2025

AP

AP® Physics 2: Algebra-Based

Free-Response Questions

PHYSICS 2

SECTION II

TIME – 1 HOUR AND 40 MINUTES

Directions:

Section II has 4 questions and lasts 1 hour and 40 minutes.

You may use the available paper for scratch work and planning, but you must write your answers in the free-response booklet. Label parts (e.g., A, B, C) and sub-parts (e.g., i, ii, iii) as needed. Use a pencil or a pen with black or dark blue ink to write your responses.

A calculator is allowed in this section, as well as a ruler and straightedge. You may use a handheld four-function, scientific, or graphing calculator, or the calculator available in this application. Reference information, including lists of equations, can also be accessed in this application and is available throughout the exam.

All final numerical answers should include appropriate units when applicable. Credit for your work depends on demonstrating that you know which physical principles to apply in a particular situation. Credit will be awarded only for work that is clearly designated as the solution to a specific part of a question. Credit also depends on the quality of your solutions and explanations. Therefore, you should show your work for each part in the space provided for that part. If you need more space, be sure to clearly indicate where you continue your work. When constructing a graph or diagram, use only one color of ink or pencil.

You may pace yourself as you answer the questions in this section, or you may use these optional timing recommendations:

It is suggested that you spend about 25 minutes each on Questions 1 and 3, about 30 minutes on Question 2, and about 20 minutes on Question 4.

You can go back and forth between questions in this section until time expires. The clock will turn red when 5 minutes remain—**the proctor will not give you any time updates or warnings.**

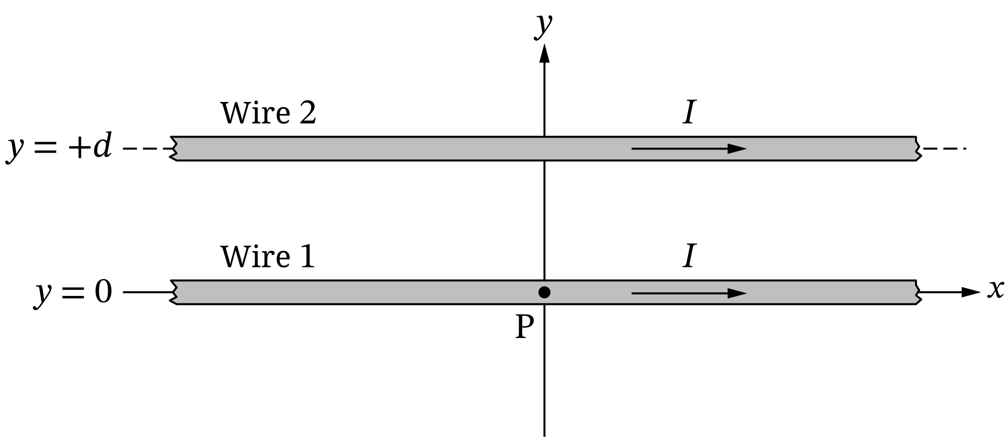
Note: This exam was originally administered digitally. It is presented here in a format optimized for teacher and student use in the classroom.

During the AP Exam administration, students have access to reference information. To see the reference information for this course, please visit AP Central: https://apcentral.collegeboard.org/courses/ap-physics-2/exam

Question 1: Version J

1. Very long Wire 1 carries current I in the $+x$-direction along the line $y = 0$. Very long Wire 2 carries current I in the $+x$-direction along the line $y = +d$. Point P is located along Wire 1 at the origin, as shown in Figure 1. The diameters of the wires are small compared to the distance between the wires. Both wires are in the xy-plane.

Figure 1



Note: Figure not drawn to scale.

A.

i. Complete the following tasks in figures 2 and 3. Use either arrows or the symbols shown in the box above the figures for your response.

- **Indicate** the direction of the magnetic field from Wire 2 at Point P in Figure 2.
- **Indicate** the direction of the magnetic force that is exerted on Wire 1 by Wire 2 in Figure 3.

Symbols

✕ Into the page ● Out of the page

Magnetic Field from Wire 2 at Point P

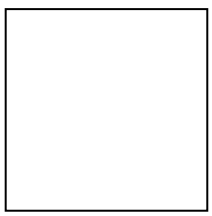


Figure 2

Magnetic Force on Wire 1 by Wire 2

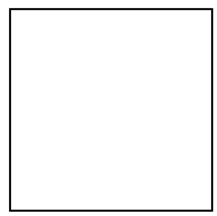


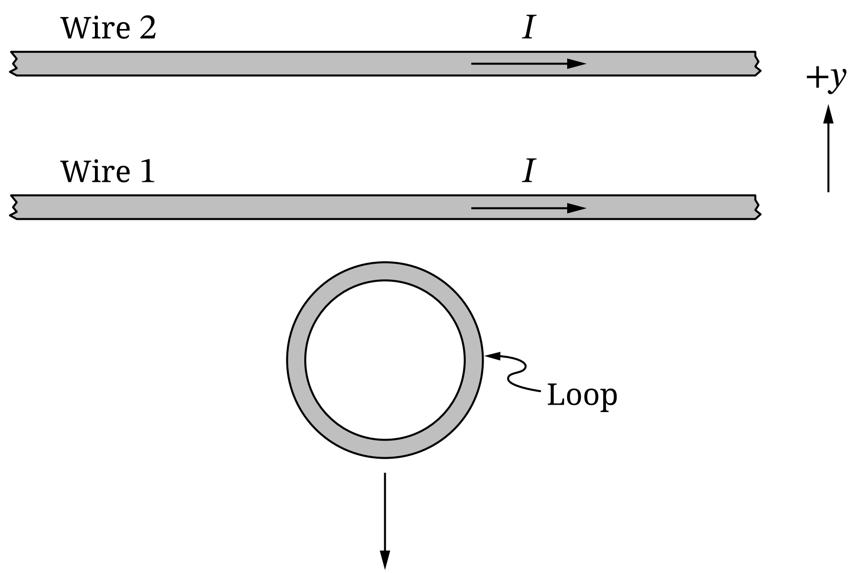
Figure 3

ii. Very long Wire 3 carrying current $2I$ in the $+x$-direction is placed in the xy-plane along the line $y = y_3$. The net magnetic force exerted on Wire 1 by the currents in wires 2 and 3 is zero.

Derive an expression for y_3 in terms of d. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

B. Wire 3 is moved very far away from wires 1 and 2. A circular conducting loop in the xy-plane is initially held at rest below Wire 1. The loop is then moved at a constant speed in the $-y$-direction, as shown in Figure 4.

Figure 4



Note: Figure not drawn to scale.

Indicate whether there is a clockwise induced current in the loop, a counterclockwise induced current in the loop, or no induced current in the loop.

______ Clockwise

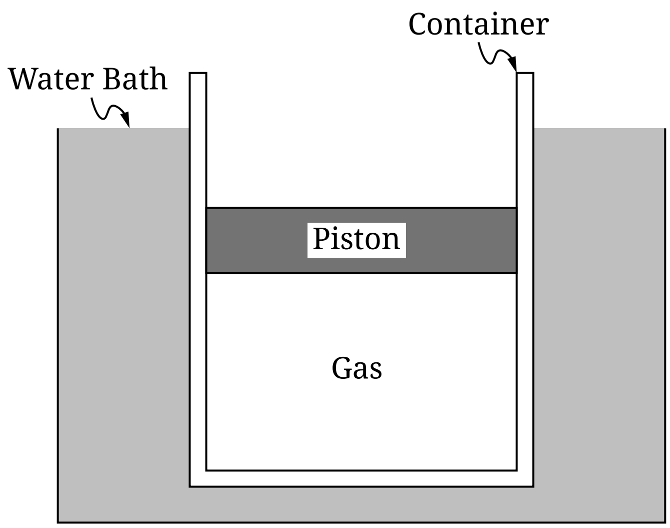
______ Counterclockwise

______ There is no induced current in the loop.

Justify your answer.

Question 2: Version J

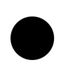
2. A sample of a monatomic ideal gas is sealed in a thermally conducting container by a movable piston of mass M and area A. The container is in a large water bath that is held at a constant temperature T_0. The piston is free to move with negligible friction. At the instant shown, the gas is in thermal equilibrium with the water bath, the piston is at rest, and the gas occupies volume V_0. The pressure of the air above the piston is P_{atm}.



Side View

Note: Figure not drawn to scale.

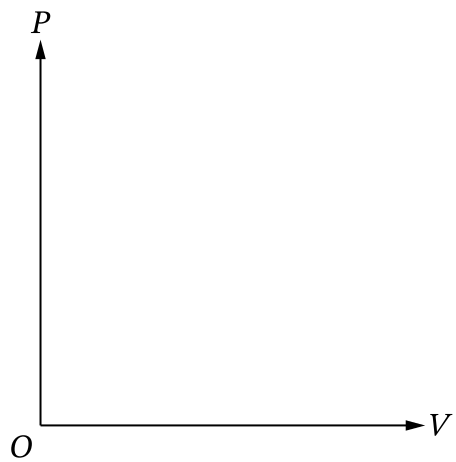
A. On the dot shown, representing the piston, **draw** and **label** the forces that are exerted on the piston. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.



B. **Derive** an expression for the internal energy of the gas in terms of M, A, V_0, P_{atm}, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

C. A block, also of mass M, is placed on the piston at time $t = t_0$ and is slowly lowered. The piston comes to rest at $t = t_f$ when the block is completely released.

On the axes provided, **sketch** the expected relationship between the pressure P and volume V of the gas for the thermodynamic process that the gas undergoes during time interval $t_0 \leq t \leq t_f$. **Draw** an arrow on your sketch to represent the direction of the thermodynamic process.



D. With the block still on the piston, the temperature of the water bath is changed to a new constant temperature T_{new}. The gas occupies the original volume V_0 when the sample of gas and the water bath come to thermal equilibrium.

Indicate whether T_{new} is greater than, less than, or equal to T_0.

______ $T_{new} > T_0$

______ $T_{new} < T_0$

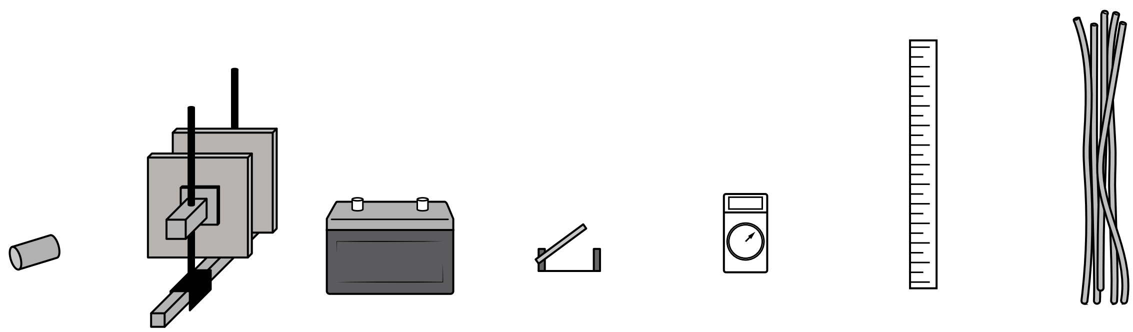
______ $T_{new} = T_0$

Briefly **justify** your answer by referencing at least one feature of your answers to parts A, B, or C.

Question 3

3. In Experiment 1, a student is given a resistor of unknown resistance and an air-filled parallel-plate capacitor of unknown capacitance. The student is asked to predict the expected time constant τ of a circuit if these two circuit elements were connected in series with a battery. The student has access to a battery of known emf, a switch, an ammeter, a ruler, and wires, as shown in Figure 1. The plates of the capacitor are square, and the separation between the plates is small compared to the dimensions of the plates. The capacitor is initially uncharged. Assume that the dielectric constant of air is 1.

Figure 1



Note: Figure not drawn to scale.

A. Describe a procedure for collecting data that would allow the student to determine the expected time constant τ. In your description, include the measurements to be made. Include any steps necessary to reduce experimental uncertainty.

B. Describe how the collected data could be analyzed to determine τ. Include references to appropriate equations and to relationships between measured and known quantities.

C. In Experiment 2, the student is asked to determine the capacitance C of a new parallel-plate capacitor. For each trial, the absolute value $|\Delta V|$ of the potential difference across the capacitor is varied and the charge q stored on one plate of the fully charged capacitor is measured. Table 1 contains the data collected.

Table 1

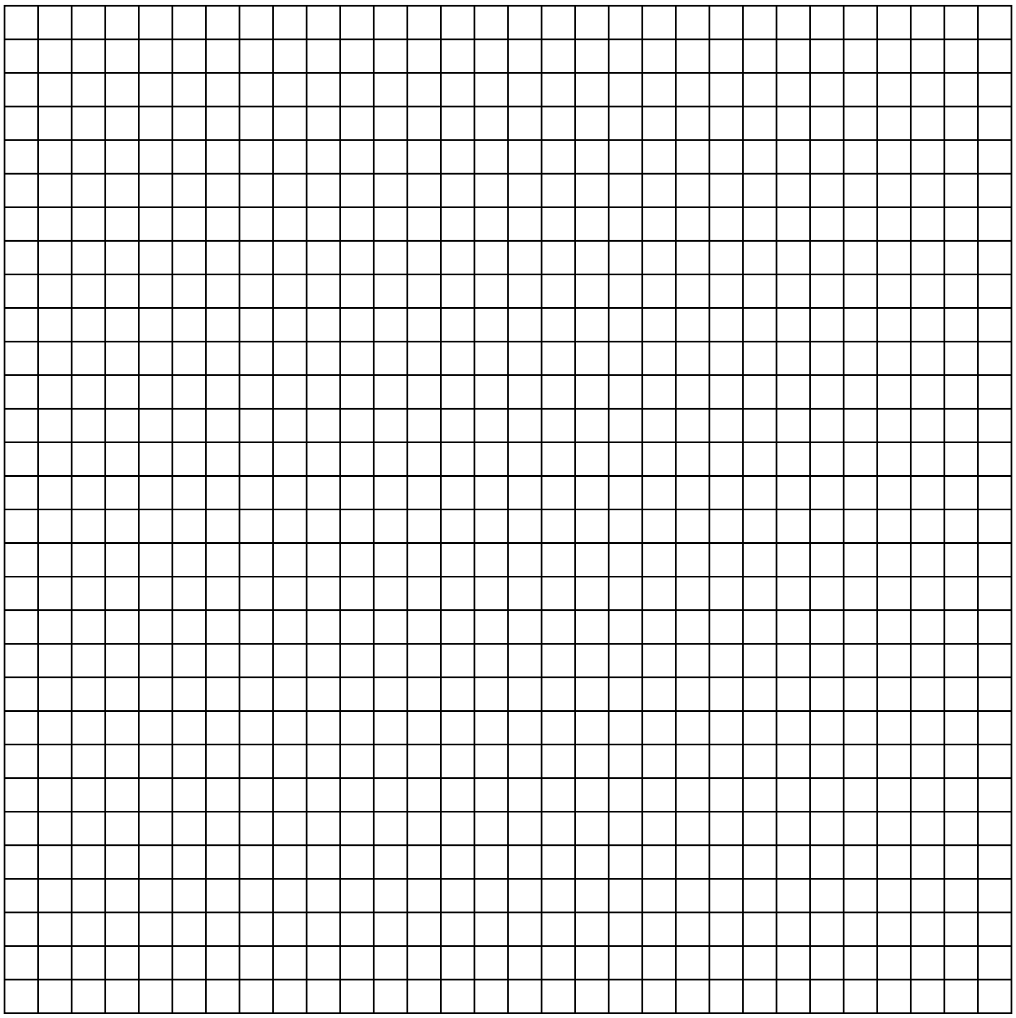
$\lvert\Delta V\rvert$ (V)	$q\ (\times 10^{-10}\ \text{C})$
3.0	2.4
5.0	4.2
7.2	5.6
8.0	6.6
10.0	8.0

i. **Indicate** two quantities, either measured quantities from Table 1 or additional calculated quantities, that could be graphed to produce a straight line that could be used to determine C.

Vertical axis: ______ Horizontal axis: ______

ii. On the grid provided, create a graph of the quantities indicated in part C (i).

- Use Table 2 to record the measured or calculated quantities that you will plot.
- Clearly **label** the axes, including units as appropriate.
- **Plot** the points you recorded in Table 2.

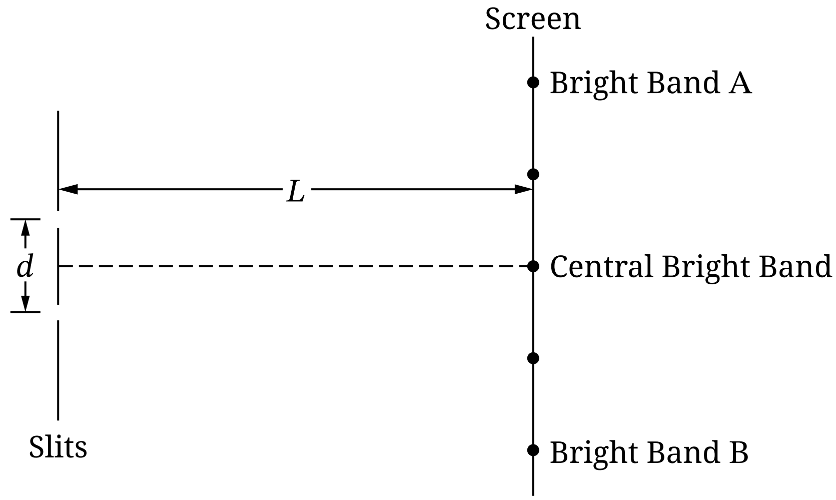


iii. **Draw** a best-fit line for the data graphed in part C (ii).

D. Using the best-fit line that you drew in part C (iii), **calculate** an experimental value for capacitance C.

Question 4

4. Two narrow slits are a distance d apart. A screen is a distance L from the midpoint of the slits, where $L \gg d$. When a laser emits monochromatic light toward the slits, a pattern of narrow bright and dark bands is observed on the screen. The centers of bright bands A and B are indicated. Three additional bright bands, including the central bright band, are observed on the screen between bands A and B, as shown.



Note: Figure not drawn to scale.

A student claims that the distance between the center of Band A and the center of the central bright band is smaller when using a laser that emits violet light than when using a laser that emits red light.

A. **Indicate** whether the student's claim is correct or incorrect. Without manipulating equations, **justify** your answer by referencing the difference in path length traveled by the light from each slit to the center of Band A.

B. **Derive** an expression for the distance between the centers of bands A and B when light of frequency f is emitted toward the slits. Express your answer in terms of d, L, f, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

C. **Indicate** whether the expression you derived in part B is or is not consistent with your answer from part A. Briefly **justify** your answer.

STOP

END OF EXAM