State of Israel
Ministry of Education
Type of exam: *Bagrut*
Exam date: Summer 2018
Exam number: 36361
Attachment: Formulas and data for 5-point Physics
English translation (3)

Physics
Mechanics

Instructions for examinees

א. Duration of the exam: One hour and forty-five minutes.

ב. Exam structure and breakdown of points:
This exam has six questions. Answer three of them only.
Each question – $33\frac{1}{3}$ points; $3 \times 33\frac{1}{3} = 100$ points

ג. Material that may be used during the exam:
(1) A calculator.
(2) The physics formulas and data 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 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 units. If you do not write out the formula or do not insert the 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 the free-fall acceleration g or the elementary charge e.
(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. 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"ח, 2018
מספר השאלון: 36361
נספח: נוסחאות ונתונים בפיזיקה ל-5 יח"ל
תרגום לאנגלית (3)

פיזיקה
מכניקה

הוראות לנבחן

א. משך הבחינה: שעה וארבעים וחמש דקות.

ב. מבנה השאלון ומפתח ההערכה:
בשאלון זה שש שאלות, ומהן עליך לענות על שלוש שאלות 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, 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

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. 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.

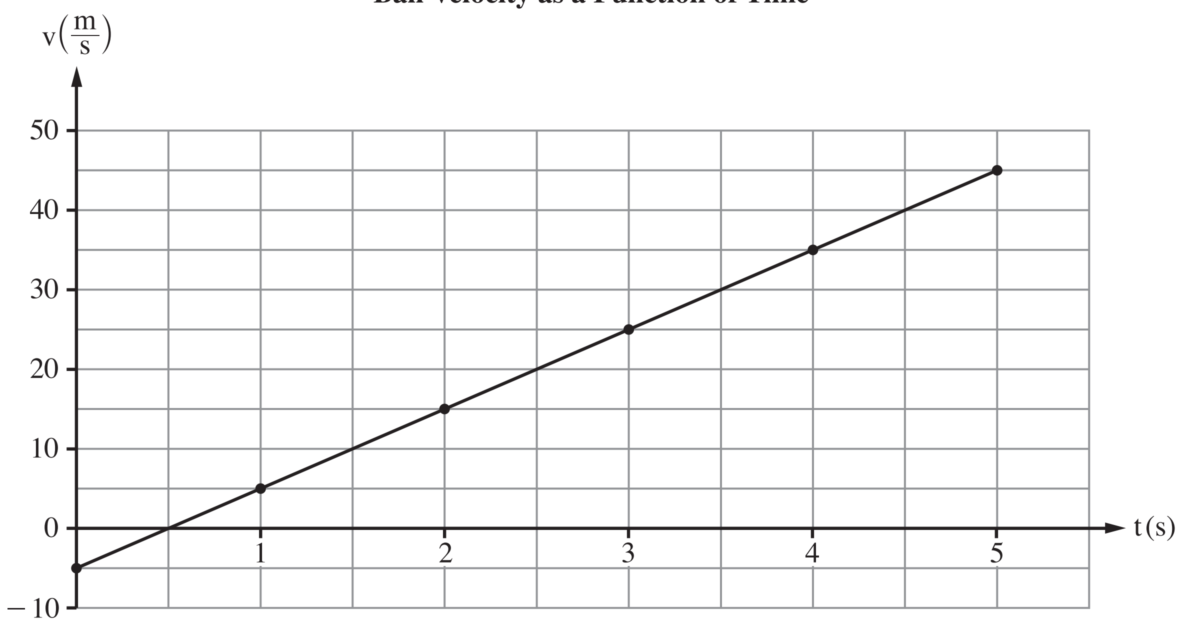
Ball C was released from a state of rest.

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



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

/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. (6 points)

ב. Calculate the height of the tower, H. (6 points)

ג. Calculate the vertical distance between the location of Ball A and the location of Ball B at time $t = 2s$. (8 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

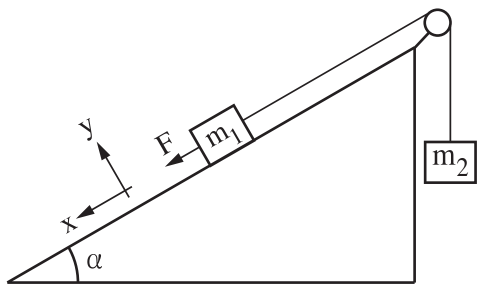
(3) The area enclosed between the graph and the time axis

(9 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. ($4\frac{1}{3}$ points)

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



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

/Continued on page 4/

The system is composed of two bodies whose masses are m_1 and m_2.

Body m_1 lies on a smooth 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 each of the two bodies during their motion. Label each force with its name. (5 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. (8 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
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. (8 points)

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

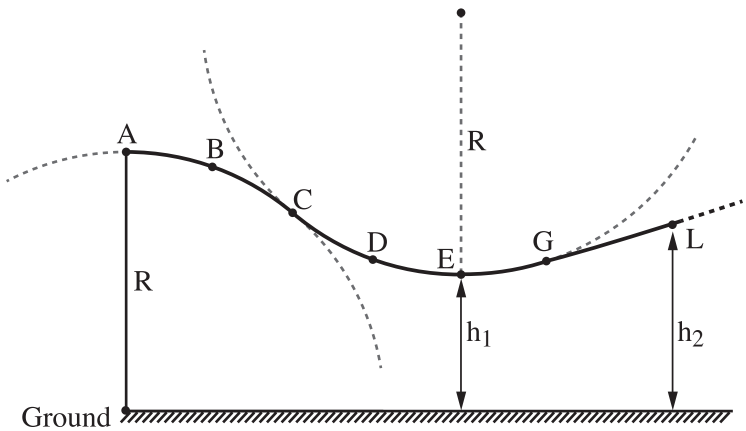
ד. Using the graph that you sketched, calculate the mass m. (7 points)

ה. Using the graph, determine at what magnitude of force F will the system move with a uniform motion (constant velocity). Explain your answer. ($5\frac{1}{3}$ points)

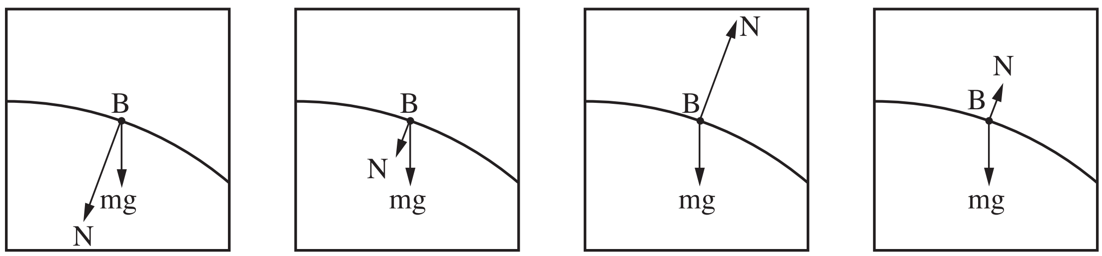
/Continued on page 5/

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 <u>cannot</u> 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 <u>correctly</u> represents the diagram of forces acting on the skier at point B. <u>Explain your answer</u>. (8 points)



4 3 2 1

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

(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).

(7 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. (5 points)

ד. Calculate the force (magnitude and direction) that the skier exerts on the track at point E. (8 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. ($5\frac{1}{3}$ points)

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 on the next page 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 .

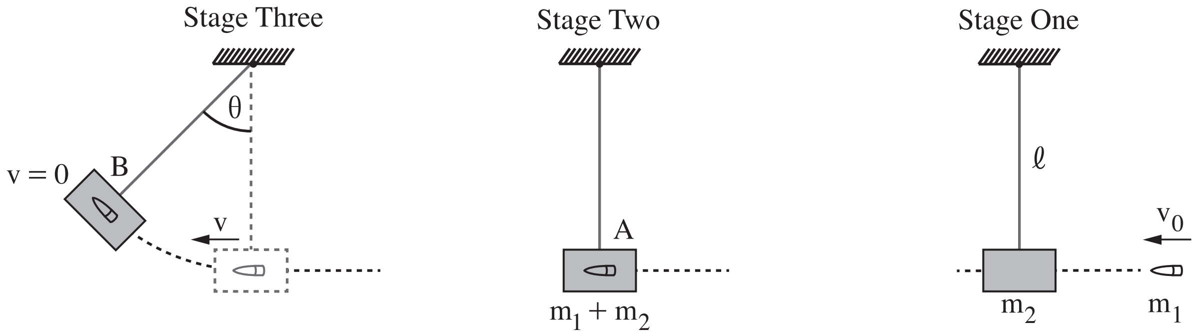
In the second stage, the bullet strikes the body at point A with a horizontal velocity of magnitude v_0, penetrates the body and comes to a stop inside it. The penetration time of the bullet into the body is extremely short, and therefore the movement of the body during this time can be ignored.

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 7/



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. (6 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. (6 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 $\theta = 12^{\circ}$.

ג. Calculate the kinetic energy of the system immediately after the body (with the bullet inside it) started moving at point A. (9 points)

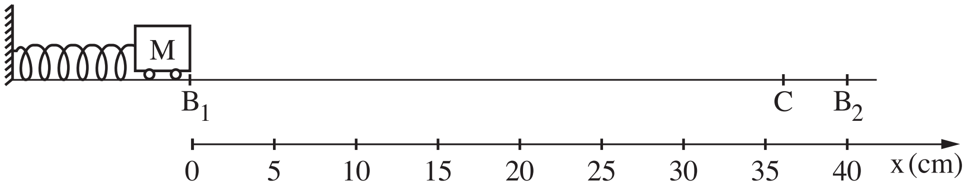
ד. Calculate v_0, the speed of the bullet at the moment it struck the body. (7 points)

ה. Calculate the mechanical energy that was "lost" due to friction. ($5\frac{1}{3}$ points)

/Continued on page 8/

Harmonic Motion

5. A wagon of mass M is located on a smooth horizontal surface. A spring that is compressed by 20cm relative to its relaxed length is attached at one end to the wagon and at its other end to a wall (see diagram).



The wagon was released from rest and was photographed from the moment it began to move at point B_1 until it stopped momentarily at point B_2. The wagon then continued to move between points B_2 and B_1 in simple harmonic motion. Using a sequence of pictures made at 0.1s intervals, the location of the wagon was measured with a ruler placed on the surface (see diagram). The table below shows the measurements.

Point	B_1								C		B_2
t(s)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
x(cm)	0	1.0	3.9	8.3	13.8	20.0	26.2	31.7	36.1	39.0	40.0

א. Determine the period [זמן המחזור] T and the amplitude [המשרעת] A of the simple harmonic motion of the wagon. (3 points)

ב. Using the data in the table, calculate the wagon's maximum speed. (7 points)

Given: The mass of the wagon is M = 3kg.

ג. Calculate the spring constant k. (7 points)

The wagon passed point C for the first time at $t_1 = 0.8s$ from the moment it was released at point B_1 (see table).

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

/Continued on page 9/

ד. **(1)** In your answer booklet, sketch a diagram of all the forces acting on the wagon at point C.

(2) Calculate the resultant force [הכוח השקול] (magnitude and direction) acting on the wagon.

(3) At time t_2, $(t_2 > 0.8s)$, a force identical (in magnitude and direction) to that which you calculated in Sub-item (2) acted on the wagon again. Determine what the smallest t_2 is. Explain your answer.

(10 points)

ה. Each of the following sub-items (1)-(3) describes a change made to the system described at the beginning of the question. After each change, the system is returned to its initial state.

For each of the sub-items (1)-(3), determine whether, as a result of the change, the period T of the motion will be **greater**, **smaller**, or **unchanged**.

Explain all your answers.

(1) The wagon is replaced with another wagon, M_1, whose mass is double, $M_1 = 2M$.

(2) At the beginning of the motion, the spring is compressed by 10cm relative to its relaxed state (rather than by 20cm).

(3) The existing spring is replaced by another spring, k_1 , whose spring constant is double, $k_1 = 2k$.

($6\frac{1}{3}$ points)

Gravitation

6. 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.

The satellite is equipped with two innovative jet engines that were developed in Israel and will be tested in space for the first time.

/Continued on page 10/

The satellite is intended to stay in space for about three and a half years:

In the first stage, the satellite will orbit at an altitude of 720km above the earth.

In the second stage, the satellite will orbit at an altitude of 410km above the earth.

Note: – Assume that the satellite travels in a circular orbit.

– Consider only the influence of the earth on the motion of the satellite. The influence of other celestial bodies can be ignored.

א. Calculate the free-fall acceleration of the satellite during its motion in the first stage (magnitude and direction). (7 points).

ב. Calculate the period and tangential velocity of the satellite while in orbit in the second stage. (10 points)

ג. For each one of the following three statements, determine whether it is **correct**, **incorrect**, or **cannot be determined**.

(1) The gravitational potential energy of the satellite in the first stage is greater than its gravitational potential energy in the second stage.

(2) The kinetic energy of the satellite in the first stage is greater than its kinetic energy in the second stage.

(3) The total energy of the satellite in the first stage is equal to its total energy in the second stage.

Explain all your answers.

(10 points)

Item ד below discusses a hypothetical satellite.

Consider a satellite that travels around the earth in a circular orbit of radius 6900 km.

The mass of the satellite is 300 kg.

ד. Calculate the minimum additional energy required to bring the satellite to a state at which it will break free of the influence of the earth's gravity. ($6\frac{1}{3}$ points)

Good Luck!

בהצלחה!