רפורמה

המינהל הפדגוגי — משרד החינוך — אגף בכיר בחינות

מחברת בחינה

לנבחנים ולנבחנות שלום,

נא לקרוא את ההוראות בעמוד זה ולמלא אותן בדייקנות. אי־מילוי ההוראות עלול לגרום לתקלות ואף להביא לידי פסילת הבחינה.

הבחינה נועדה לבדוק הישגים אישיים, ולכן יש לעבוד עבודה עצמית בלבד. בזמן הבחינה אין להיעזר בזולת ואין לתת או לקבל חומר בכתב או בעל פה.

אין להכניס לחדר הבחינה חומר עזר — ספרים, מחברות, רשימות — פרט ל"חומר עזר מותר בשימוש" המפורט בגוף השאלון או בהוראות מוקדמות של המשרד. כמו כן אין להכניס לחדר הבחינה טלפונים או מחשבים ניידים. שימוש בחומר עזר שאינו מותר יוביל לפסילת הבחינה.

כל חומר עזר שאינו מותר בשימוש, יש למסור למשגיח לפני תחילת הבחינה.

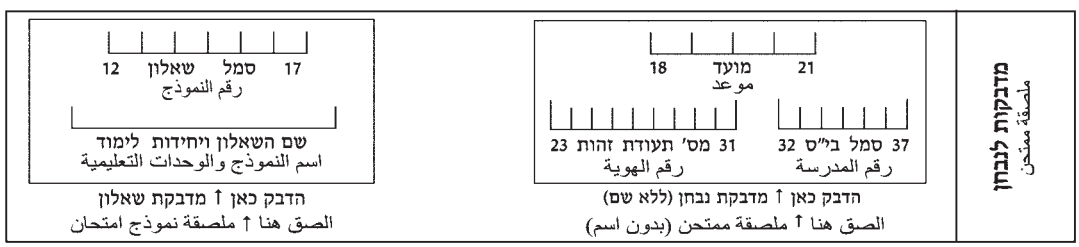
לאחר סיום כתיבת הבחינה יש למסור את המחברת למשגיח ולעזוב בשקט את חדר הבחינה.

יש להקפיד על טוהר הבחינות!

הוראות לבחינה

1. יש לוודא כי במדבקות הנבחן שקיבלת מודפסים הפרטים האישיים שלך, ובמדבקות השאלון שקיבלת מודפסים פרטי השאלון המיועד לך.
2. אם לא קיבלת מדבקה, יש למלא בכתב יד את הפרטים במקום המיועד למדבקת הנבחן.
3. אסור לכתוב בשולי המחברת (החלק המקווקו) משום שחלק זה לא ייסרק. מותר לכתוב משני צדי הדף במחברת הבחינה.
4. לטיוטה ישמשו אך ורק דפי מחברת הבחינה. **אין לתלוש או להוסיף דפים**. מחברת שתוגש לא שלמה תעורר חשד לאי־קיום טוהר הבחינות.
5. אין לכתוב שם בתוך המחברת, משום שהבחינה נבדקת בעילום שם.
6. אין להוסיף או לשנות שום פרט במדבקות, כדי למנוע עיכוב בזיהוי המחברת וברישום הציונים.

ב ה צ ל ח ה !



* הוראות בשפה הערבית מעבר לדף

* التّعليمات باللّغة العربيّة على ظهر الصّفحة

وزارة التّربية والتّعليم

الإدارة التّربويّة **القسم الكبير للامتحانات**

دفتر امتحان

تحيّة للممتحَنين وللممتحَنات !

الرجاء قراءة التعليمات في هذه الصفحة والعمل وفقًا لها بالضبط. عدم تنفيذ التعليمات قد يؤدّي إلى عوائق مختلفة وحتّى إلى إلغاء الامتحان. أُعدّ الامتحان لفحص تحصيلاتك الشخصيّة، لذلك يجب العمل بشكل ذاتيّ فقط. أثناء الامتحان، لا يُسمح طلب المساعدة من الغير ويُمنع إعطاء أو أخذ موادّ مكتوبة أو الحديث.

لا يُسمح إدخال موادّ مساعدة – كتب، دفاتر، قوائم – إلى غرفة الامتحان، ما عدا "موادّ مساعدة يُسمح استعمالها" المفصّلة في نموذج الامتحان أو في تعليمات مسبقة من الوزارة. كما لا يُسمح إدخال هواتف أو حواسيب محمولة إلى غرفة الامتحان. استعمال موادّ مساعدة غير مسموح بها يؤدّي إلى إلغاء الامتحان.

يجب تسليم كلّ مادّة مساعدة لا يُسمح استعمالها للمراقب قبل بدء الامتحان.

بعد الانتهاء من كتابة الامتحان، يجب تسليم الدفتر للمراقب، ومغادرة غرفة الامتحان بهدوء.

يجب المحافظة على نزاهة الامتحانات!

تعليمات للامتحان

1. يجب التأكّد بأنّ تفاصيلك الشخصيّة مطبوعة على ملصَقات الممتحَن التي حصلت عليها، وبأنّ تفاصيل نموذج الامتحان المعدّ لك مطبوعة على ملصَقات نموذج الامتحان التي حصلت عليها.
2. في حال عدم حصولك على ملصَقة، يجب ملء التفاصيل في المكان المعدّ لملصَقة الممتحَن، بخطّ يد.
3. لا يُسمح الكتابة في هوامش الدفتر (في المنطقة المخطّطة)، لأنّه لن يتمّ مسح ضوئيّ لهذه المنطقة. يُسمح الكتابة على جهتَي الصفحة في دفتر الامتحان.
4. للمسوّدة يمكن استعمال صفحات من دفتر الامتحان فقط. **يُمنع نزع أو إضافة صفحات**. الدفتر الذي يُسلّم وهو غير كامل سيثير الشكّ بعدم الالتزام بنزاهة الامتحانات.
5. لا يُسمح كتابة الاسم داخل الدفتر، لأنّ الامتحان يُفحص بدون ذكر اسم.
6. لا يُسمح إضافة أو تغيير أيّة تفاصيل في الملصَقات، وذلك لمنع عوائق في تشخيص الدفتر وفي تسجيل العلامات.

نتمنّى لك النجاح!

State of Israel

Ministry of Education

Type of Examination: Highschool matriculation

Exam date: Summer 2017

Exam Code: 036382

Appendices: – Physics data and formulas for 5 units

– appendix booklet

Physics – Research Questionnaire

In compliance with the Meaningful Learning reform program

Instructions

a. Duration of the exam: two hours.

b. Questionnaire structure and evaluation key: This questionnaire consists of ten questions. You have to answer **all** questions 1-8 and **one** of questions 9-10.

Total: 100 points.

c. Allowed materials: calculator and ruler.

d. Special instructions: pencil may be used for drawing/sketching only.

e. Pages 17-18 may be used as draft paper.

Write all your drafts (outlines, calculations and so forth) in the exam booklet only, on pages 17-18. Writing drafts on any paperother than the test booklet can disqualify your exam!

This questionnaire consists of 18 pages, appendix booklet and formula pages.

Good Luck!

Continue to next page ▶

מדינת ישראל

משרד החינוך

סוג הבחינה: בגרות לבתי־ספר על־יסודיים

מועד הבחינה: קיץ תשע"ז, 2017

סמל השאלון: 036382

נספחים: – נתונים ונוסחאות בפיזיקה לחמש יח"ל

– חוברת נספחים

תרגום לאנגלית (3)

פיזיקה – שאלון חקר

על־פי תכנית הרפורמה ללמידה משמעותית

הוראות לנבחן

א. משך הבחינה: שעתיים.

ב. מבנה השאלון ומפתח ההערכה:

בשאלון זה עשר שאלות. עליך לענות על **כל** השאלות 1–8, ועל שאלה **אחת** מבין השאלות 9–10.

סה"כ – 100 נקודות.

ג. חומר עזר מותר לשימוש: מחשבון וסרגל.

ד. הוראות מיוחדות: מותר להשתמש בעיפרון לסרטוטים בלבד.

ה. העמודים 17–18 משמשים כטיוטה.

כתוב **במחברת הבחינה בלבד**, בעמודים 17–18, כל מה שברצונך לכתוב **כטיוטה** (ראשי פרקים, חישובים וכדומה).
רישום טיוטות כלשהן על דפים שמחוץ למחברת הבחינה עלול לגרום לפסילת הבחינה!

בשאלון זה 18 עמודים, חוברת נספחים ונוסחאון.

בהצלחה!

ההנחיות בשאלון זה מנוסחות בלשון זכר, אך מכוונות לנבחנות ולנבחנים כאחד.

המשך מעבר לדף ◀

Part A: Exploring the passage of light through gratings

Please answer all of questions 1–8.

Theoretical background

The world as we know it is composed of material and radiation. The main component of radiation in the universe is electromagnetic radiation. Visible light is just a small section of this radiation.

The three main parameters by which we describe electromagnetic radiation are velocity v [m/sec], frequency f [Hz = 1/sec] and wavelength λ [m]. The relationship between them is given in the formula $v = \lambda \cdot f$.

Waves in general, and particularly light waves, demonstrate the phenomena of **superposition** and **interference**. This means that when two or more waves meet and pass through each other, a new pattern appears in the area where they overlap, that is different than the pattern each wave has when moving by itself.

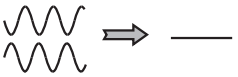
We distinguish between two different cases:

Constructive interference – when two or more waves reach the same place at the same time in the same phase, for example at the top point or at the low point of the wave. The displacements add up, as can be seen in Figure a1.

Constructive interference

Figure a1

Destructive interference – when two waves reach the same place at the same time in opposite phases, for example when one is at its top point and the other at its low point. Summing up the displacements can result in an equivalent displacement of zero, as can be seen in Figure a2



Destructive interference

Figure a2

Different combinations of waves passing through each other create unique and fascinating patterns, which can show us much about the nature and properties of waves.

A **diffraction grating** is an optical component which splits the light hitting it to different directions. A diffraction grating which transmits that light is called a **transmission grating**, whereas a diffraction grating which reflects that light is called a **reflection grating**.

In this experiment we will use two types of diffraction gratings: a transmission grating, which is a transparency with multiple vertical, narrow parallel slits with an interval d between them; and a CD which serves as a reflection grating. When a laser beam is projected on the grating, each of the slits in the grating functions as a point source of the light emerging from it. The interference pattern of the light emitting from the slits can be seen on a screen located at a distance L from the grating. The points on the screen represent constructive interferences, expressed as maximal light intensity.

Continue to page 3

The letter k marks the order of interference (the ordinal number of a point of light on the screen, counting from the central point): k = 0,1,2…

N* marks the density of the slits on the grating (called "the grating constant"), for which the following relationship holds: N* = 1/d.

The grating equation is the mathematical relationship between the grating constant (N*), the wavelength of the light (λ) and the scattering angle (α_k) of the light emerging from the slits of the grating.

(1) $$\mathbf{\sin(\alpha_k) = k \cdot \lambda \cdot N^*}$$

This formula is valid for both transmission gratings and reflection gratings, given the following conditions:

The laser beam is perpendicular to the grating plane; k is of a low order; for the distance d between the slits, $d \gtrsim \lambda$ and $d << L$.

The scattering angle (α_k), shown in Figure b, can be determined using the formula:

(2) $$\mathbf{\tan(\alpha_k) = \frac{x_k}{L}}$$

where x_k is the distance between the central point of light on the screen and the k point to its right or left.

Note: for smaller angles, the following relationship holds: $\mathbf{\sin(\alpha_k) \approx \tan(\alpha_k)}$

In this experiment, Δx is the distance between the central point of light and the two points of light adjacent to it, as described in Figure b.

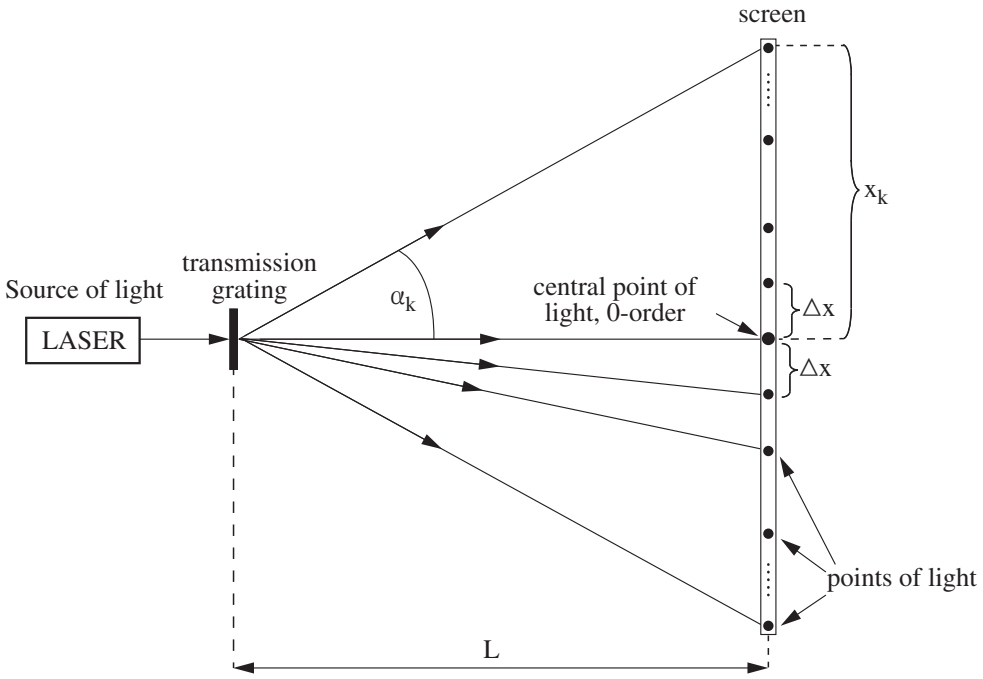


Figure b

Continue to page 4

Equipment used in the experiment

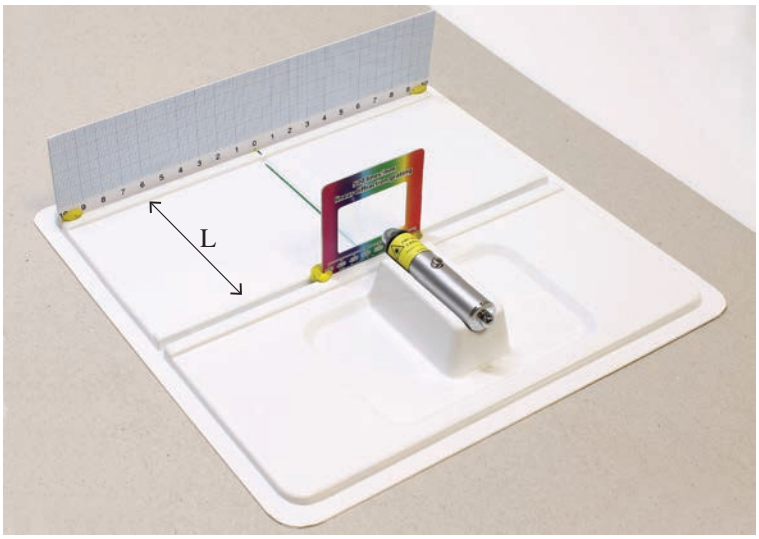
1. a surface on which the experiment apparatus will be placed
2. a laser pointer emitting a narrow light beam
3. three transparencies serving as transmission gratings: a grating transparency with a density of $190\frac{\text{lines}}{\text{mm}}$, a grating transparency with a density of $500\frac{\text{lines}}{\text{mm}}$, and a grating transparency with a density of $1000\frac{\text{lines}}{\text{mm}}$
4. a CD serving as a reflection grating
5. a calibrated ruler serving as a screen
6. a calibrated ruler, with a round hole for the laser beam, serving as a screen
7. a mass of plasticine
8. a transparent plastic container
9. a 500 ml bottle of mineral water

The experiment

Comments:

1. **The photographs of the experiment setup included in this booklet are only for illustration. You must perform the measurements required in the experiment only with the rulers found in 1:1 scale in the appendix booklet.**
2. **The distance between the grating and the ruler is L = 10 cm throughout the experiment.**

Photograph 1 shows the surface on which the laser pointer, the transparency used as a transmission grating and the ruler serving as a screen are placed. The transparency and the ruler are perpendicular to the surface plane.



Photograph 1 of the experiment setup with a grating transparency, L = 10 cm

Continue to page 5

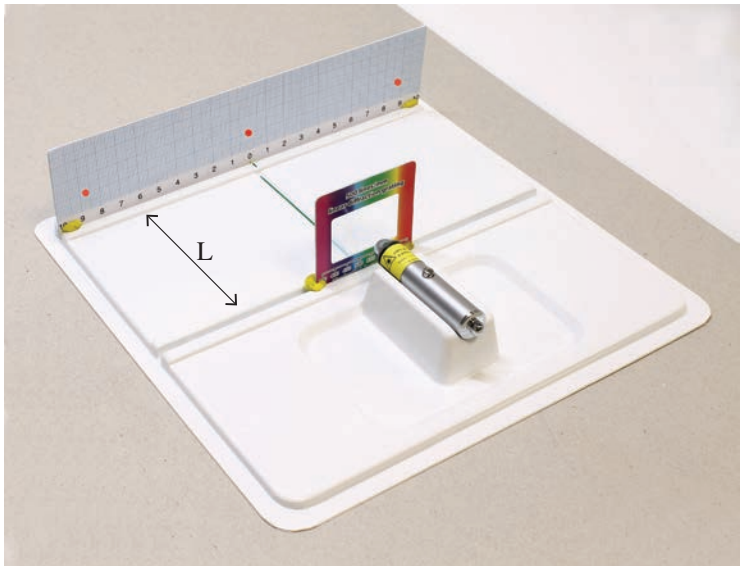
Questions 1–4 refer to the experiment setup in Photograph 1.

Question 1 (4 pts.)

According to formulas (1) and (2) in the theoretical background, the distance between two adjacent points of light on the ruler ($x_{k+1} - x_k$) is constant when their corresponding scattering angles (α_k and α_{k+1}) are small. Show that the following relationship holds: $\mathbf{\Delta x = L \cdot \lambda \cdot N^*}$.

Question 2 (10 pts.)

For this question the grating with a density of $N^* = 1000\frac{\text{lines}}{\text{mm}}$ has been placed in the appropriate slit on the surface. The laser pointer has been turned on. **Red points, which are part of the interference pattern, have appeared on the ruler. At these points there is constructive interference, expressed as maximal light intensity (peak points), as described in Photograph 2, and as shown in 1:1 scale in the appendix to question 2 in the appendix booklet.**



Photograph 2 of the experiment setup with a grating transparency, L = 10 cm

(2 pts.) a. Measure and write the distance Δx from the central point to the point to its right.

(2 pts.) b. Measure and write the distance Δx from the central point to the point to its left.

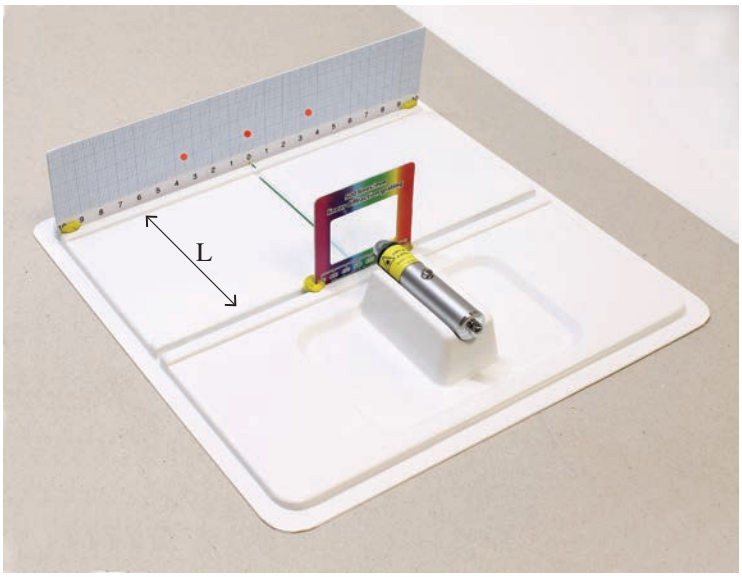
Continue to page 6

(3 pts.) **c.** Why is it best to take measurements from both sides of the central point, rather than from just one side?

(3 pts.) **d.** Calculate the average of the two measurements taken in sections (a) and (b).

Question 3 (14 pts.)

For this question the grating with a density of $N^* = 500\frac{\text{lines}}{\text{mm}}$ has been placed in the appropriate slit on the surface. The laser pointer has been turned on. The image described in Photograph 3 (which is in 1:1 scale in the appendix to question 3 in the appendix booklet) has appeared on the ruler.



Photograph 3 of the experiment setup with a grating transparency, L = 10 cm

(3 pts.) **a.** Measure and write the distance between the two first-order points of light (adjacent to the central point of light from both sides). Using this measurement, find the distance Δx . Show your calculations.

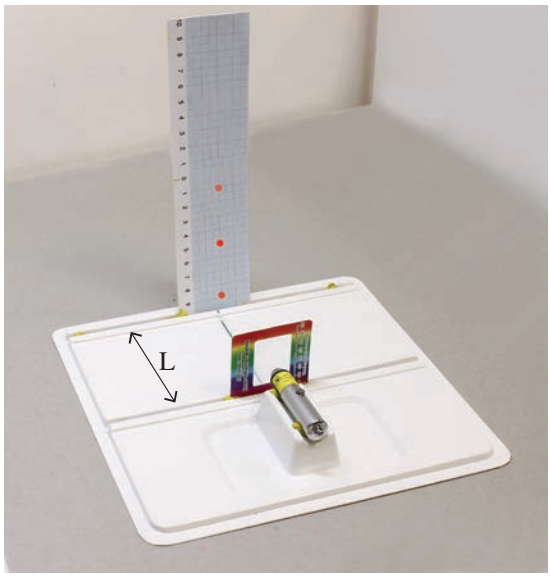
(3 pts.) **b.** Explain why the method for finding the distance Δx in section (a) is more precise than the method in question 2.

Continue to page 7

(4 pts.) **c.** Find the distance Δx which would have been between two adjacent points of light had you used a grating with a density of $N^* = 300\frac{\text{lines}}{\text{mm}}$ in the experiment setup. Use your answer to question 1 and a result of one of the previous measurements. Show your calculations.

(4 pts.) **d.** The grating and the ruler have been rotated by 90° as shown in Photograph 4. The laser pointer has been turned on. The interference pattern seen on the ruler is described in the photograph.

Give a qualitative explanation for the difference between the pattern received at the beginning of the question and the pattern received here.

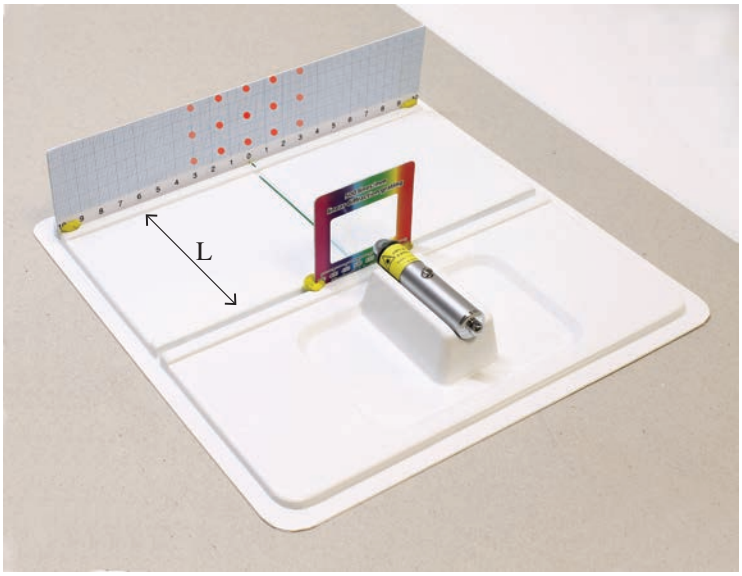


Photograph 4 of the experiment setup with grating transparency and ruler rotated by 90°, L = 10 cm

Continue to page 8

Question 4 (12 pts.)

For this question the grating with a density of $N^* = 190\frac{\text{lines}}{\text{mm}}$ has been placed in the appropriate slit on the surface. The ruler has been returned to its original position and the laser pointer has been turned on. The image described in Photograph 5 (which is in 1:1 scale in the appendix to question 4 in the appendix booklet) has appeared on the ruler.



Photograph 5 of the experiment setup with a grating transparency, L = 10 cm

(5 pts.) a.

(1 pt.) 1. Describe interference pattern seen on the ruler.

(4 pts.) 2. What do you think is the reason for this pattern? In your answer refer to the structure of the grating.

(2 pts.) b. Find and write the distance Δx between two adjacent **"horizontal"** points of light, as required in section (a) of question 3.

(2 pts.) c. Find and write the distance Δy between two adjacent **"vertical"** points of light, as required in section (a) of question 3.

(3 pts.) d. Is the grating constant in the horizontal dimension identical to that in the vertical dimension? Explain your answer.

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Question 5 (10 pts.)

The experiment with the CD, which has slits created with a laser beam and which can serve as a reflection grating, has been conducted. The density of its slits is $N^* = 680\frac{\text{lines}}{\text{mm}}$. The light reflected from the CD creates several orders of peak points corresponding to the various k values, as explained in the theoretical background.

Figure 5a shows an aerial view of the experiment setup, and Figure 5b shows a frontal view of the CD.

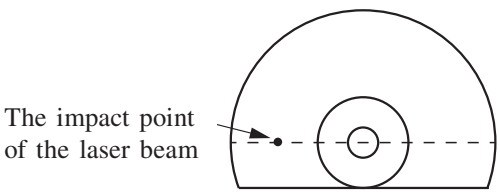


Figure 5b

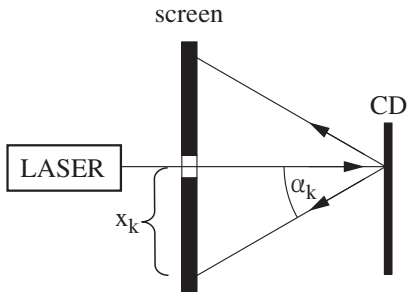
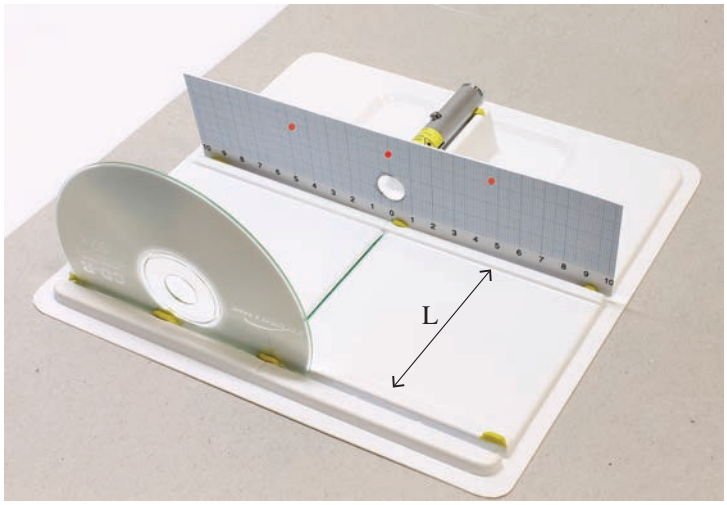


Figure 5a

The apparatus was set up as shown in Figure (a), resulting in the image shown in Photograph 6.

The interference pattern which appeared on the ruler is shown in 1:1 scale in the appendix to question 5 in the appendix booklet.



Photograph 6 of the experiment setup with the CD, L = 10 cm

Find the distance Δx between two adjacent points of light, as required in section (a) of question 3.

Continue to page 10

Question 6 (9 pts.)

In this experiment you have measured the distance Δx or calculated its values. Use formulas (**1**) and (**2**) from the theoretical background to calculate **tan** (α_1), α_1, and **sin** (α_1) for each case. Fill in the following table with your results:

question number / variable	2d	3a	3c	4b	5
N* $\left[\frac{1}{\text{mm}}\right]$					
Δ**x** [mm]					
tan (α_1)					
α_1 [°]					
sin (α_1)					

Question 7 (21 pts.)

(2 pts.) **a.** Use formula (**1**) from the theoretical background to explain why the relationship between the variables sin (α_1) and N* is linear.

(2 pts.) **b.** Use your answer to section (a) to determine which variable in the experiment is independent and which is dependent.

(4 pts.) **c.** On the millimeter paper in the **next page**, draw a scatter diagram of the dependent variable as a function of the independent variable, according to the table in question 6 and your answers to sections (a) and (b).
Note: You may also use an electronic worksheet according to the examiner instructions. If you use an electronic worksheet, print it, put your examinee sticker on the printout and add it to the questionnaire.

(4 pts.) **d.** Draw a trend line on your diagram.

(3 pts.) **e.** Calculate the slope of the trend line and write its measurement units.

(3 pts.) **f.** Find λ, the laser pointer wavelength.

(3 pts.) **g.** Give two examples of a measurement error which can be used to explain why the trend line does not **necessarily** pass through the origin.

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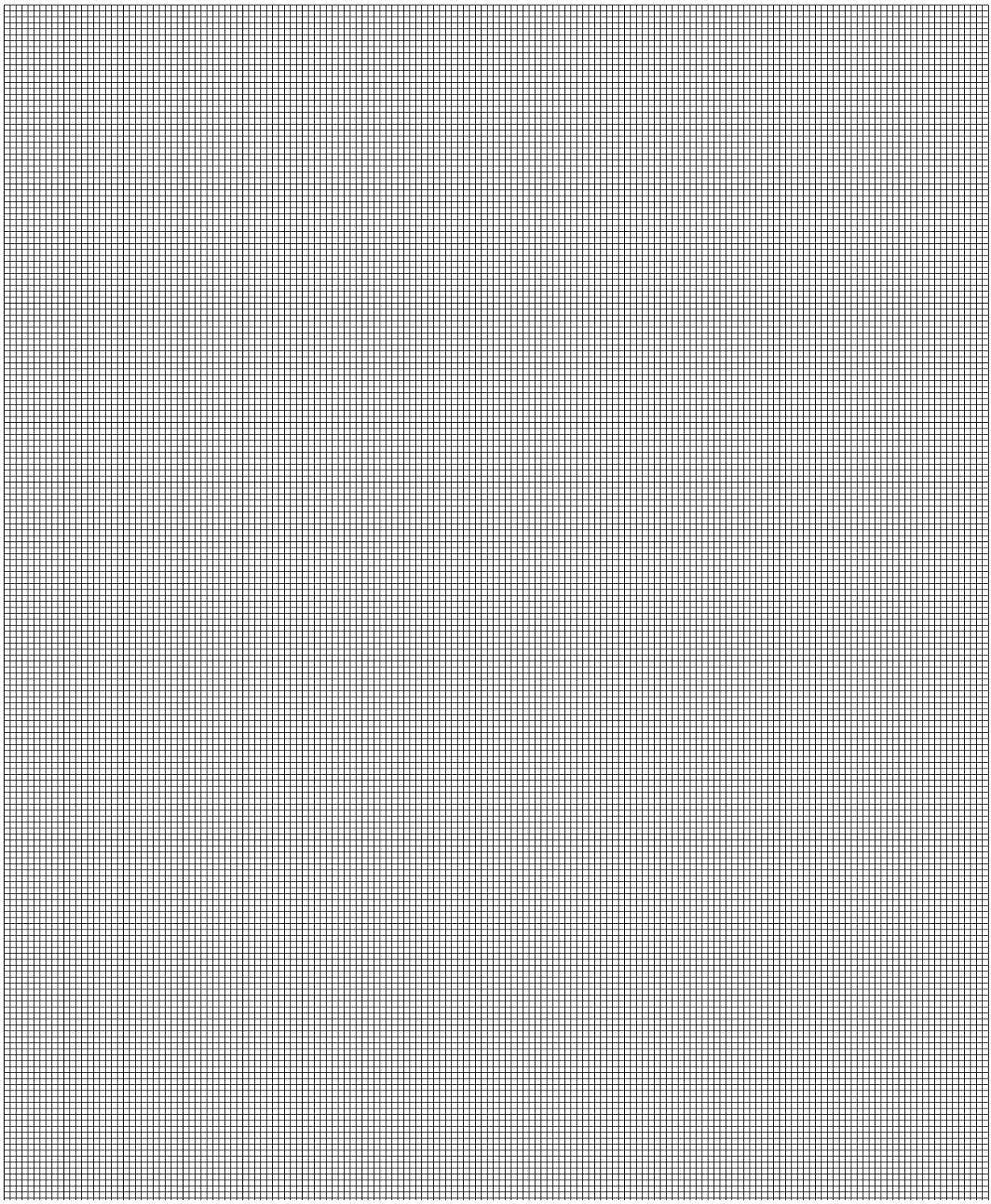

On page 16 you will find additional millimeter paper that you may use if necessary.

Continue to page 12

Theoretical background (continued)

When light passes from one optically transparent material to another, it breaks and changes its direction (see Figure c).

The refractive index of a material is marked by n, and is defined as the ratio between the speed of light through vacuum (c) and the speed of light through the material (v) – namely, $n = c / v$.
The speeds of light passing through vacuum and through air can be regarded as approximately equal ($c = 3 \cdot 10^8$ m/sec), and therefore the refractive index of air is n = 1. The relationship between the angle of incidence α of light (through air) and its angle of refraction β (through another material) is derived from Snell's law, and is described by the formula:

(3) $$\sin\alpha = n \cdot \sin\beta$$

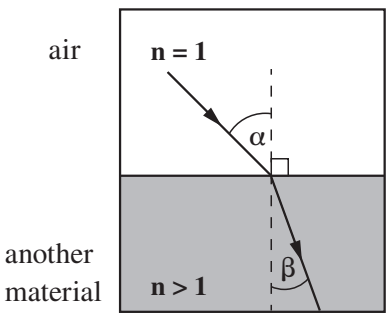

Figure c

If the light emitted from the grating slits passes through a material different than air (with a refractive index n), formula (**1**) from the theoretical background gives us this relationship:

(4) $$\sin(\alpha_k) = k \cdot \lambda' \cdot N^*$$

where: $$\lambda' = \frac{\lambda}{n}$$

Question 8 (10 pts.)

For this question the grating with a density of $N^* = 500 \frac{\text{lines}}{\text{mm}}$ has been placed in the appropriate slit on the surface, as described in question 3. The transparent plastic container has been placed between the grating and the calibrated ruler and the water bottle has been emptied into the container.
The laser pointer has been turned on so that the light passes through the water (the effect of the passage of light through the container walls can be considered negligible).
Photograph 7 (**on the next page**) describes the resulting image.

The interference pattern which appeared on the ruler is shown in 1:1 scale in the appendix to question 8 in the appendix booklet.

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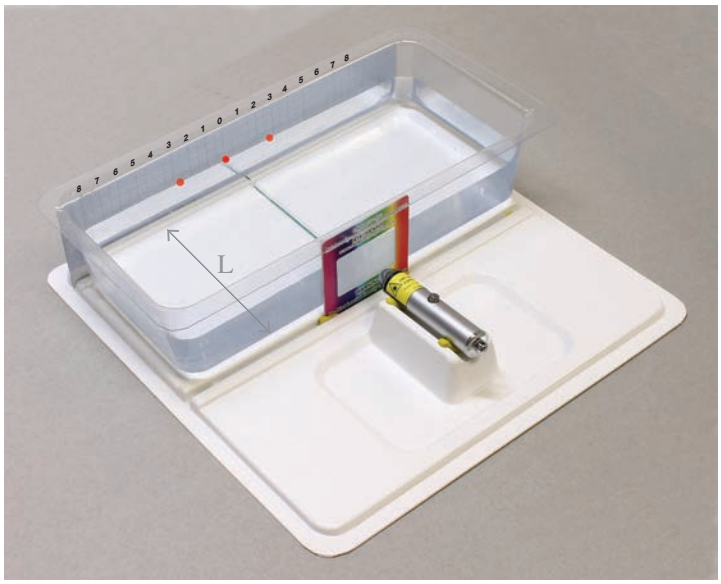

Photograph 7 of the experiment setup with the water container, L = 10 cm

(2 pts.) **a.** Measure the distance between the two first-order points of light seen on the ruler, calculate Δx and write it.

(2 pts.) **b.** Is the distance Δx calculated in section (a) larger, smaller or equal to the distance Δx calculated in question 3a? Explain your answer based on the theoretical background of the experiment.

(3 pts.) **c.** Use the distance Δx which you have calculated in section (a) to calculate the refractive index of water.

(3 pts.) **d.** Assuming that the refractive index of water is 1.33:

(2 pts.) 1. Find the relative error between the result received in section (c) and the given value of the refractive index.

(1 pt.) 2. Which factor can account for this error?

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Part B: Questions about the compulsory experiments

Answer one of questions 9–10 (10 points per question).

Question 9 (10 pts.)

Collision in two dimensions

In this experiment we mark the point hit by a steel ball falling from a rail, and then the points hit by two equal mass steel balls after they collided with each other. In the following figure the three straight lines show the horizontal courses of the three balls.

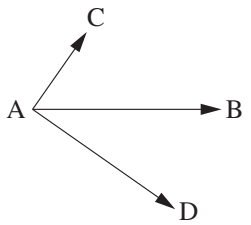

Figure 9

(3 pts.) **a.** What additional physical magnitude is represented by the horizontal displacement vectors the balls passed following the collision? Explain your answer.

(4 pts.) **b.** How is it possible to show geometrically that the overall kinetic energy of the two colliding balls is conserved after the collision? In your answer refer also to the conservation of energy equation in this experiment.

(3 pts.) **c.** Can Part B of the experiment be conducted with the steel ball at the end of the rail and the smaller-mass ball being released from the course? Explain your answer.

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Question 10 (10 pts.)

Tangent galvanometer

(3 pts.) **a.** Why is it important to keep the tangent galvanometer apart from other parts of the electric circuit and from iron objects?

(4 pts.) **b.** Explain why the coil is positioned so that the plane of the ring is in a north-south direction.

(3 pts.) **c.** Why should the tangent galvanometer not be used in occasions that would cause the compass needle to deviate in large acute angles?

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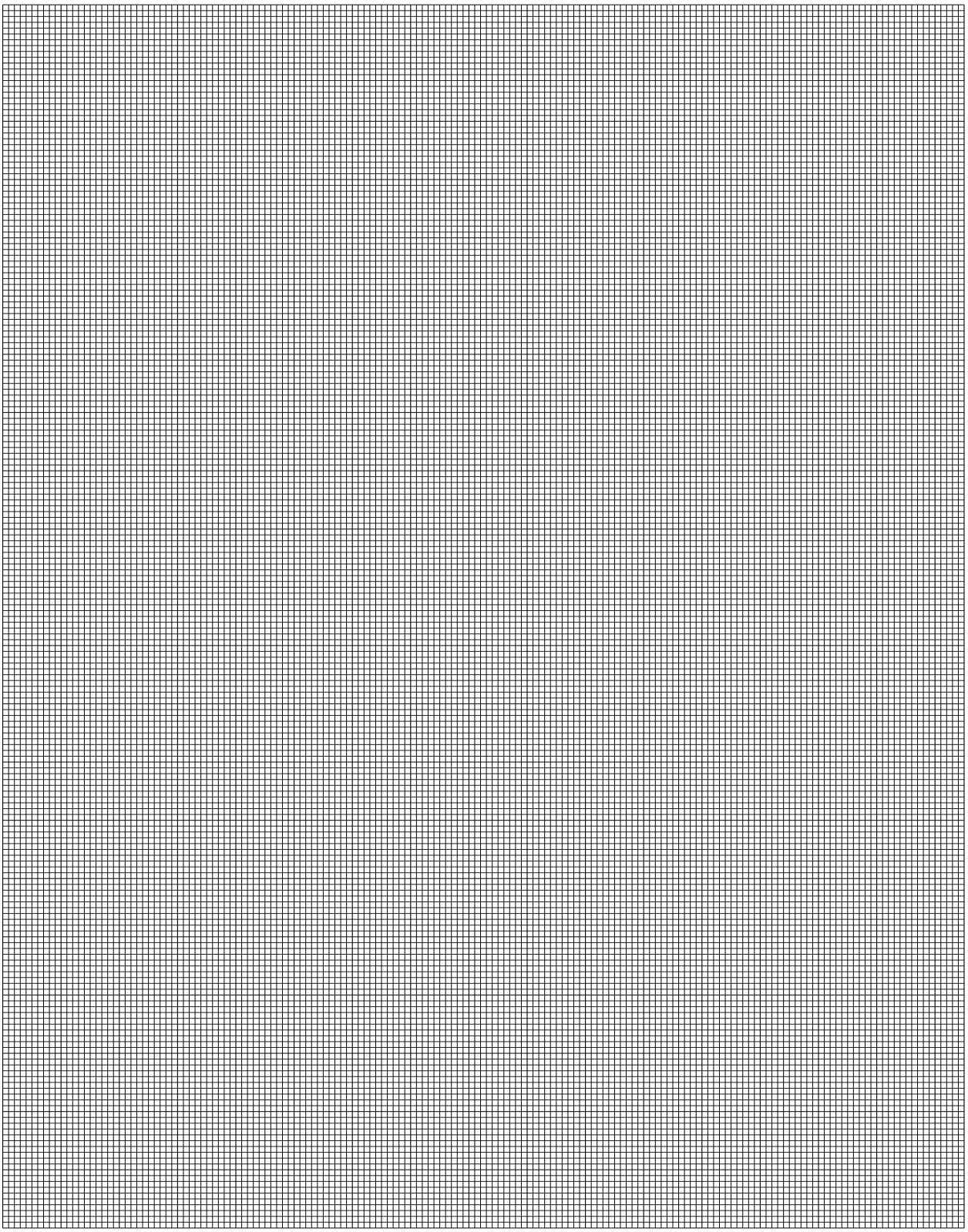

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Draft paper

Good Luck!

מדבקת משגיח
ملصقة مراقب

"אתך בכל מקום, גם בבגרות.
בהצלחה, מועצת התלמידים והנוער הארצית"
"معك في كلّ مكان، وفي البجروت أيضًا.
بالنجاح، مجلس الطلّاب والشبيبة القطريّ"

Appendix booklet

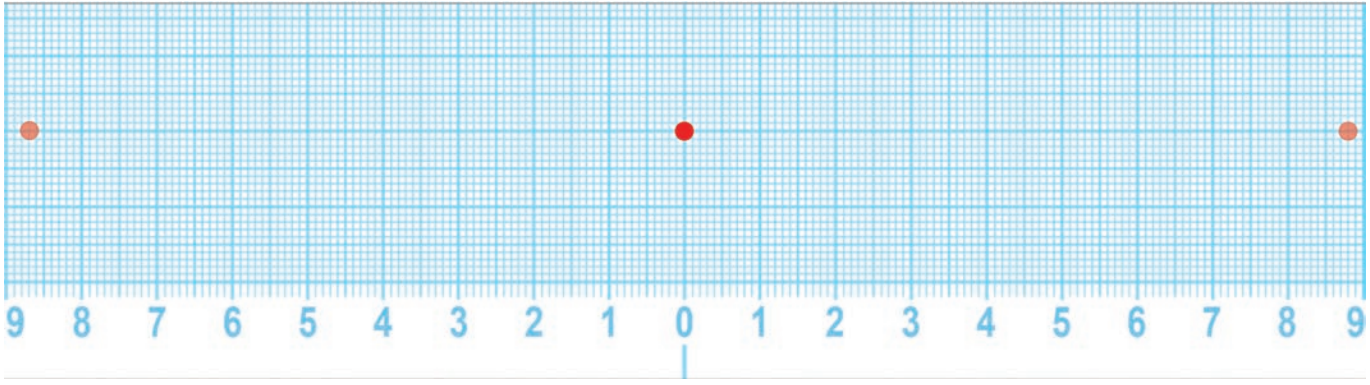
Physics – Research Questionnaire

Exam Code: 036382

Summer 2017

This booklet consists of 6 pages

Appendix to question 2



The interference pattern (in scale of 1:1) on the ruler in Photograph 2

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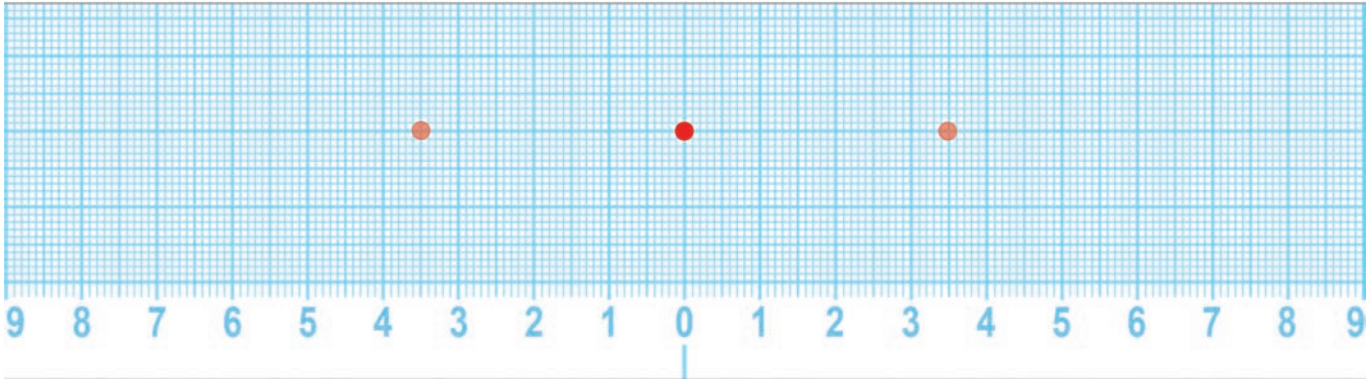
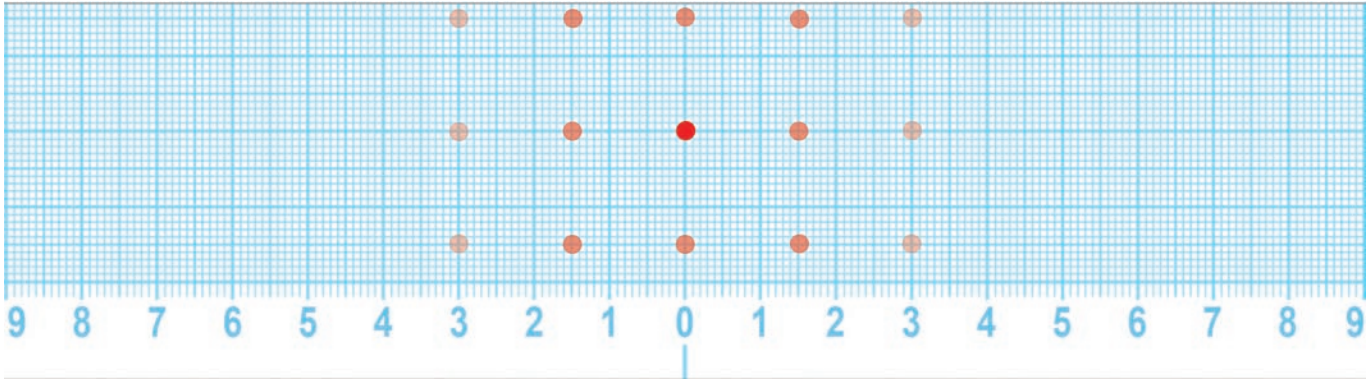
Appendix to question 3



The interference pattern (in scale of 1:1) on the ruler in Photograph 3

Continue to page 4

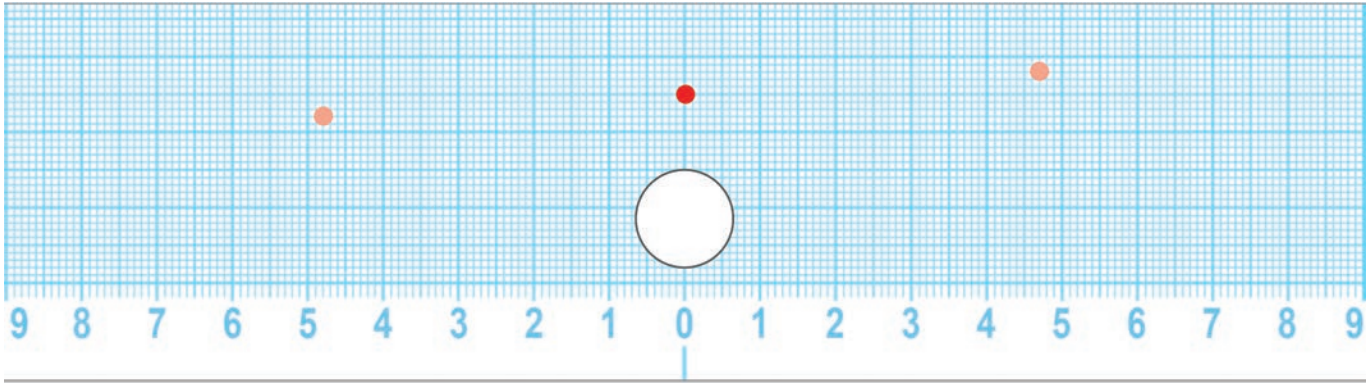
Appendix to question 4



The interference pattern (in scale of 1:1) on the ruler in Photograph 5

Continue to page 5

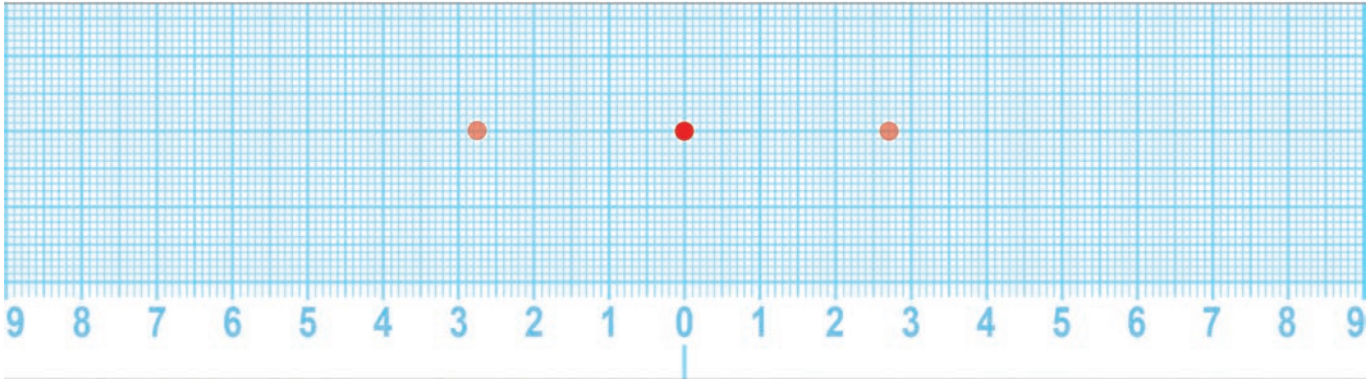
Appendix to question 5



The interference pattern (in scale of 1:1) on the ruler in Photograph 6

Continue to page 6

Appendix to question 8



The interference pattern (in scale of 1:1) on the ruler in Photograph 7