State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2018
Exam number: 036201, 656
Attachment: Data and formulas for 5-point Physics
English translation (3)

Physics
Mechanics, Optics and Waves
for 5 points

Instructions for examinees

א. Duration of the exam: Two and a half hours (150 minutes).

ב. Exam structure and breakdown of points:

This exam has two parts.

Part One — Mechanics	—	3×25	— 75 points
Part Two — Optics and Waves	—	$2 \times 12\frac{1}{2}$	— 25 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.
(Answers will be graded in the order that they appear in the answer booklet.)

(2) In the solutions to 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.
In your answers, write the appropriate units.
If you do not write out the formula or write out the formula with the inserted values or write the units, points may be deducted from your score.

(3) When you are asked to express a value using data provided in the question, write out a mathematical expression that includes all or some of the given data. When necessary, you may also use basic constants, such as the free-falling acceleration g or the elementary charge e.

(4) In your calculations, use the value 10 m/s^2 for free-falling acceleration.

(5) Write your answers in pen. Writing in pencil or erasing with White-Out will prohibit any possibility of appealing your score. You may use a pencil for drawings only.

Write in the answer booklet only, on separate pages, everything that 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 draft material outside the test booklet may lead to the disqualification of your exam!

Good Luck!

מדינת ישראל
משרד החינוך
סוג הבחינה: בגרות
מועד הבחינה: קיץ תשע"ח, 2018
מספר השאלון: 036201, 656
נספח: נתונים ונוסחאות בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

פיזיקה
מכניקה, אופטיקה וגלים
לתלמידי 5 יחידות לימוד

הוראות לנבחן

א. משך הבחינה: שעתיים וחצי (150 דקות).

ב. מבנה השאלון ומפתח ההערכה: בשאלון זה שני פרקים.

פרק ראשון	— מכניקה	25×3 —	75 נקודות
פרק שני	— אופטיקה וגלים	$12\frac{1}{2} \times 2$ —	25 נקודות
	סה"כ	—	100 נקודות

ג. חומר עזר מותר בשימוש:

(1) מחשבון.
(2) נספח נתונים ונוסחאות 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 את 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, 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

Part One — Mechanics (75 points)

Answer three of the questions 1-5.

(Each question – 25 points; the point value of each item is given.)

1. For a high-school physics investigative project, the students decided to examine the motion of objects thrown vertically. To do this, they went to the top of a tower of height H and then simultaneously threw three identical balls: A, B, and C.

Ball A was thrown downward with an initial velocity of magnitude v_0.

Ball B was thrown upward with an initial velocity of magnitude equal to the magnitude of Ball A's initial velocity.

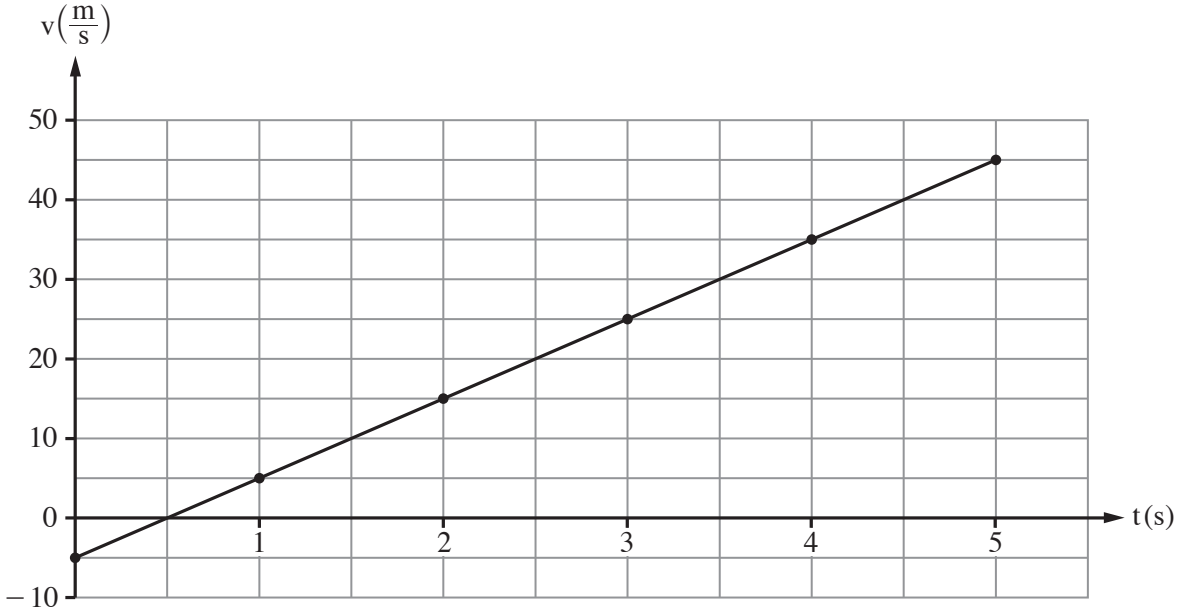
Ball C was released from a state of rest.

The three balls did not collide while they were moving.

The students assigned the positive vertical axis of their graphs to the downward motion.

They drew a graph of velocity vs. time for one of the balls from the moment it was thrown until it was about to hit the ground, as shown in the following diagram.

Ball Velocity as a Function of Time



/Continued on page 3/

In Items א-ד, assume that the frictional force between the balls and the air can be ignored.

א. Determine whether the graph describes the velocity of Ball A, Ball B, or Ball C. Explain your answer. (5 points)

ב. Calculate the height of the tower, H. (5 points)

ג. Calculate the vertical distance between the location of Ball A and the location of Ball B at time $t = 2s$. (6 points)

On the same set of axes, the students added graphs corresponding to the other two balls.

ד. Explain the physical meaning of each of the following values (1) - (3), and determine which of these have identical numeric values for all three graphs.

(1) The slope of the graph

(2) The point of intersection of the graph with the velocity axis

(3) The area enclosed between the graph and the time axis

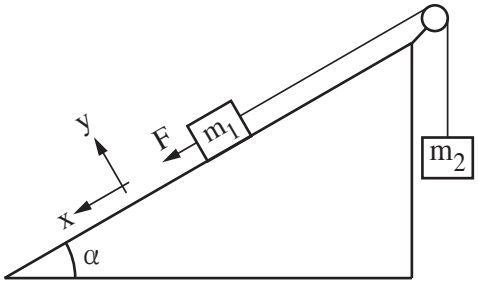
(6 points)

ה. For this item, assume there was a frictional force between the ball and the air, of a magnitude that was constant and smaller than the weight of the ball. Remember, all the balls are identical.

Determine whether the magnitude of the velocity of Ball A at the moment it strikes the ground is **less** than, **greater** than, or **equal** to, the magnitude of the velocity of Ball B at the moment it strikes the ground. Explain your answer using energy considerations or kinematic considerations. (3 points)

/Continued on page 4/

2. A student in a physics laboratory constructed the system shown in the diagram.



The system is composed of two bodies whose masses are m_1 and m_2.
Body m_1 lies on a <u>smooth</u> inclined plane that slopes at an angle α. Body m_2 is hanging and is tied to Body m_1 by a string that runs over a frictionless pulley (see diagram).
The string's length is constant, and the bodies never reach the pulley at any time.
Air resistance, the pulley's mass, and the string's mass can all be ignored.
The student held the system at rest. At a certain moment, she released the system from rest, and at that moment she began to exert a constant force of magnitude F on Body m_1 in the downward direction of the inclined plane and parallel to it, as shown in the diagram (this direction is defined as positive). Body m_1 moved down the inclined plane, and the student measured the acceleration of the system.

א. Sketch in your answer booklet a diagram of the forces acting on <u>each</u> of the two bodies during their motion. Label each force with its name. (4 points)

ב. Develop a linear expression (of the form $y = Ax + B$) for the magnitude of the acceleration, a, as a function of the magnitude of the force F.
Express your answer in terms of g, α, m_1, m_2, and F. (6 points)

The student repeated the experiment several times. Each time she changed the magnitude of the force F and measured the magnitude of the acceleration a. The results obtained are shown in the following table.

F(N)	20	30	40	50	60
$\mathbf{a}\left(\frac{m}{s^2}\right)$	3.0	5.0	7.4	9.1	12.5

ג. In your answer booklet, sketch a graph of a (the acceleration of the system) as a function of the force F. (7 points)

Given: The masses of the two bodies are equal, $m_1 = m_2 = m$.

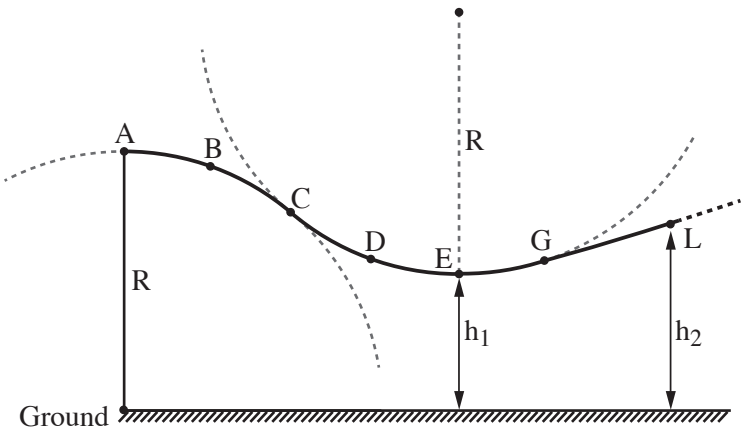
ד. Using the graph that you sketched, calculate the mass m. (5 points)

ה. Using the graph, determine at what magnitude of force F will the system move with a uniform motion (constant velocity). <u>Explain your answer</u>. (3 points)

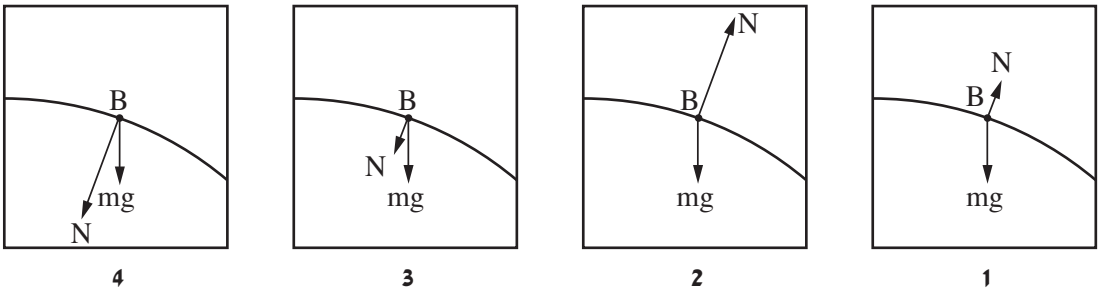
/Continued on page 5/

3. The diagram below shows a ski slope that is composed of three sections: AC, CG, and GL. The first two sections, AC and CG, are circular arcs of radius R. The third section, GL, is a non-circular path. In sections AC and CG, the friction between the skier and the slope can be ignored, but starting from point G, there is friction that cannot be ignored.

A skier starts moving from rest at point A. He moves only by sliding and does not use ski poles to aid him. Throughout his entire motion, the skier never loses contact with the slope. The air resistance can be ignored.



א. Determine which of the four figures 1-4 below correctly represents the diagram of forces acting on the skier at point B. Explain your answer. (6 points)



ב. **(1)** Determine whether the acceleration of the skier at point D has a tangential component. Explain your answer.

(2) Copy the circular section CG to your answer booklet (an approximate sketch), and add to the sketch an arrow that describes the resultant acceleration of the skier at point D (it is not necessary to actually calculate it).

(5 points)

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

/Continued on page 6/

Given: R = 60m, and the mass of the skier with his ski equipment is m = 80kg.

The height of point E above the ground is $h_1 = 32m$ (E is the lowest point on the slope).

ג. Calculate the magnitude of the skier's velocity as he passes through point E. (4 points)

ד. Calculate the force (magnitude and direction) that the skier exerts on the track at point E. (6 points)

Given: The total work of the frictional force from point G to the point where the skier stops is 20kJ.

The height of point L above the ground is $h_2 = 36m$.

ה. Determine whether the skier reached point L. Explain your answer using a calculation. (4 points)

/Continued on page 7/

4. Until the eighteenth century, the speed of fast objects such as rifle bullets could not be measured. In 1742, the English scientist Benjamin Robins invented a method for measuring the speed of bullets using a ballistic pendulum.

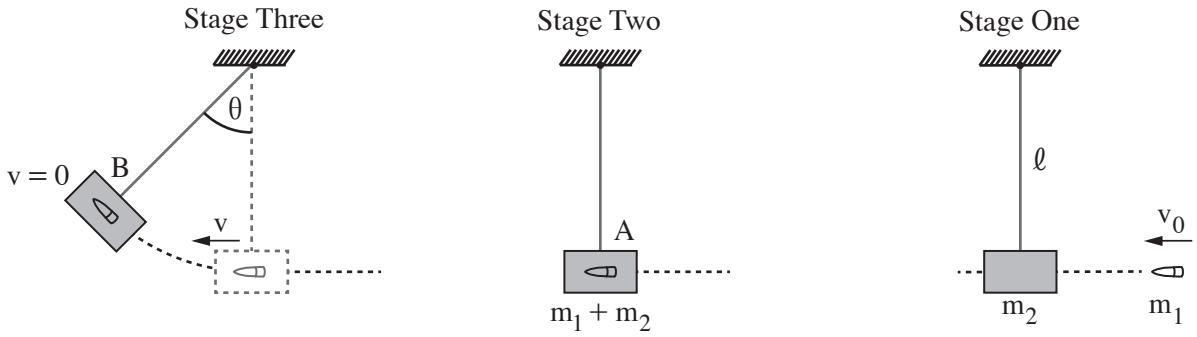
The diagram below depicts this method in three stages.

In the first stage, a bullet of mass m_1 is fired toward a body of mass m_2 that is hanging on a string of length ℓ.

In the second stage, the bullet strikes the body at point A with a horizontal velocity of magnitude v_0, penetrates the body, and comes to a stop inside it. The penetration time of the bullet into the body is extremely short, and therefore the movement of the body during this time can be ignored.

In the third stage, the body (with the bullet inside it) rises to point B and stops there momentarily. At this point, the angle of deviation of the string from the vertical [אנך] is θ.

Ignore the air resistance and the mass of the string.



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

/Continued on page 8/

The following items refer to the system consisting of the body + bullet.

א. Determine whether the momentum and the mechanical energy are conserved during the time interval from the moment the bullet strikes the body until the bullet stops within the body. Explain your answers. (4 points)

ב. Determine whether the momentum and the mechanical energy are conserved during the time interval from the moment the body begins to move until it stops momentarily at point B. Explain your answers. (4 points)

System data: mass of the bullet $m_1 = 0.015\text{kg}$, mass of the body $m_2 = 4.985\text{kg}$,
string length $\ell = 0.6\text{m}$, angle of maximum deviation of the string $\theta = 12^o$.

ג. Calculate the kinetic energy of the system immediately after the body (with the bullet inside it) started moving at point A. (7 points)

ד. Calculate v_0, the speed of the bullet at the moment it struck the body. (6 points)

ה. Calculate the mechanical energy that was "lost" due to friction. (4 points)

/Continued on page 9/

5. In August 2017, the Israeli space agency, together with the French space agency, launched a microsatellite called VENμS (Vegetation and Environment monitoring on a New MicroSatellite) for unique scientific observation and research purposes. The satellite is equipped with sophisticated technological devices, some developed and manufactured in Israel. From space, the satellite will photograph, among other things, fields and plots of land for research projects that monitor the state of soil, vegetation, and water quality.

Assume that the satellite will travel in a circular orbit of radius r = 7100 km.

א. Calculate the free-fall acceleration of the satellite during its motion (magnitude and direction). (6 points)

ב. Calculate the <u>period</u> and the <u>tangential velocity</u> of the satellite. (8 points)

In the future, an identical satellite may be placed into a circular orbit around the planet Mars.

Given: M_E and R_E are the mass and radius, respectively, of the planet Earth.
M_M and R_M are the mass and radius, respectively, of the planet Mars.
$M_E = 9.3M_M$, $R_E = 1.88R_M$.

In Items ג and ד, assume that the radius of the satellite's orbit around Mars will be equal to the radius of VENμS's orbit around Earth (r = 7100 km).

ג. Determine whether the free-fall acceleration of the satellite orbiting Mars will be **less than**, **greater than**, or **equal to** the acceleration that you calculated in Item א.
<u>Explain your answer</u>. (5 points)

A student claims that the periods of the two satellites are equal. He bases himself on Kepler's Third Law and on the fact that the radii of the two orbits are equal.

ד. Explain why the student's claim is <u>incorrect</u>. (3 points)

T_1 is the period of a satellite in an orbit of radius r_1 around Mars, and T_2 is the period of an identical satellite in an orbit of radius r_2 around Earth $(r_1 \neq r_2)$.

ה. Express the relation $\left(\frac{T_1}{T_2}\right)^2$ in terms of r_1 and r_2 . (3 points)

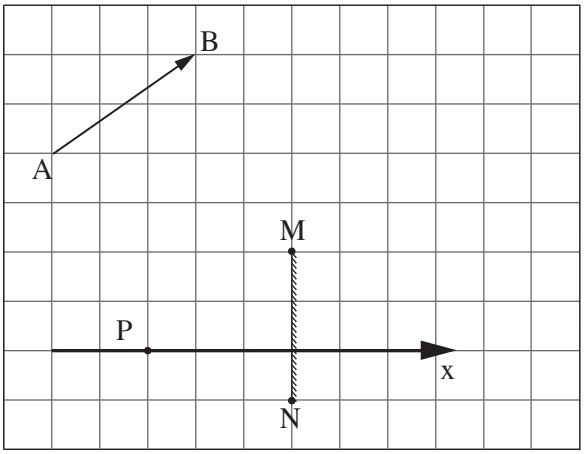
/Continued on page 10/

Part Two — Optics and Waves (25 points)

Answer two of the questions 6-8.

(Each question is worth $12\frac{1}{2}$ points; the point value of each item is given.)

6. The diagram below describes a cross-section of a plane mirror [מראה מישורית] MN, an arrow-shaped body AB, and a point P where the eye of an observer is located. The length of the side of each square in the diagram represents 20 cm in the real world.



א. Copy the diagram to your answer booklet. Each square in the diagram should be represented by a square in your answer booklet. (1 point)

ב. Add to the diagram in your answer booklet:

(1) the image A_1B_1 of the body AB that is formed by the mirror.

(2) the path of the ray that starts from the end A of the body, strikes the mirror, and is reflected from it to point P (the eye). Explain your considerations.

(5 points)

The observer (the eye) can move along the x-axis marked on the diagram.

ג. Determine whether he must move away from or closer to the mirror in order to see a larger part of the image A_1B_1 in the mirror. (3 points)

ד. Using the diagram, determine what the minimum distance (in centimeters) is from the point P that the eye needs to move along the x-axis in order to see the entire image A_1B_1 (note the scale). ($3\frac{1}{2}$ points)

/Continued on page 11/

7. A point light source S is located in the air (n = 1). A ray of light that is emitted from the source propagates in the air and strikes point P on the surface of a liquid in a container (see Figure 1). Some of the light is reflected and some is refracted. S is the only light source in the environment.

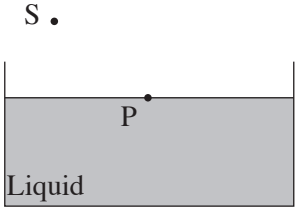


Figure 1

א. Copy the figure to your answer booklet and add to it:
(1) the ray of light that is emitted from the source S and strikes the liquid at point P.
(2) the path of the ray of light that is reflected from the surface of the liquid at point P.
(3) the path of the ray of light that is refracted into the liquid.
(1 point)

ב. On your drawing, label the angle of incidence of the ray of light with the letter α, the angle of reflection with the letter β, and the angle of refraction with the letter γ.
(1 point)

ג. Determine whether in this case the angle of reflection β is **greater than**, **smaller than**, or **equal to** the angle of refraction γ. Explain your answer. (3 points)

Given: $\alpha = 51^{o}$, and the angle between the refracted ray and the reflected ray is 90°.

ד. Calculate the index of refraction of the liquid. (4 points)

The point light source is then placed in the center of the base of the container holding the liquid. The light emerges from the liquid to the air only through part of the surface of the liquid (see Figure 2).

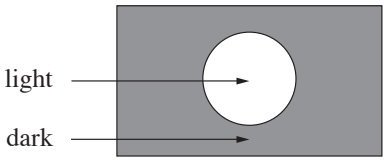


Figure 2

ה. Explain this phenomenon, based on the laws of refraction. ($3\frac{1}{2}$ points)

/Continued on page 12/

8. Figure 1 below describes a segment of rope, with a transverse wave [גל רוחב] propagating toward the right. Figure 2 describes the same segment of rope, 0.3 seconds after the moment described in Figure 1. The period of the wave is greater than 0.3 seconds.

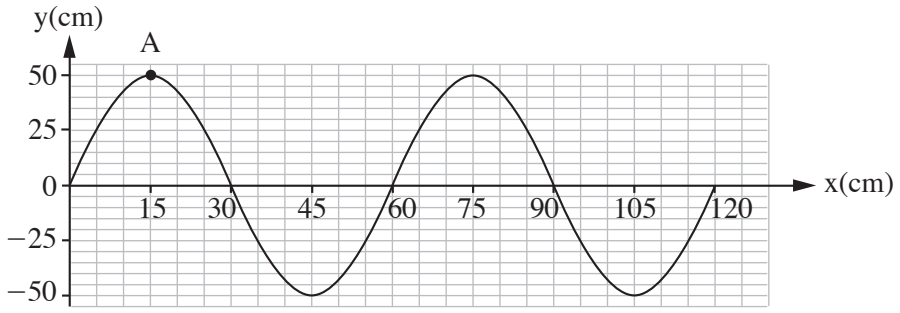


Figure 1

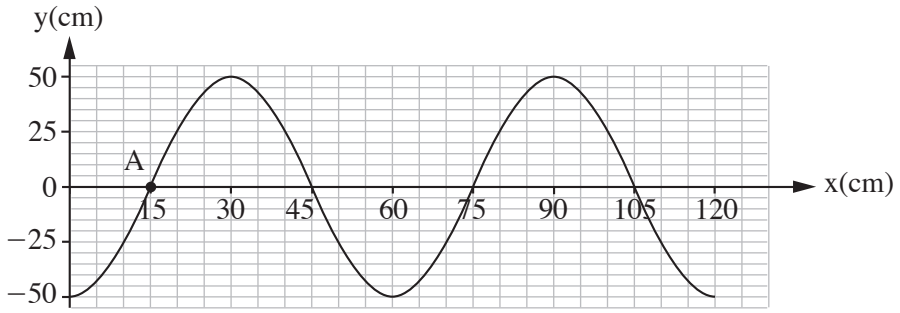


Figure 2

א. Explain the difference between a longitudinal wave [גל אורך] and a transverse wave [גל רוחב]. (2 points)

ב. Determine or calculate:

(1) the amplitude of the wave [משרעת הגל].

(2) the period of the wave.

(3) the frequency of the wave.

(4 points)

ג. Calculate the speed of propagation of the wave [מהירות ההתקדמות של הגל]. (3 points)

ד. Sketch in your answer booklet a rough graph that describes the height of point A as a function of time, during the time interval between the two states described in Figure 1 and Figure 2. ($3\frac{1}{2}$ points)

Good Luck!

בהצלחה!