברת הבחינה בלבד. רשום "טיוטה" בראש כל עמוד המשמש טיוטה. כתיבת טיוטה בדפים שאינם במחברת הבחינה עלולה לגרום לפסילת הבחינה.

בהצלחה!

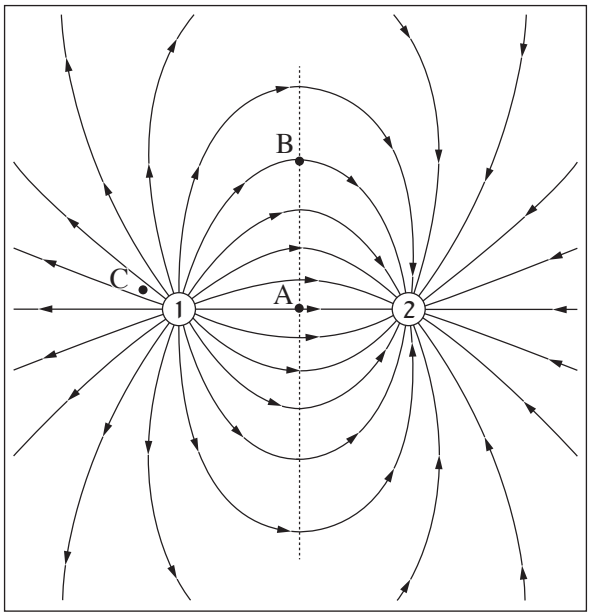
Questions

Answer three of the questions 1-6.

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

1. The figure below describes a system with two electric charges located in a vacuum, Charge 1 and Charge 2, and the system's electric field lines.

In this question the electric potential energy at infinity is zero.



א. Define the term "electric field line". (5 points)

ב. Based on the illustration, explain why the charges have the same absolute value. (4 points)

Point A is the midpoint of the segment that connects the two charges.

ג. **(1)** Does the intensity of the field of this system of charges at Point A equal zero? Explain your answer.

(2) Does the electric potential at Point A equal zero? Explain your answer.

(8 points)

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

/Continued on page 3/

Point B is on the perpendicular bisector [האנך האמצעי] of the segment connecting the two charges.

ד. If a negative point charge is placed at Point B, what will be the direction of the electric force exerted on the charge at this point? Explain your answer.

($4\frac{1}{3}$ points)

ה. Where is the intensity (magnitude) of the electric field greater, at Point A or at Point C? Explain your answer. (4 points)

Given: The absolute value of each of the two charges is 10^{-8}C, and the distance between them is 6 cm.

ו. Calculate the electric potential energy of the system of charges (relative to infinity).

(8 points)

/Continued on page 4/

2. In Figure 1 below, the electric circuit has a voltage source with emf [כא"מ] $\varepsilon = 90V$ and internal resistance $r = 50\Omega$, a resistor with resistance $R_1 = 1{,}000\Omega$, a resistor with resistance R_2, and two ideal measuring instruments (a voltmeter and an ammeter).

Both resistors are made of the same type of conductive wire, and differ from each other only in length. The length of Resistor R_2 is 0.75 of the length of resistor R_1.

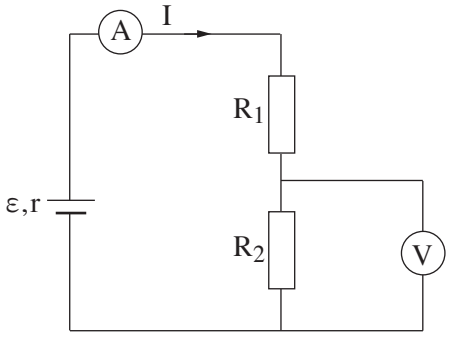


Figure 1

א. Calculate the external resistance of this circuit. (5 points)

ב. Calculate the reading on the ammeter [אמפרמטר] and the reading on the voltmeter [וולטמטר]. (9 points)

ג. Calculate the quantity of charge that passes through the ammeter in one minute. (5 points)

In the food industry, it is necessary to measure the temperature of food. This is done using thermistors. A thermistor is an electronic component whose resistance changes according to the temperature.

A thermistor is placed in the electric circuit described in Figure 1 above, in place of Resistor R_1.

The resistance of the thermistor as a function of temperature is shown in Figure 2 on the following page.

/Continued on page 5/

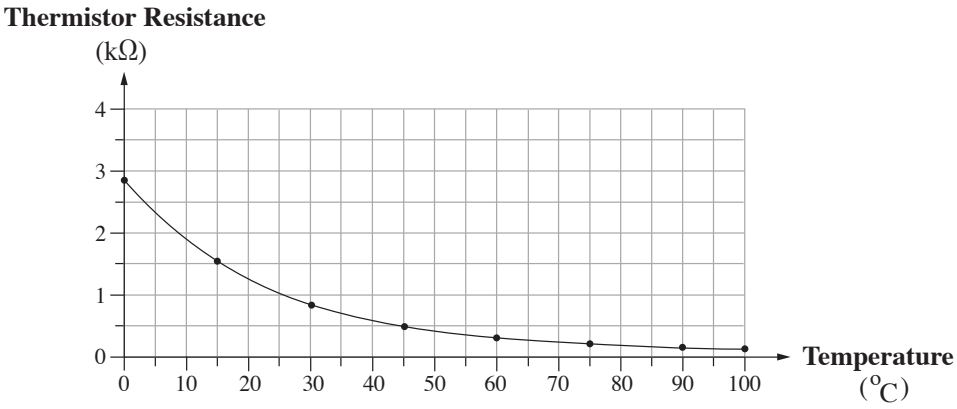


Figure 2

The temperature of the thermistor is calculated based on the voltage reading on the voltmeter.

ד. Calculate the temperature of the thermistor when the voltmeter reading is $V_{R_2} = 52V$.

($7\frac{1}{3}$ points)

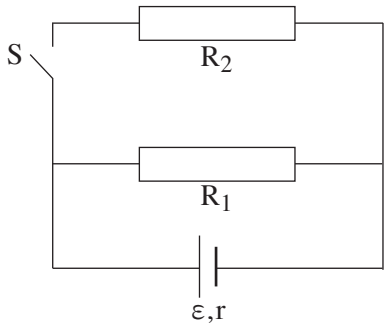
Now the thermistor is removed and Resistor R_1 is put back instead, and the voltmeter is replaced with a **non-ideal** voltmeter.

ה. Will the ammeter reading be higher, lower, or unchanged? Explain your answer.

(7 points)

/Continued on page 6/

3. The electric circuit in the figure below is composed of a voltage source with emf $\varepsilon = 36V$ and internal resistance $r = 6\Omega$, a resistor with a resistance $R_1 = 12\Omega$, a resistor with a resistance R_2, a switch S, and conductive wires with negligible resistance.



Switch S is open.

א. Calculate the quantity of energy that is dissipated in Resistor R_1 over a time interval of $\Delta t = 200s$. (5 points)

ב. Calculate the circuit efficiency [נצילות]. (6 points)

ג. Express the external power, P, of this circuit using ε, r, and I (I is the intensity of the current passing through the voltage source). (5 points)

Now Switch S is closed. The intensity of the current passing through the voltage source changes, but the external power of the circuit does not change.

ד. Use your answer to Item ג to calculate the intensity of the current passing through the voltage source after the switch is closed. (8 points)

ה. Determine whether, after closing the switch, the circuit efficiency increases, decreases, or remains unchanged. Explain your answer. (6 points)

ו. Which of the units 1-5 below is a unit of power? Explain your answer. ($3\frac{1}{3}$ points)

1. $\frac{N}{C}$
2. $\frac{C^2 \cdot \Omega}{s^2}$
3. $J \cdot s$
4. $V \cdot C$
5. $kW \cdot h$

/Continued on page 7/

4. Figure 1 below describes a system for measuring a magnetic field of a horseshoe magnet. In this system a conductive rod, PC, hangs in between and parallel to the X pole and the Y pole of the horseshoe magnet.

Rod PC is part of an electric circuit that contains a voltage source, a switch S, and ideal conductive wires.

The mass of the magnet is m, and it is standing on an electronic balance [מאזניים דיגיטליים].

There is a uniform magnetic field B between the poles of the magnet.

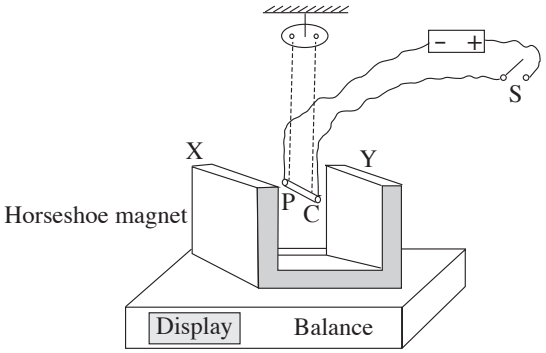


Figure 1

When you solve this problem, ignore Earth's magnetic field and the forces exerted on the wires.

When the switch S is closed, a current I passes through the rod PC, and the reading on the balance increases.

א. Determine the direction of the force that the magnetic field exerts on the rod PC: upward or downward. Explain your answer. (5 points)

ב. Determine the direction of the magnetic field: X → Y or Y → X.
Provide detailed reasoning. (5 points)

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

/Continued on page 8/

During an experiment the rod PC is rotated horizontally at an angle β relative to its initial position (see top view, Figure 2). During the experiment, a constant current, $I = 15A$, passes through the rod. The length of the rod PC is $\ell = 4cm$.

The balance reading, F, is recorded in units of newtons (N) for various angles β.

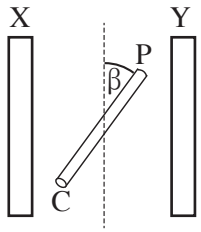


Figure 2

The following table shows a few of the results of this experiment:

$\beta(^o)$	0	36	48	72	90	120
cos β	1	0.81	0.67	0.31	0	− 0.5
F (N)	0.88	0.80	0.70	0.56	0.40	0.18

ג. Draw a graph in your notebook that describes the balance reading, F, as a function of $\cos\beta$. (8 points)

ד. Express the relation between the balance reading F and $\cos\beta$ in terms of the parameters B , ℓ , I , m , g (g is the magnitude of free fall acceleration). (6 points)

ה. Use the graph and the expression you developed to calculate the magnitude of the magnetic field B. (5 points)

ו. Calculate the mass of the magnet, m . ($4\frac{1}{3}$ points)

/Continued on page 9/

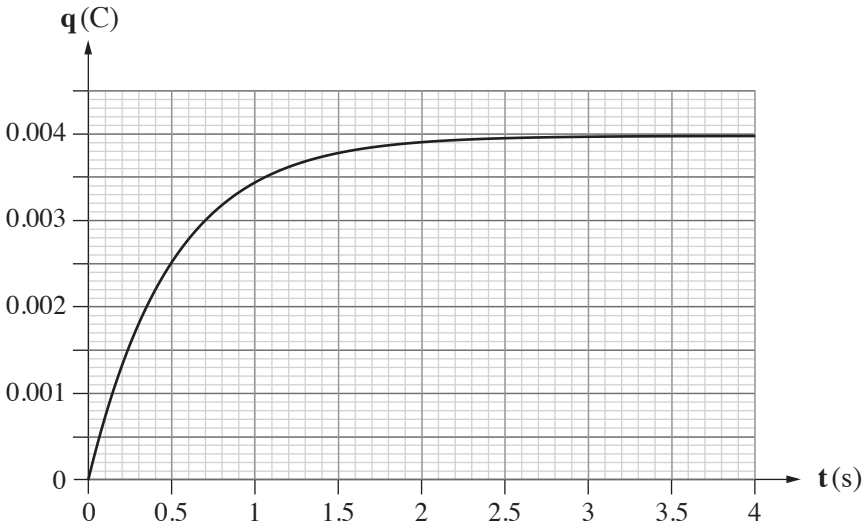
Capacitance

5. A student conducted an experiment in which he charged a capacitor in a series electric circuit. The circuit was composed of the capacitor whose capacitance was C, a battery with emf ε and negligible internal resistance, a resistor with a resistance $R = 1{,}000\Omega$, a switch, and ideal conductive wires.

א. Draw a diagram of the electric circuit. (3 points)

The student measured the quantity of charge on the capacitor as a function of time. His measurements are shown in the figure below.

Quantity of charge on the capacitor as a function of time



ב. The figure shows that the slopes of the tangents to the curve decrease as a function of time.

(1) What is the physical meaning of the slopes of the tangents to the curve?

(2) What is the <u>physical</u> reason that the slopes of the tangents are decreasing?

(9 points)

The formula describing the quantity of charge q on the capacitor as a function of time t, as it is being charged, is:

$$q(t) = \varepsilon \cdot C \cdot (1 - e^{-\frac{t}{\tau}})$$

Remember that τ is the 'time constant' [קבוע הזמן].

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

/Continued on page 10 /

ג. Based on the formula, prove that the quantity of charge on the capacitor was about 63% of the maximum quantity, after a time interval equal to the time constant τ has passed from the moment charging began. (5 points)

ד. What is the value of the time constant in the experiment that the student conducted? Explain. (6 points)

ה. Calculate the capacitance of the capacitor. (5 points)

ו. Calculate the emf of the battery. ($5\frac{1}{3}$ points)

/Continued on page 11/

Induction

6. A magnet is released from a point located above a conductive circular current loop [כריכה מעגלית] (see Figure 1). Assume that while it is falling the magnet does not turn and that the magnetic forces exerted on it are negligible. As a result, the magnet's motion approximates free falling.

The loop is connected to an electric circuit with a resistor R, and a voltage sensor V that is also connected to a computer. The sensor measures the voltage across the terminals of the resistor.

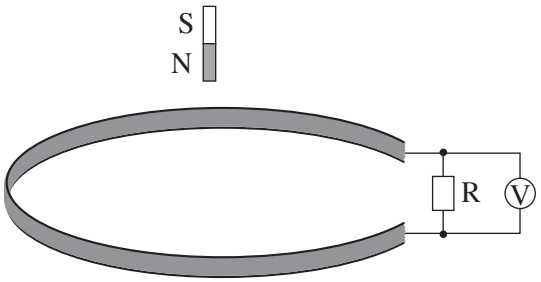


Figure 1

As the magnet falls, the following graph is displayed on the computer screen (see Figure 2, below).

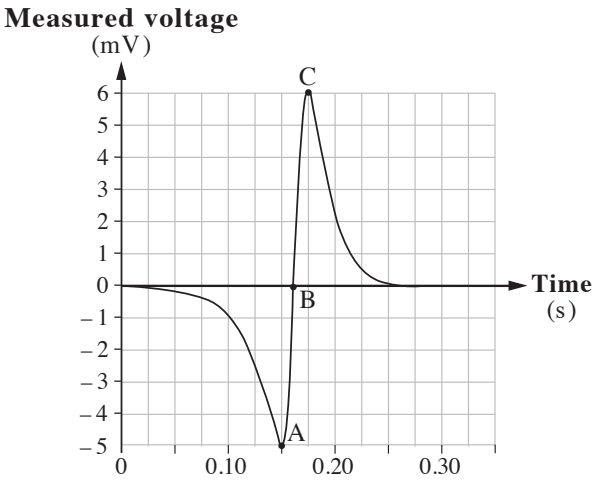


Figure 2

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

/Continued on page 12/

Use Faraday's Law, or Lenz's Law, or both laws to answer the following items.

א. Explain why voltage is generated across the terminals of the resistor. (5 points)

ב. What is the direction of the induced magnetic field generated in the loop as the magnet approaches the loop? Explain your answer. (6 points)

ג. As the magnet moves, the measured voltage changes from negative to positive. Explain why. (5 points)

ד. The highest voltage measured when the magnet exits the loop (Point C on the graph) is greater than the absolute value of the voltage when the magnet enters the loop (Point A on the graph). Explain why. (7 points)

ה. Unrelated to the data in this question, show that it is possible to represent magnetic flux [שטף מגנטי] in units of $V \cdot s$ (volt-seconds). (5 points)

ו. Use the graph to approximately calculate the change in magnetic flux during the first 0.15 seconds of the magnet's movement. ($5\frac{1}{3}$ points)

Good Luck!

בהצלחה!