State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2017
Exam number: 36381
Attachment: Data and formulas for 5-point Physics
English translation (3)

Physics
Reform for Meaningful Learning Program
Mechanics and Electricity

Instructions for examinees

א. Duration of the exam: Three and a half hours

ב. Exam structure and breakdown of points:

Part One	— Mechanics	— (20×2) —	40 points
Part Two	— Electricity	— (20×2) —	40 points
Part Three	— Additional Subjects in Mechanics and Electricity	— (20×1) —	20 points
		Total —	100 points

ג. Material that may be used during the exam:
(1) A calculator.
(2) The physics data and formulas 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, insert the appropriate values into the formulas.
Write your final answer in the appropriate measurement units. If you do not write out the formula or do not write out the formula with the inserted values or do not write 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 given to you in the question.
If necessary, you may also use basic constants, such as g for free-falling acceleration or e for elementary charge.
(4) In your calculations, use the value 10 m/s^2 for the magnitude of free-falling acceleration at the Earth's surface.
(5) Write your answers in pen. Writing in pencil or erasing with White-Out will preclude any possibility of appealing your score.
Use pencil for sketches only.

Write in the answer booklet only, on separate pages, everything you want to write as a draft (notes, calculations, etc.). Write the word "טיוטה" at the top of each draft page. Writing any sort of drafts on pages outside of the answer booklet may lead to the disqualification of your exam!

Good Luck!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ז, 2017
מספר השאלון: 36381
נספח: נוסחאות ונתונים בפיזיקה ברמה של 5 יח"ל
תרגום לאנגלית (3)

פיזיקה
על פי תכנית הרפורמה ללמידה משמעותית
מכניקה וחשמל

הוראות לנבחן

א. משך הבחינה: שלוש שעות וחצי.

ב. מבנה השאלון ומפתח ההערכה:

פרק ראשון	— מכניקה	(2 × 20) —	40 נקודות
פרק שני	— חשמל	(2 × 20) —	40 נקודות
פרק שלישי	— נושאים נוספים במכניקה וחשמל	(1 × 20) —	20 נקודות
		סה"כ —	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 מחשב, הצב את הערכים המתאימים בנוסחאות.
רשום את התוצאה שקיבלת ביחידות המתאימות.
אי-רישום הנוסחה או אי-ביצוע ההצבה או אי-רישום יחידות עלולים להפחית נקודות מהציון.
(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 לגודלה של תאוצת הנפילה החופשית על פני כדור הארץ.
(5) כתוב את תשובותיך בעט. כתיבה בעיפרון או מחיקה בטיפקס לא יאפשרו ערעור.
השתמש בעיפרון לסרטוטים בלבד.

כתוב במחברת הבחינה בלבד, בעמודים נפרדים, כל מה שברצונך לכתוב כטיוטה (ראשי פרקים, חישובים וכדומה). רשום "טיוטה" בראש כל עמוד טיוטה. רישום טיוטות כלשהן על דפים שמחוץ למחברת הבחינה עלול לגרום לפסילת הבחינה!

בהצלחה!

Questions

Note: Answer only five questions.

Part One — Mechanics

Answer two questions from Part One (Questions 1-3).
(Each question – 20 points; the point value of each item is given.)

1. A player came up to take a penalty kick at a soccer game. To mislead the goalkeeper, the player looked at one corner of the goal, but kicked the ball to the center of the goal. This technique is called a Panenka after a Czech player by that name. When kicked this way, the ball follows a parabolic trajectory on a plane that is perpendicular to the field, so that the projection of the trajectory on the field is perpendicular to the goal line (see Figure 1). Let us denote by:

- d — the ball's distance from the goal line before kicking the ball
- v_0 — the magnitude of the ball's initial velocity
- α — the angle between the direction of the initial velocity and the plane of the field

Air resistance is negligible.

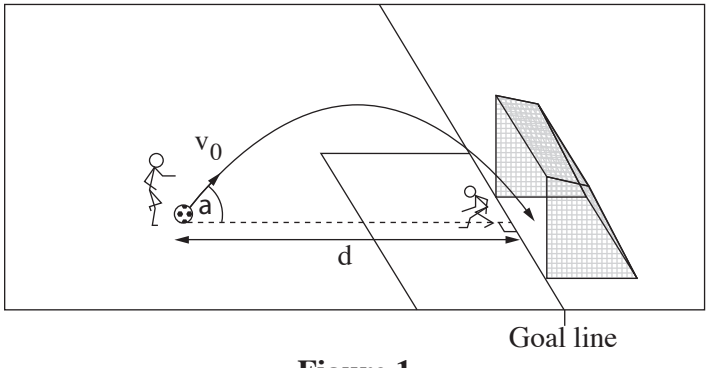
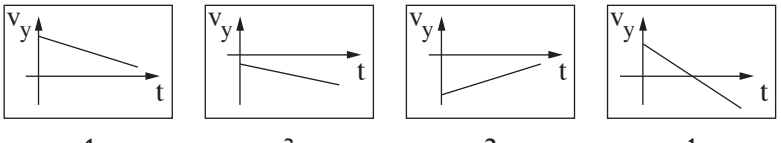


Figure 1

א. Determine which one of the four graphs 1-4 below correctly represents the vertical component of the ball's velocity as it moves through the air, as a function of time. Justify your answer. (4 points)



/Continued on page 3/

ב. Figure 2 shows the trajectory of a ball that made it into the goal. Points P and Q are marked on the trajectory. Given: Point Q is higher than Point P.

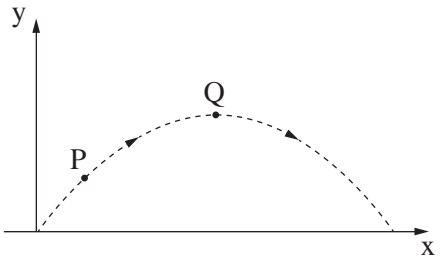


Figure 2

(1) Is the magnitude of the horizontal component of the ball's velocity at Point P less than, more than, or equal to the magnitude of the horizontal component of its velocity at Point Q? Explain your answer.

(2) Is the magnitude of the ball's acceleration at Point P less than, more than, or equal to the magnitude of its acceleration at Point Q? Explain your answer.

(6 points)

A player took a Panenka penalty kick at a distance of d = 11m from the goal line.
He gave the ball a velocity of $v_0 = 11.5\frac{m}{s}$ with an angle of $\alpha = 55^o$ above the horizontal.
Given: The goal's height is h = 2.44m.

ג. Prove that the kicked ball definitely entered the goal. Assume that the ball's movement was not disturbed (for example, by the goalkeeper). Treat the ball as a point object. (6 points)

ד. Another player kicked the ball from the same distance at the same angle, but gave the ball an initial velocity greater than v_0. Did the ball from this kick definitely enter the goal? Explain your answer.

There is no need to perform calculations. (4 points)

/Continued on page 4/

2. Students are investigating friction using a system composed of a box of mass M placed on a horizontal surface, a pulley, and a basket that can hold sand. The box is attached to the basket with a rope that passes over the pulley (see Figure 1).

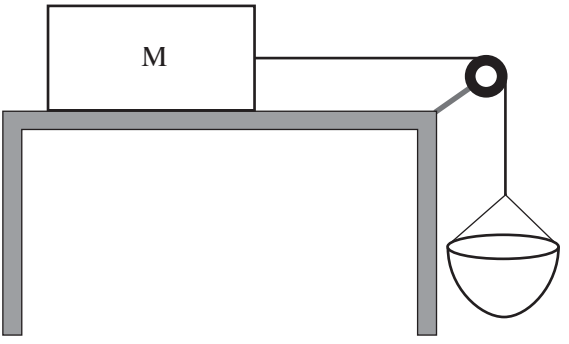


Figure 1

Friction with the air, rope mass, and pulley mass are negligible.

The system is at rest at the beginning of the experiment. The students add sand into the basket gradually and continuously, and at a certain moment the system starts moving.

Figure 2 shows a graph of the magnitude of the friction, f, exerted by the horizontal surface on the box, M, as a function of the weight of the basket with sand, W.

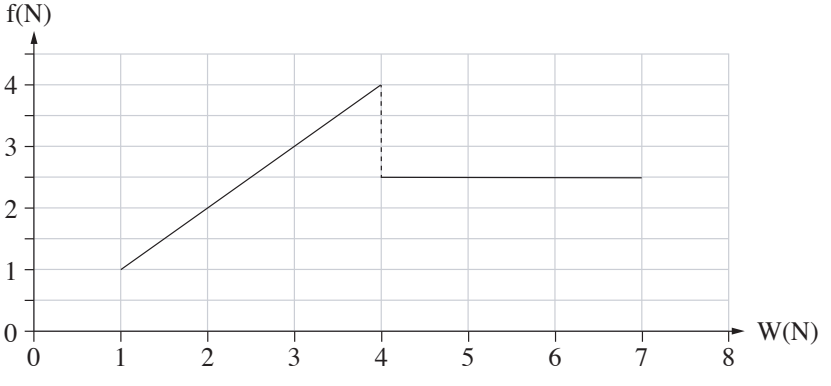


Figure 2

/Continued on page 5/

א. Without basing your answer on Figure 2, explain why the curve of the graph must pass through the origin of the axes. (2 points)

Given: M = 0.8 kg

ב. Calculate the friction coefficients (static and kinetic) between the box, M, and the surface. (6 points)

ג. Calculate the magnitude of the system's acceleration when W = 6N. (8 points)

ד. When the system shifted from a state of rest to a state of motion, did the tension in the rope increase, decrease or remain unchanged? Explain your answer. **There is no need to perform calculations**. (4 points)

/Continued on page 6/

3. Two boxes, A and B, whose masses are $m_A = 300gr$ and $m_B = 100gr$ are at rest on a smooth horizontal surface. There is a compressed spring between the boxes. A rod is attached to the top of each box, and a rope connecting the two rods prevents the boxes from moving (see Figure 1).
Given: The spring constant $k = 480\frac{N}{m}$; the length of the spring when compressed between the boxes is 10cm.
The mass of the spring is negligible.

Figure 1

At a certain moment the rope broke. This released the spring, and as it was released it pushed the boxes in opposite directions. After being pushed, the boxes, A and B, moved over the horizontal surface at the constant velocities u_A and u_B, and the spring fell vertically to the ground.
The length of the relaxed (loose) spring is 20 cm.
Items א and ב relate to the two-box and spring system during the period of time from the moment the rope broke up to the moment that the boxes disconnected from the spring.

א. Determine whether during this period of time the system's momentum was conserved. Justify your answer. (3 points)

ב. Determine whether the system's total mechanical energy was conserved during this period of time. Justify your answer. (3 points)

ג. Calculate the magnitude of the velocities u_A and u_B. (6 points)

At some point as it moved, Box A reached an inclined plane. The box ascended as far as Point C, whose height was $h_c = 0.1m$ above the horizontal surface (see Figure 1), and then descended.

ד. Prove that the inclined plane is not smooth. (5 points)

/Continued on page 7/

As Box A moved over the horizontal surface after the spring fell, a small pendulum was hung on the rod attached to this box. The pendulum was hung on the box in a way that did not affect the box's movement.

ה. Look at Illustrations I-III in Figure 2, below. Determine which illustration correctly describes the pendulum's state as Box A moved over the horizontal surface. Explain your answer. (3 points)

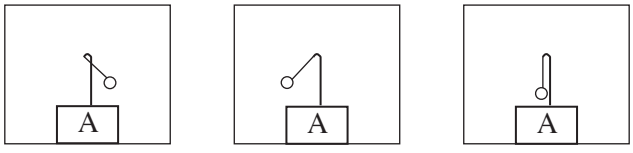


Figure 2

/Continued on page 8/

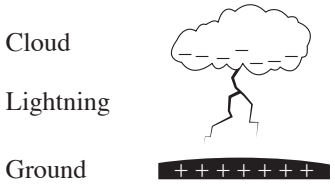
Part Two — Electricity

Answer two questions from Part Two (Questions 4-6).
(Each question – 20 points; the point value of each item is given.)

4. Lightning is an awe-inspiring natural phenomenon. It is a sudden electric discharge that often occurs between a cloud and the ground.

Sometimes, as the cloud moves, friction between ice particles causes electric separation of charges.

In most cases, the positive ions accumulate at the top of the cloud and the negative ions at its base. At the same time, charge separation also occurs on the ground beneath the cloud (see figure). This question relates to this type of cloud.



א. Explain why the ground under the cloud becomes positively charged.

(3 points)

Let us treat the area between the ground and the cloud's base as an area with a uniform electric field.

ב. Describe the electrostatic field lines and the equipotential lines in the area between the cloud and the ground.

Illustrate your answer with a schematic drawing of these lines.

(4 points)

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

/Continued on page 9/

The following table shows the values of the electric potential at several elevations (note the units).

y = 0 at ground level.

y(m)	0	100	200	300	400	500
V(kV)	0	−20.6	−39	−60.8	−79.4	−101

ג. In your answer booklet, draw a graph of the electrical potential as a function of elevation. (5 points)

The relation between the intensity of a uniform electric field and the potential difference between two points within it is defined as:

$$E = -\frac{\triangle V}{\triangle x}$$

ד. Use the graph to find the intensity of the electric field. (4 points)

Given: The distance between the base of the described cloud and the ground is d = 500m.

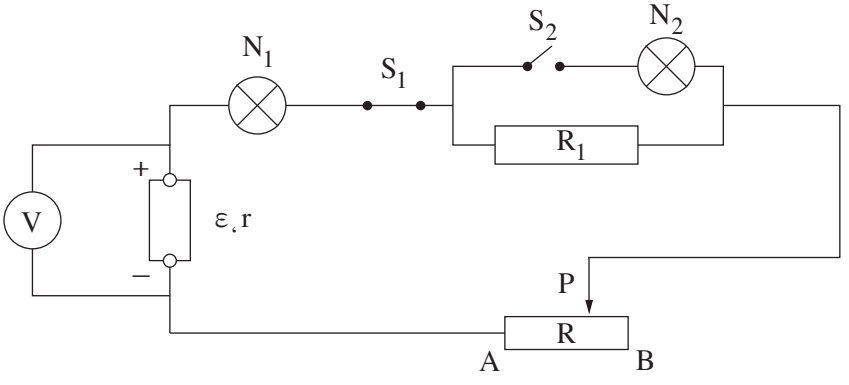
ה. Will a proton that leaves the cloud's base at a velocity of $2 \cdot 10^5 \frac{m}{s}$ make it to the ground? Explain.

Ignore the changes in gravitational potential energy in your calculation.

(4 points)

/Continued on page 10 /

5. The electrical circuit in the figure below contains the following components: a voltage source with an emf of ε and internal resistance r; two bulbs, N_1 and N_2; two switches, S_1 and S_2; a fixed resistor $R_1 = 200\Omega$; a variable resistor R; an ideal voltmeter and ideal wires. The bulb N_1 has the values 40W, 100V written on it.



<u>In the first step</u> Switch S_1 is closed and Switch S_2 is open, as shown in the figure. In this state, the voltmeter reads V = 220V and the bulb N_1 lights up according to the values written on it.

א. Calculate the intensity of the current through the fixed resistor R_1. (3 points)

ב. What must the resistance of the variable resistor R be to allow Bulb N_1 to light up according to the values written on it? (4 points)

ג. Given: Electrical efficiency in this circuit is 88%.
Calculate the <u>emf</u> and the <u>internal resistance</u> of the voltage source. (5 points)

<u>In the second step</u> Switch S_2 was also closed (now both switches are closed). Neither of the bulbs burned out.

ד. Determine if, after closing Switch S_2, the light intensity in Bulb N_1 increased, decreased, or remained unchanged.
<u>Explain your answer</u>. (5 points)

ה. Did the voltmeter reading change after closing Switch S_2?
If not, explain why.
If it did, determine in which direction (toward A or B) the slider P on the variable resistor R must be moved so that the voltmeter reading will go back to V = 220V. <u>Explain your answer</u>. (3 points)

/Continued on page 11/

6. Point A is located in a uniform magnetic field whose intensity is $B = 6.8 \cdot 10^{-4}\,T$; its direction is marked in the figure below. In a process called pair production, two particles, 1 and 2, are created at time t_0 from a particle located at Point A. (Pair production is briefly explained at the end of this question; however, you do not need to understand it to solve this question.) Immediately after being created, the two particles move in the same direction (see $v_{0,1}$ and $v_{0,2}$ in the figure below).

Given: The mass of each particle is $m = 9.11 \cdot 10^{-31}\,kg$

Assume there is a vacuum in the space where the particles are moving.

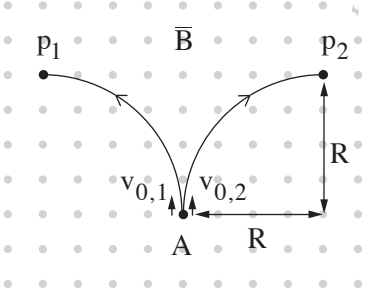


Figure 1

From the time $t_0 = 0$ until $t_1 = 1.3 \cdot 10^{-8}\,s$ each of the particles moves along a quarter circle. At time t_1, Particle 1 reaches Point P_1, and Particle 2 reaches Point P_2 (see figure).

א. Explain why the particles' trajectories up to time t_1 are circular. (3 points)

The radius of each of the two circular trajectories is R = 5cm.

ב. Calculate the magnitude of each particle's velocity. (4 points)

ג. Calculate the magnitude of each particle's electrical charge. (4 points)

/Continued on page 12/

When it reaches Point P_2, Particle 2 passes between Plates L_1 and L_2, which generate a uniform electric field.

The plates are parallel to each other and perpendicular to the plane of the page. The particle continues moving between the plates in a straight line (see Figure 2). Particle 1 continues moving in a circular trajectory.

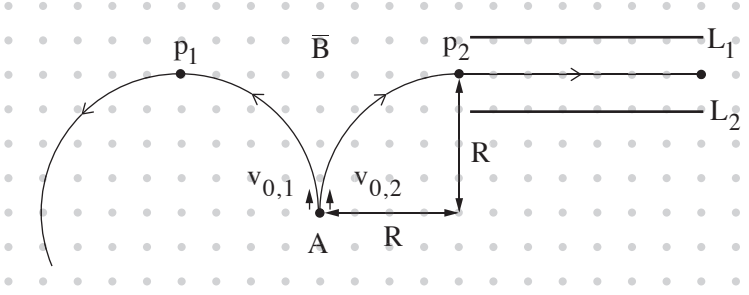


Figure 2

ד. **(1)** What is the intensity of the uniform electric field between the plates?

(2) What is the direction of the uniform electric field between the plates: from Plate L_1 to Plate L_2 or from Plate L_2 to Plate L_1? Explain.

(6 points)

ה. What shape will the trajectory of Particle 2 be if the magnetic field disappears (while the particle is still between the plates)? Explain your answer. (3 points)

Note: *Pair production* is a physical process in which a particle is annihilated and two particles are instantly created in its place. For example a photon is annihilated and an electron and a positron are created in its place. Positrons are similar to electrons but they have a positive charge, so they are also known as anti-electrons.

/Continued on page 13/

Part 3 — Additional Subjects in Mechanics and Electricity

Answer one question in this part (Questions 7-9).

(Each question – 20 points; the point value of each item is given.)

Harmonic Motion

7. A cart is at rest at Point O on a horizontal surface. A relaxed horizontal spring is tied to the cart at one end, and its other end is tied to a fixed point. Given: The cart's mass is 1.2kg; the spring constant is $30\frac{N}{m}$. The spring's mass is negligible.

The cart is drawn from Point O to Point A, extending the spring by 10 cm, and then released from rest. Friction forces in the system are negligible.

א. Determine whether the nature of the cart's motion as it travels from A to O is of uniform velocity, uniformly accelerated, or non-uniformly accelerated? Explain your answer. (3 points)

ב. Calculate how much time passed from the moment the cart was released at Point A until it first passed through Point O. (4 points)

After the cart arrives at Point O it continues moving until it stops for a moment at Point B, and then starts moving back toward Point O.

ג. Determine the cart's direction of velocity and its direction of acceleration (toward B or toward O) as it moved from Point B toward Point O. Justify each of your answers. (5 points)

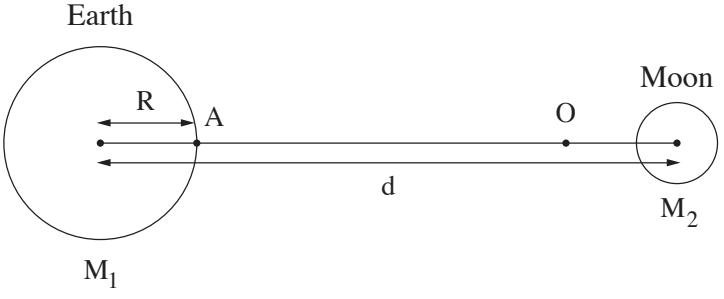
ד. Find the magnitude of the cart's velocity and the magnitude of the cart's acceleration at the moment it passed through Point O. (5 points)

ה. Is it possible that at some point the cart's velocity was zero, but its acceleration was not zero? Explain your answer. (3 points)

/Continued on page 14/

Gravity

8. This question relates to the system of the earth and the moon, but ignores their motion and the effects of other celestial bodies on this system. The figure below shows the earth and the moon in cross-section.
The figure is not drawn to scale.



Let us denote by:

M_1 — the earth's mass M2 — the moon's mass R — the earth's radius

d — the distance between the center of the earth and the center of the moon

g — the magnitude of free-fall acceleration on Earth

Given: $M_2 = \frac{M_1}{81}$; d = 60R

Point O is located on the line that connects the center of the earth and the center of the moon (see figure).

At this point, an object that is placed at rest will remain at rest.

א. Express the distance of Point O from the center of the earth in terms of R. (6 points)

A spacecraft with mass m is launched from Point A on Earth (see figure) to the moon.

ב. Express, in terms of R, m, and g, the minimal energy, E, that must be applied to the spacecraft to bring it to Point O.

Note: Take into account the effects of the earth and the moon on the spacecraft. (10 points)

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

/Continued on page 15/

On December 21, 1968, the spacecraft Apollo 8 was launched into space, and its crew was the first to orbit the moon.

103 years earlier, Jules Verne described a journey similar to that of the Apollo 8 in his book *From the Earth to the Moon*.

In response to the question "Is it possible to send a projectile to the moon?" Jules Verne's book proposes the following answer (loosely translated):

"It is possible to send a projectile to the moon if it is given an initial velocity of approximately $v = 11 \frac{km}{s}$.

This velocity is sufficient for the projectile to reach the point where the forces exerted on it by the earth and the moon are equal in magnitude. Beyond this point, the earth will no longer pull on the projectile, and only the moon will pull it, so if the projectile passes this point on its way to the moon, it will indeed reach the moon."

ג. Determine whether this entire description is correct.

Justify your answer. **There is no need to perform calculations.**

(4 points)

/Continued on page 16/

Capacitance

9. A student built an electrical circuit that can charge and discharge a parallel-plate capacitor. The components of this circuit are: an ideal voltage source with an emf $\varepsilon = 8V$; two resistors R_1 and R_2; two switches, S_1 and S_2; a capacitor whose plates are labeled A and B; an ideal ammeter, and ideal wires.

This circuit is shown in Figure 1, below.

Given: The resistance of the resistor R_1 is 1000Ω and it is greater than the resistance of the resistor R_2.

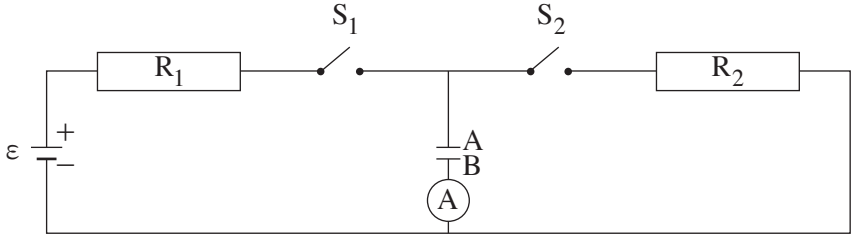


Figure 1

At time t = 0 the student closed Switch S_1 (Switch S_2 remained open) and the capacitor began charging.

א. Calculate the intensity, I_0, of the current that flowed through the ammeter at the moment at which the switch was closed. (3 points)

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

/Continued on page 17/

Figure 2, below, shows a graph of current intensity, i, as a function of time, t, [i(t)], while the capacitor was charging.

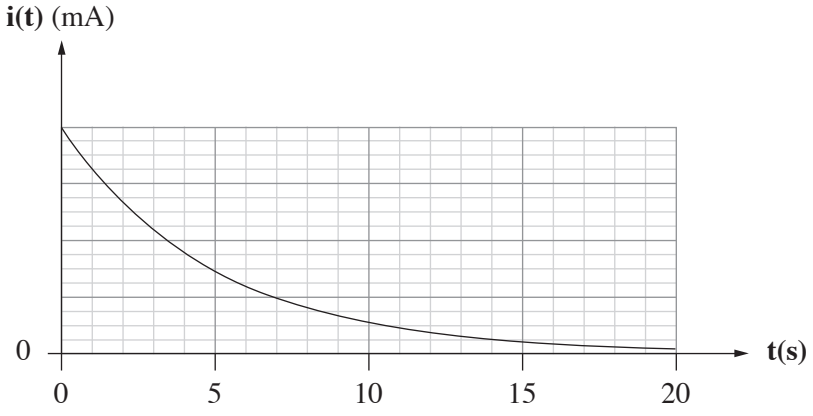


Figure 2

ב. Use the graph to find the time constant τ_1 for the charging circuit (the time constant is $\tau = R \cdot C$). (4 points)

ג. Find the charge Q (magnitude and sign) on each of the capacitor plates, A and B, when it is fully charged. (6 points)

After a long while, when the capacitor had been fully charged, the student opened Switch S_1 and closed Switch S_2.

ד. Determine whether τ_2, the time constant for discharging, is greater than, smaller than, or equal to τ_1, the time constant for charging. Explain your answer. (3 points)

The student drew a graph which described the current intensity, i, as a function of time, t, while the capacitor was being discharged.

ה. Determine whether the area enclosed by the curve and the horizontal axis in the graph that the student drew is greater than, smaller than or equal to the area enclosed by the curve and the horizontal axis in Figure 2. Explain your answer. (4 points)

Good Luck!

בהצלחה!