2018

AP CollegeBoard

AP Physics 2: Algebra-Based

Sample Student Reponses and Scoring Notes

DRAFT

General Notes About 2018 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution embeds the application of that equation to the problem in other work, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based Course and Exam Description* and the *AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

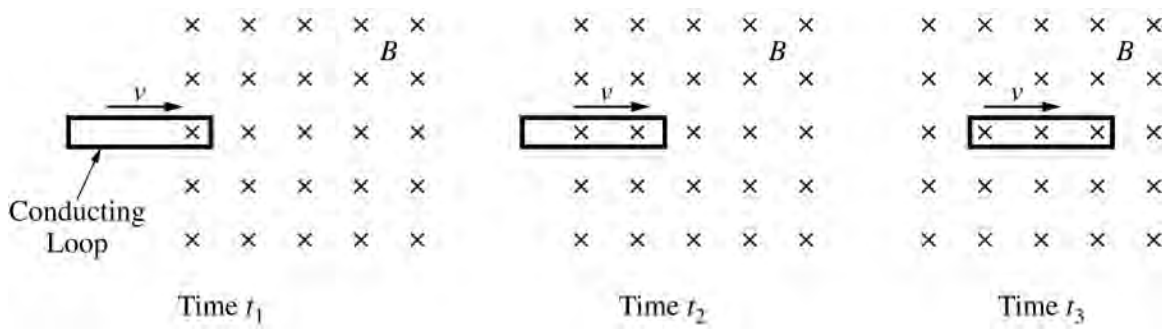
PHYSICS 2

Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



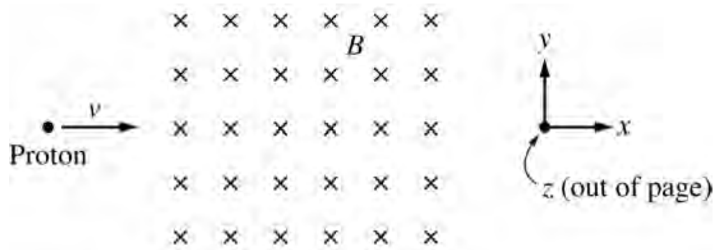
1. (10 points, suggested time 20 minutes)

   The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

   (a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

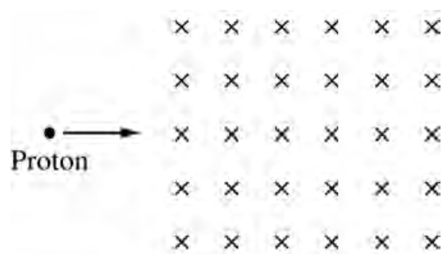
GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



i. Calculate the magnitude of the force on the proton as it enters the field.

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.

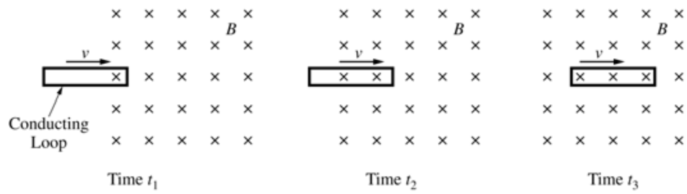


iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

Question 1

10 points total — **Distribution of points**



The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed *v* into and through a region of constant, uniform magnetic field *B* directed into the page. The magnetic field is zero outside the region.

(a) LO 2.D.1.1, SP 2.2; LO 4.E.2.1, SP 6.4
5 points

In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

For indicating that the currents at t_1 and t_2 have equal non-zero magnitudes and are in the same direction		1 point
For indicating that there is no current at t_3		1 point
For correctly indicating that the currents depend on the change in flux through the loop or the forces on the charges moving in the field		1 point
For correctly identifying the direction of the current as counter-clockwise and either explaining that the direction of the current generates a magnetic field that opposes the change in flux <u>or</u> analyzing the force on the charge carriers in each segment of the loop		1 point
For an on-topic response that has sufficient paragraph structure, as described in the published requirements for the paragraph length response		1 point

(b)

The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.

Question 1 (continued)

Distribution of points

(b) (continued)

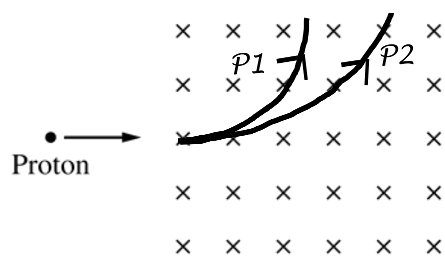
i) LO 2.D.1.1, SP 2.2
1 point

Calculate the magnitude of the force on the proton as it enters the field.

For correct substitutions into a correct expression and correct units on the final answer		1 point
$F = qvB$		
$F = \left(1.6 \times 10^{-19} \text{ C}\right)\left(3.0 \times 10^{5} \text{ m/s}\right)(0.03 \text{ T})$		
$F = 1.4 \times 10^{-15}$ N		

ii) LO 2.D.1.1, SP 2.2; LO 3.B.1.4, SP 6.4; LO 3.C.3.1, SP 1.4
1 point

On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



For drawing a curved arc through the field, curved upward where the proton enters		1 point
Anything greater than a semi-circle or a path that does not reach the edge of the field does not earn credit. Any path after exiting the field is ignored.		

iii) LO 2.D.1.1, SP 2.2; LO 3.B.1.4, SP 6.4
1 point

A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

For drawing a path with a larger radius that is consistent with answer to (b)(ii)		1 point

Question 1 (continued)

Distribution of points

(b) (continued)

iv) LO 2.C.1.1, SP 6.4; LO 2.C.1.2, SP 2.2; LO 3.B.2.1, SP 1.4, 2.2
2 points

Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

For indicating a direction of the electric field that is consistent with the response to (b)(ii)		1 point
Given the correct response to (b)(ii) illustrated above, the electric field must be directed in the -*y* direction (or toward the bottom of the page)		
For equating the electric and magnetic forces and substituting into the correct expression using values consistent with the response to (b)(i)		1 point
$qE = qvB$ (Implicitly equating the calculated magnetic force to the electric force is acceptable.)		
$E = vB$		
$E = \left(3.0 \times 10^5 \text{ m/s}\right)(0.03 \text{ T})$		
$E = 9000 \text{ N/C}$		

LO 2.C.1.1: The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge *q* placed in an electric field *E* using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation.**[SP 6.4, 7.2**]

LO 2.C.1.2: The student is able to calculate any one of the variables — electric force, electric charge, and electric field — at a point given the values and sign or direction of the other two quantities.**[SP 2.2**]

LO 2.D.1.1: The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. **[SP 2.2**]

LO 3.B.1.4: The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations. **[SP 6.4, 7.2]**

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. **[SP 1.1, 1.4, 2.2]**

LO 3.C.3.1: The student is able to use right-hand rules to analyze a situation involving a current-carrying conductor and a moving electrically charged object to determine the direction of the magnetic force exerted on the charged object due to the magnetic field created by the current-carrying conductor. **[SP 1.4]**

LO 4.E.2.1: The student is able to construct an explanation of the function of a simple electromagnetic device in which an induced emf is produced by a changing magnetic flux through an area defined by a current loop (i.e., a simple microphone or generator) or of the effect on behavior of a device in which an induced emf is produced by a constant magnetic field through a changing area. **[SP 6.4**]

PHYSICS 2

Section II

Time—1 hour and 30 minutes

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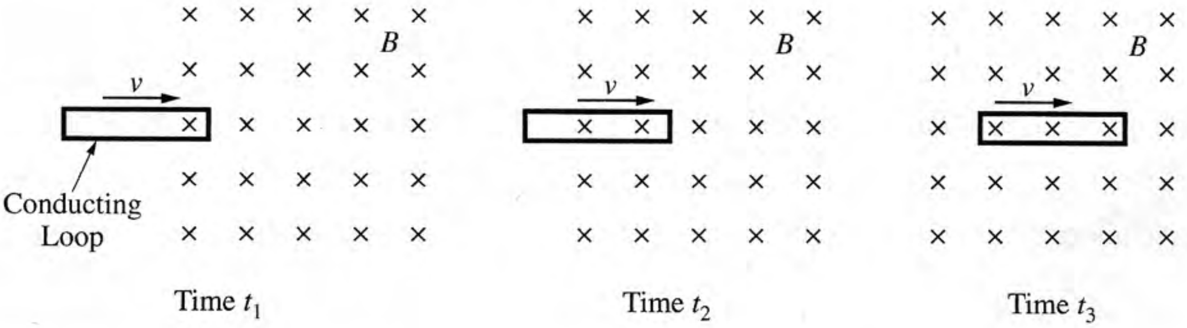

1. (10 points, suggested time 20 minutes)

The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

At time t_1, there is an induced current acting counter-clockwise in the loop of wire. This is due to the net change in magnetic flux being into the page, a change in magnetic flux induces current in a loop of wire so that the wire's magnetic field formed as a result of the current points in the opposite direction. The magnitude of this induced current and magnetic field is proportional to the rate of change of magnetic flux in the loop. At times t_1 and t_2, the induced current is equal in magnitude and direction because the direction of the change in magnetic flux is equivalent, as well as the rate at which it changes (which is dependent on v). However, there is no induced current at t_3 because the magnetic flux is not changing. The entire loop is in a uniform magnetic field experiencing the same constant magnetic flux.

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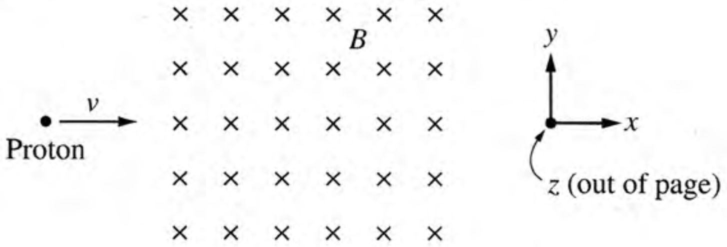
GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



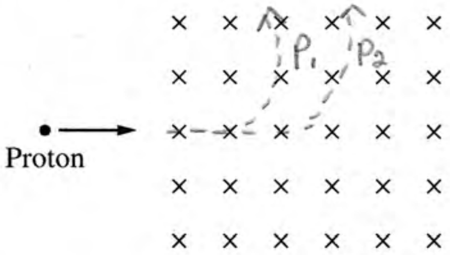
i. Calculate the magnitude of the force on the proton as it enters the field.

$F_B = qvB$ ~~(sin θ)~~

$= (1.602\times10^{19})(3.0\times10^5)(0.030)$

$F_B = 1.442\times10^{-15}\ N$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



$r = \frac{mv}{qB}$

iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$F_E = F_B = qE$

$E = \frac{F_B}{q} = \frac{qvB}{q} = vB = (3.0\times10^5)(0.030)$

$E = 9000\ N/C$ downward (↓) (−y direction)

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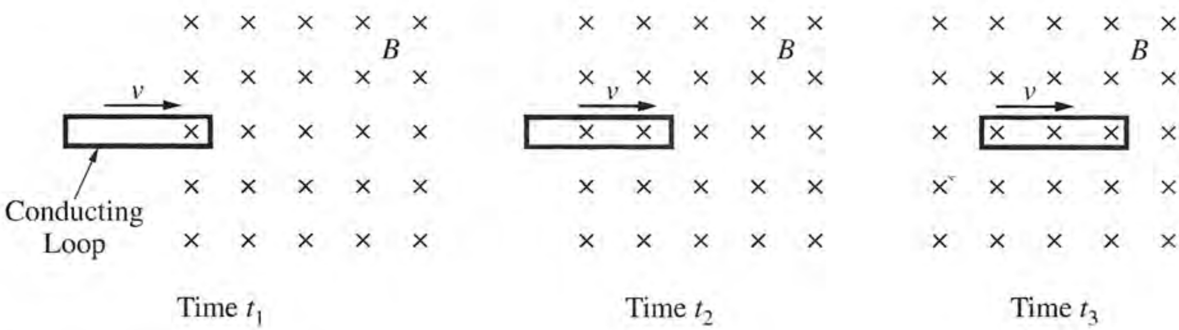

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At time t_1 and t_2, currents are equal in magnitude, and have the same direction, counterclockwise. Using the right hand rule, with velocity directed right for both, and magnetic field directed into the page for both, the force on a positive particle is up. Therefore, since the loop is entering the field at times t_1 and t_2, current will be directed counterclockwise because along the right edge of the rectangle, positive charges will flow upwards, creating a circuit that flows counterclockwise. The magnitudes of current at time t_1 and t_2 will be the same because for the entire time a conducting loop is entering a field, current flows on that loop (a changing field results in a constantly changing flux). No current is induced at time t_3 because since their is no change in field, there will also be no change in flux, meaning no current will be induced.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.

i. Calculate the magnitude of the force on the proton as it enters the field.

$F_m = q v \cdot B$

$F_m = 1.6 \times 10^{-19} C \cdot 3.0 \times 10^5 m/s \cdot 0.030 T$

$F_m = 1.44 \times 10^{-15} N$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.

iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

$m \cdot \frac{v^2}{R}$ = constant, if v increased, R must decrease ... $R_2 = \frac{1}{4} R_1$

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$F_m = F_E$

Protons travel in direction of electric field ↓

$1.44 \times 10^{-15} N = q \cdot E$

$E = \frac{1.44 \times 10^{-15} N}{1.6 \times 10^{-19} C}$ = 9000 N/C directed in the negative y direction

$\vec{E}$ ↓

GO ON TO THE NEXT PAGE.

P2 Q1 C p1

PHYSICS 2
Section II
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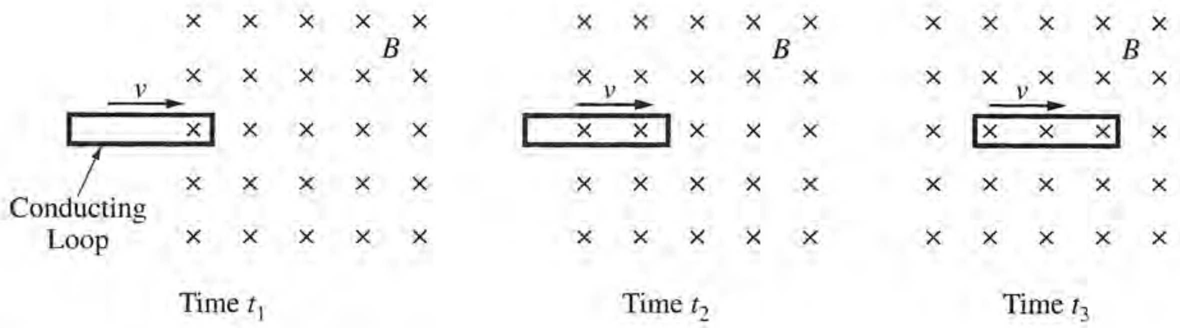


1. (10 points, suggested time 20 minutes)

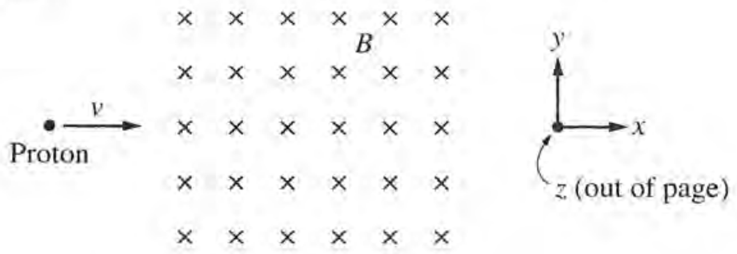
The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

t_1 the current induced will be counterclockwise as the loop enters the field, because the ~~magnetic~~ field begins to enter the loop creating a change in flux, inducing a current counter clockwise. At t_2 the loop is still entering the field and changing the flux continuing the inducing of current counterclockwise. The current will be the same strength as t_1. At t_3 the loop is allready in the field so there is no more change in flux and therefore no more current.

GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



i. Calculate the magnitude of the force on the proton as it enters the field.

$F = qVB$

$1.6 \times 10^{-19} \cdot 3.0 \times 10^5 \times .03T = 1.44 \times 10^{-15}\ N$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.

iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$F = qVB = Eq$

$VB = E$

$3.0 \times 10^5 \times .03 = E = 9000\ \frac{N}{C}$ downward ↓

PHYSICS 2

Section II

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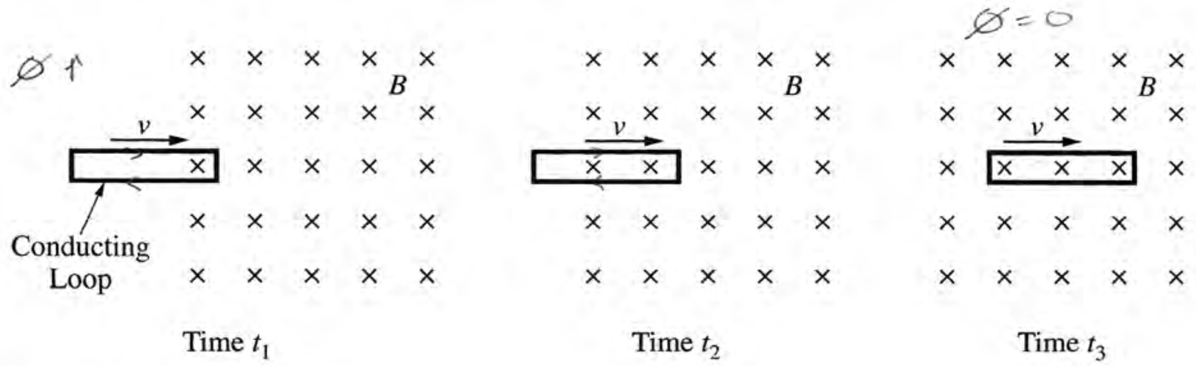

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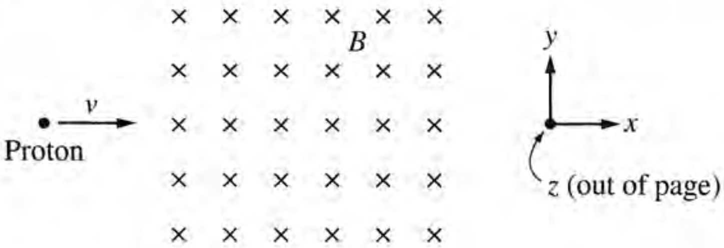
at t_1 the magnetic flux is increasing due to the area within the B increasing so induced B goes with external and the current would be clockwise. At t_2 flux is again increasing so the induced B goes with external and current clockwise. However at t_3 neither B or A is changes so flux is not changing resulting in no current.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



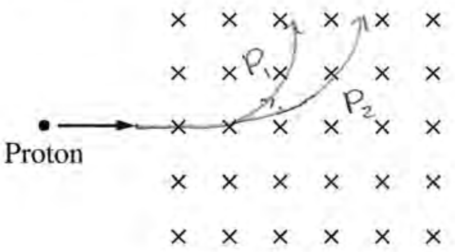
i. Calculate the magnitude of the force on the proton as it enters the field.

$F_B = qvB$

$F_B = (1.6\times10^{-19})(3\times10^5)(0.03)$

$F_B = 1.44\times10^{-15}$ N

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



$ma_c = F_B$

$\frac{mv^2}{r} = qvB$

$r = \frac{mv}{qB}$

v goes up ; r goes up

iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$F_E = F_B$

$F_{net} = \Sigma F$

$ma = F_B - F_E$

$qE = qvB$

$E = (3\times10^5)(0.03)$

$E = 9000$ N/C

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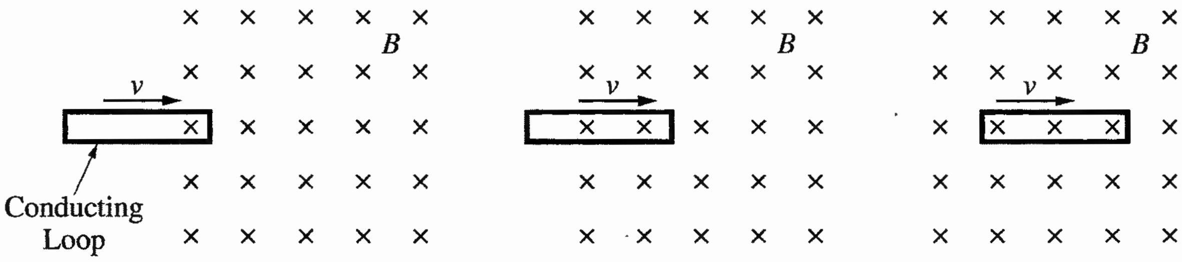

Time t_1 Time t_2 Time t_3

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~~At time t_1~~ The magnitude of the current is greatest at time t_3, smallest at time t_1, and in-between at time t_2. The direction of the current is the same at all times as the velocity of the loop is constant. The magnitude of the current at time t_3 is greatest because the greatest area of the wire (its entire area) is under the influence of the field. Likewise, more of the wire is influenced at t_2 than at t_1.

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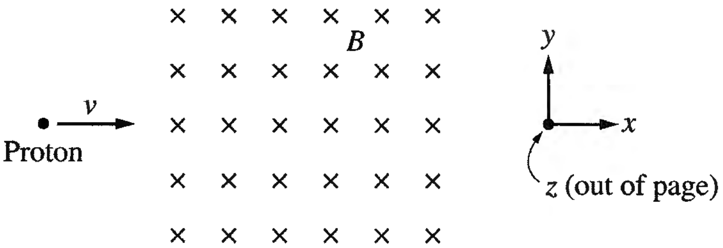


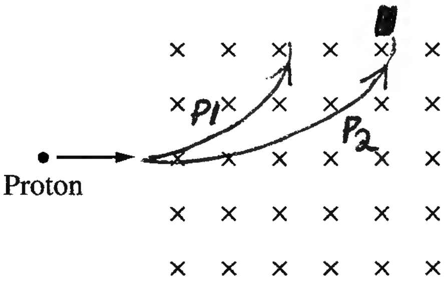
i. Calculate the magnitude of the force on the proton as it enters the field.

F_M ~~F_B~~ $= qV \times B$

F_M ~~F_B~~ $= (+1.6 \times 10^{-19}\ C)(3 \times 10^5\ \frac{m}{s})(.030\ T)$

$F_M = 1.44 \times 10^{-15}$ N

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$\vec{E} = \frac{\vec{F_E}}{q}$; $|\vec{E}| = \left|\frac{F_E}{q}\right|$; $E = \frac{(1.44 \times 10^{-15}\ N)}{(1.6 \times 10^{-19}\ C)} = 9000\ \frac{N}{C}$

The direction of the electric field relative to the coordinate system shown in part (b) is down (towards the bottom of the page.)

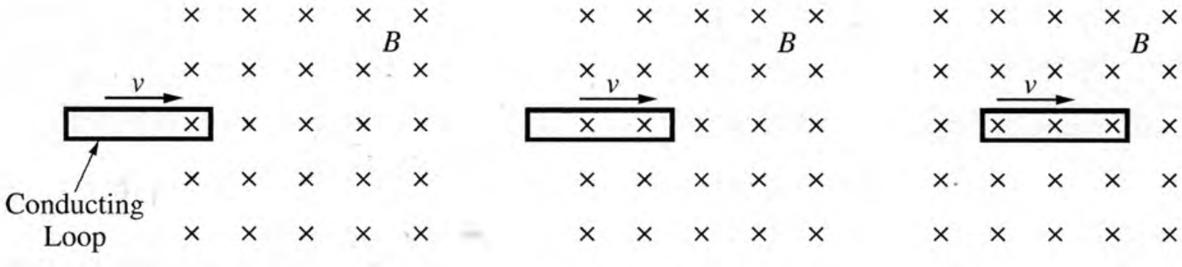
PHYSICS 2

Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



Time t_1 Time t_2 Time t_3

1. (10 points, suggested time 20 minutes)

The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

At t_1 and t_2 the direction of the current is going towards the top of the page, according to the right hand rule. But the magnitude of the current at t_1 is greater than t_2, because the current decreases as you enter the magnetic field. And at $t=3$, there ~~is~~ is no current, because there is no current inside a magnetic field only around it.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.

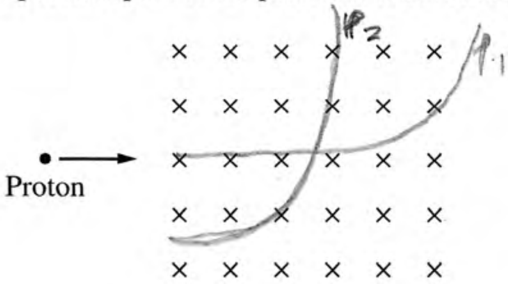
i. Calculate the magnitude of the force on the proton as it enters the field.

$F_m = q\vec{v}\vec{B}$

$= (1.6 \times 10^{-19}\ c)(3 \times 10^5\ m/s)(.03\ T)$

$= 1.44 \times 10^{-15}\ N$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$F_e = Eq$

$F_m = qvB$

$E = 9 \times 10^3$ N/c towards the bottom of the page.

$F_e = F_m$

$Eq = qvB$

$E = vB$

$= (3 \times 10^5\ m/s)(.03T)$

$= 9 \times 10^3\ N/c$, ↑

GO ON TO THE NEXT PAGE.

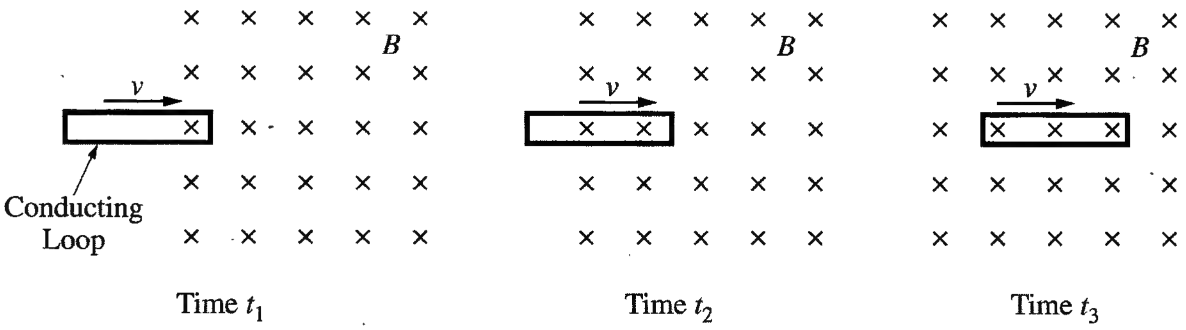
PHYSICS 2

Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points, suggested time 20 minutes)

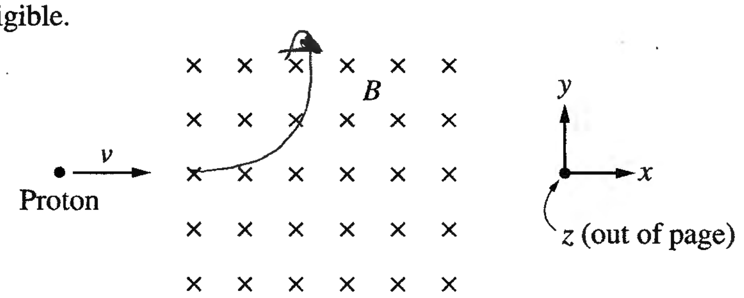
The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

In t_1 the current direction is clockwise but magnitude would be low because more field lines through a wire means more current being produce ∴ t_1 it would be lowest. In t_2 the direction is the same clockwise but this time there is more current then before because more field lines. In t_3 there's no current because the electrons are countering eachother ∴ no current

GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



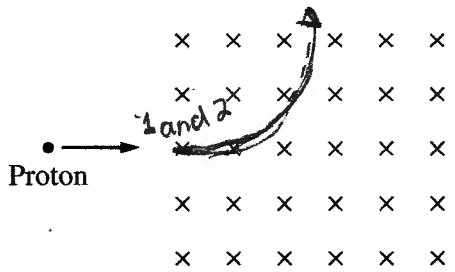
i. Calculate the magnitude of the force on the proton as it enters the field.

$F_M = qvB =$

$= (1.60 \cdot 10^{-19} C)(3 \cdot 10^5 m/s)(0.030 T)$

$F = 1.4 \cdot 10^{-15} N$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$Eq = qvB$

$E = vB$

$= (3.6 \cdot 10^5 m/s)(0.030 T)$

$E = 9000$ N/C [Out of page]

PHYSICS 2

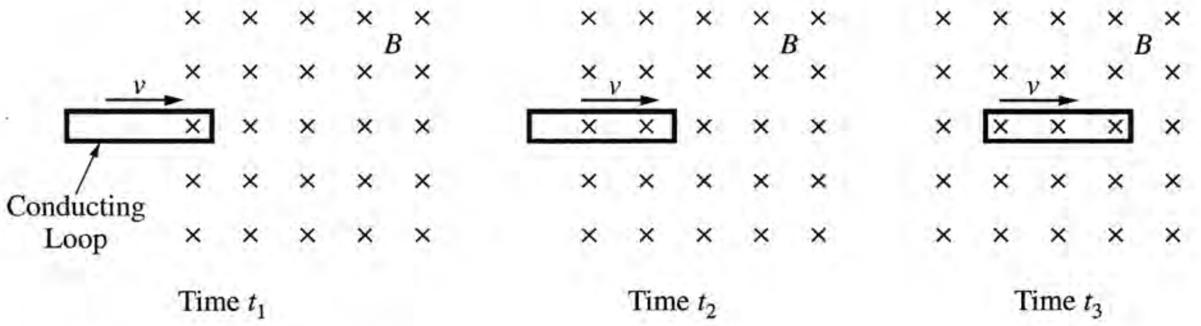
Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.

$B = \frac{\mu I}{2r}$



1. (10 points, suggested time 20 minutes)

The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

The direction of the current is the same ~~the~~ at times t_1, t_2, and t_3 because the initial magnetic field stays in the same direction, due to $F = \vec{l} I \cdot \vec{B}$. The magnitude of the current ~~increases~~ decreases from t_1 to t_2 and ~~increases~~ decreases again from t_2 to t_3 because the rectangular conducting loop moves across the magnetic field. As the B becomes stronger, the current decreases because the current is indirectly proportional to B.

GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.

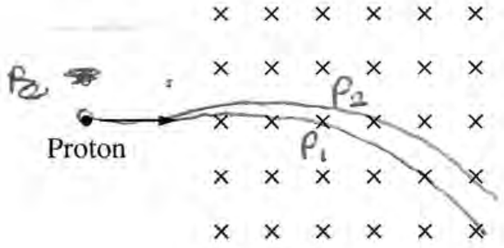
i. Calculate the magnitude of the force on the proton as it enters the field.

$F = qvB$

$F = 1.6\times10^{-19}\,C \cdot 3\times10^{5}\,\frac{m}{s} \cdot .03T$

$= 1.44\times10^{-15}\,N$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

$E = \frac{Q}{\varepsilon_0 A}$ $\quad \Phi_B = B \cdot A$

$A = \frac{Q}{\varepsilon_0 E}$

$\Phi = B \cdot A$

$\Phi = B \cdot \frac{Q}{\varepsilon_0 E}$

$1.44\times10^{-5} = .03 \cdot \frac{1.6\times10^{-19}}{8.85\times10^{-12} \cdot E}$

$1.44\times10^{-5} = \frac{5.42\times10^{-10}}{E}$

$E = 3.76\times10^{-6}\,\frac{N}{C}$

GO ON TO THE NEXT PAGE.

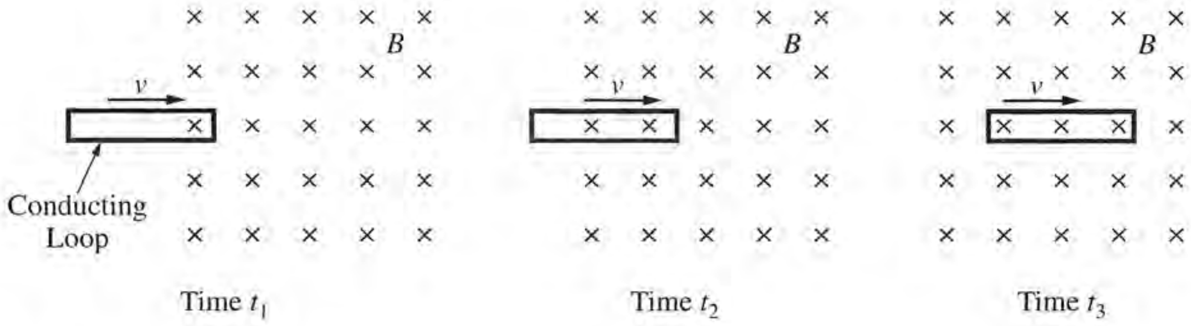
PHYSICS 2

Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points, suggested time 20 minutes)

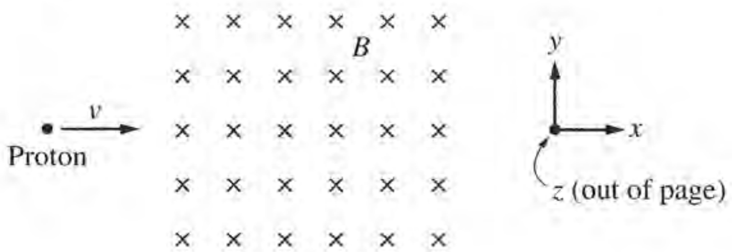
The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

The conducting rectangular loop has a greatest current at t_3 because it ~~has~~ is entirely covered. At t_2 half the rectangular loop is in the magnetic field thus having a smaller current but still greater than at t_1. At all 3 times the direction of the current is clockwise.

GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.



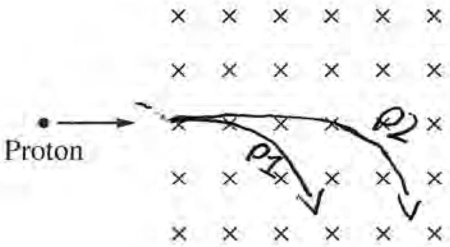
i. Calculate the magnitude of the force on the proton as it enters the field.

$F_m = qv \times B$

~~$F_m = (1.67\times10^{-27}\,kg)(3\times10^5\,m/s)(.030\,T)$~~

$F_m = 1.5\times10^{-23}\,T$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

The magnitude is .030T and it is out of the page

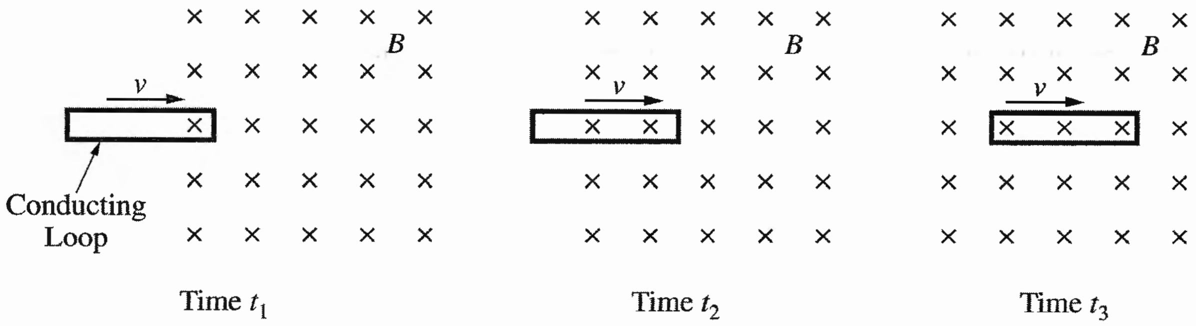
PHYSICS 2

Section II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points, suggested time 20 minutes)

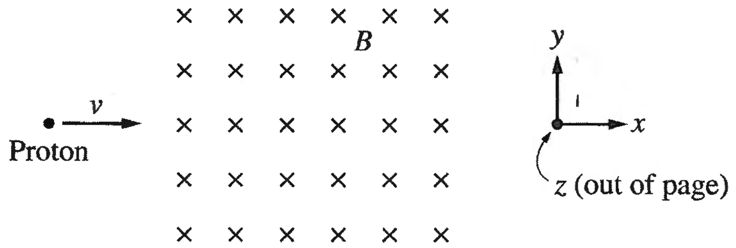
The figures above show a rectangular conducting loop at three instants in time. The loop moves at a constant speed v into and through a region of constant, uniform magnetic field B directed into the page. The magnetic field is zero outside the region.

(a) In a coherent paragraph-length response, compare the magnitude and direction of the current at times t_1, t_2, and t_3. Include an explanation of why there is or is not a current and the direction of the current if one is present. Use fundamental physics concepts and principles in your explanation.

At time t_1, the magnitude of the current is the least, this is because of $F = IB$. At t_1, the magnitude of the force is the least, and therefore causes the current to have the least magnitude. Using the same explanation, this would imply the current at time t_2 is in the middle, ~~it has the~~ The magnitude of the current at t_2 is in between t_1 & t_3. therefore, the magnitude at time t_3 must have the greatest magnitude of current. This is because there is the greatest amount of force acting on the bar at t_3.

GO ON TO THE NEXT PAGE.

(b) The loop is removed. A proton traveling to the right in the plane of the page, as shown below, then enters the region of magnetic field with a speed $v = 3.0 \times 10^5$ m/s. The magnitude of the field is 0.030 T. The effects of gravity are negligible.

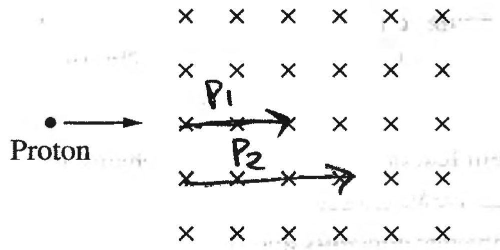


i. Calculate the magnitude of the force on the proton as it enters the field.

$F = qv \sin\theta B = (1.60 \times 10^{19})(3 \times 10^5)(.030) =$

$\boxed{1.44 \times 10^{-15} \text{ N}}$

ii. On the figure below, sketch a possible path of the proton as it travels through the magnetic field. Clearly label the path P1.



iii. A second proton now enters the magnetic field at the same point and from the same direction but at a greater speed than the first proton. On the figure above, draw the path of the second proton as it travels through the field. Clearly label the path P2.

iv. Next an electric field is applied in the same region as the magnetic field, such that there is no net force on the first proton as it enters the region. Calculate the magnitude and indicate the direction of the electric field relative to the coordinate system shown in part (b).

~~Because B = .030 T, F must =~~ $[\,|F_m| = |F_e|\,]$

$F = qvB$ ~~= 0~~ ~~$\frac{qv}{F}$~~ $= (1.6 \times 10^{19})(3 \times 10^5)(.030)$

~~.030~~ $= 1.44 \times 10^{-15}$ N

$F_e = -1.44 \times 10^{-15}$ pointing out of the page

Question 1

Sample Identifier: P2 Q1 A
Score: 10

- a) Full credit 5pts
- b(i) 1pt for correct answer and unit
- b(ii) 1pt for upward curve
- b(iii) 1pt for larger upward curve
- b(iv) 2pts for correct magnitude and direction

Sample Identifier: P2 Q1 B
Score: 9

- a) Full credit 5pts
- b(i) 1pt for correct answer and unit
- b(ii) 1pt for upward curve
- b(iii) No credit for smaller curve
- b(iv) 2pts for correct magnitude and direction

Sample Identifier: P2 Q1 C
Score: 8

- a) 1pt for stating the currents in t1 and t2 are equal in magnitude and direction, 1pt for stating the current at t3 is zero, 1pt for describing Faraday's Law, 1pt for the paragraph but the student never explained why the current is counterclockwise
- b(i) 1pt for correct answer and unit
- b(ii) 1pt for upward curve
- b(iii) No credit for smaller curve
- b(iv) 2pts for correct magnitude and direction

Sample Identifier: P2 Q1 D
Score: 7

- a) 1pt for stating current is zero at t3, 1pt for discussing a change in flux and 1pt for a coherent paragraph. While they say the current is both clockwise in t1 and t2 they do not say it has the same magnitude
- b(i) 1pt for correct answer and unit
- b(ii) 1pt for upward curve
- b(iii) 1pt for larger upward curve
- b(iv) 1pt for correct magnitude and but no direction is mentioned

Sample Identifier: P2 Q1 E
Score: 6

- a) 1pt for a coherent and consistent yet incorrect paragraph
- b(i) 1pt for correct answer and unit
- b(ii) 1pt for upward curve
- b(iii) 1pt for larger upward curve
- b(iv) 2pst for correct magnitude and direction, it is implicit that Fe = FB

Sample Identifier: P2 Q1 F
Score: 5

- a) 1pt for stating there is no current at t3, 1pt for consistent incorrect paragraph
- b(i) Correct 1pt
- b(ii) No credit due to being too straight
- b(iii) Tighter curve no credit
- b(iv) Correct magnitude and direction 2pts

Sample Identifier: P2 Q1 G
Score: 4

- a) 1pt for stating there is no current at t3 and then inconsistent description of change in flux
- b(i) 1pt for correct answer and unit
- b(ii) Curved upwards, 1pt
- b(iii) Same as curve P1 so incorrect
- b(iv) Correct magnitude but incorrect direction, 1pt

Sample Identifier: P2 Q1 H
Score: 3

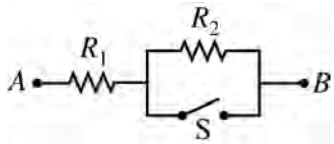
- a) Coherent yet incorrect argument, 1pt for paragraph
- b(i) 1pt for correct answer and unit
- b(ii) Curved down, incorrect
- b(iii) Larger curve consistent with P1, 1pt
- b(iv) No credit

Sample Identifier: P2 Q1 I
Score: 2

- a) Coherent argument that is incorrect, 1pt for paragraph
- b(i) Incorrect, use of proton mass for charge, no credit
- b(ii) No credit because it curves down
- b(iii) Consistent larger curve than P1, 1pt
- b(iv) No credit

Sample Identifier: P2 Q1 J
Score: 1

- a) No credit for incorrect currents, vague explanation of a force on a bar, and incorrect equation cited
- b(i) 1pt for correct force and units
- b(ii) No credit because it is straight
- b(iii) No credit because it is not possible to have a larger radius of a straight line
- b(iv) No credit, repeats calculation of the magnetic force



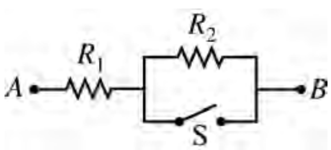
2. (12 points, suggested time 25 minutes)

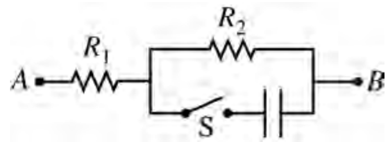
Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points *A* and *B*. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram

Describe the Experiment





A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between *A* and *B* is maintained at 9 V. The students close the switch and immediately begin to record the current through point *B*. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

ii. Calculate the values of R_1 and R_2.

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

Question 2 continues on the next page.

GO ON TO THE NEXT PAGE.

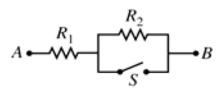
A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

GO ON TO THE NEXT PAGE.

Question 2

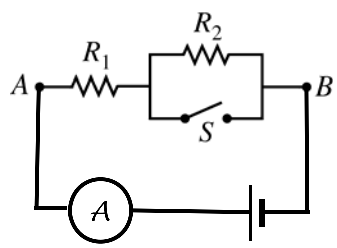
12 points total **Distribution of points**



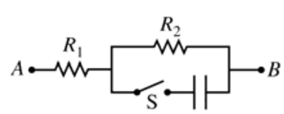
Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points *A* and *B*. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) LO 4.E.5.3, SP 2.2, 4.2, 5.1; LO 5.B.9.5, SP 6.4; LO 5.C.3.4, SP 6.4
4 points

Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.



For a diagram with an ammeter and battery in series with the resistor combination		1 point
For indicating that the current should be measured with the switch closed and open		1 point
For correctly indicating that with the switch closed $R_1 = V/I_1$		1 point
For correctly indicating that with the switch open $R_2 = (V/I_2) - R_1$		1 point



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Question 2 (continued)

Distribution of points

(b)

i) LO 4.E.5.2, SP 6.1, 6.4; LO 5.B.9.5, SP 6.4; LO 5.C.3.7, SP 1.4
3 points

Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

For indicating that the current through resistor 1 immediately after the switch is closed is greater than the current a long time after the switch is closed		1 point
For indicating that the current through resistor 2 is zero immediately after the switch is closed and nonzero a long time after the switch is closed		1 point
For indicating that the current through the switch is nonzero immediately after the switch is closed and zero a long time after the switch is closed		1 point

ii) LO 4.E.5.1, SP 2.2, 6.4
2 points

Calculate the values of R_1 and R_2.

For using the correct value of current and correctly calculating R_1		1 point
$9\text{ V} = (0.9\text{ A})R_1$		
$R_1 = 10\ \Omega$		
For using the correct value of current and correctly calculating R_2, consistent with the calculated value of R_1		1 point
$9\text{ V} = (0.3\text{ A})(R_1 + R_2) = (0.3\text{ A})(10\ \Omega + R_2)$		
$R_2 = 20\ \Omega$		

iii) LO 4.E.5.1, SP 2.2; LO 5.B.9.6, SP 2.2, LO 5.C.3.7, SP 1.4, 2.2
1 point

Determine the potential difference across the capacitor a long time after the switch is closed.

For correctly calculating the potential difference across the capacitor, including correct units, consistent with part (b)(ii)		1 point
$V_C = V_{\text{battery}} - V_{\text{resistor 1}} = 9\text{ V} - (0.3\text{ A})(10\ \Omega)$		
$V_C = 6\text{ V}$		

Question 2 (continued)

Distribution of points

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) LO 5.B.9.7, SP 5.3
2 points

How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

For correctly explaining that the third group's measured current is smaller		1 point
For correctly indicating that the third group's value of R_1 is higher than the second group's or the resistance they will determine is actually $R_1 + r$		1 point

LO 4.E.5.1: The student is able to make and justify a quantitative prediction of the effect of a change in values or arrangements of one or two circuit elements on the currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel. **[SP 2.2, 6.4]**

LO 4.E.5.2: The student is able to make and justify a qualitative prediction of the effect of a change in values or arrangements of one or two circuit elements on currents and potential differences in a circuit containing a small number of sources of emf, resistors, capacitors, and switches in series and/or parallel. **[SP 6.1, 6.4]**

LO 4.E.5.3: The student is able to plan data collection strategies and perform data analysis to examine the values of currents and potential differences in an electric circuit that is modified by changing or rearranging circuit elements, including sources of emf, resistors, and capacitors. **[SP 2.2, 4.2, 5.1**]

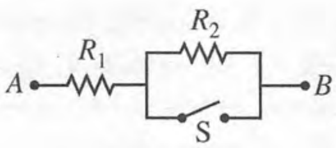
LO 5.B.9.5: The student is able to use conservation of energy principles (Kirchhoff's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors. **[SP 6.4]**

LO 5.B.9.6: The student is able to mathematically express the changes in electric potential energy of a loop in a multiloop electrical circuit and justify this expression using the principle of the conservation of energy. **[SP 2.1, 2.2]**

LO 5.B.9.7: The student is able to refine and analyze a scientific question for an experiment using Kirchhoff's Loop rule for circuits that includes determination of internal resistance of the battery and analysis of a non-ohmic resistor. **[SP 4.1, 4.2, 5.1, 5.3]**

LO 5.C.3.4: The student is able to predict or explain current values in series and parallel arrangements of resistors and other branching circuits using Kirchhoff's junction rule and relate the rule to the law of charge conservation. **[SP 6.4, 7.2]**

LO 5.C.3.7: The student is able to determine missing values, direction of electric current, charge of capacitors at steady state, and potential differences within a circuit with resistors and capacitors from values and directions of current in other branches of the circuit. **[SP 1.4, 2.2**]

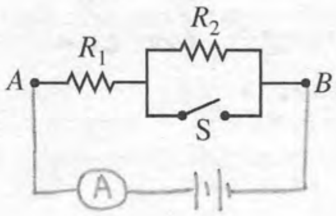


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



Describe the Experiment

First, close the switch. Record the current through the ammeter as I_1. Use Ohm's law to calculate R_1 as follows:

$\Delta V = IR$

$R_1 = \frac{\Delta V}{I_1} = \frac{(9V)}{I_1}$

Next, open the switch. Record the current through the ammeter as I_2. Use Ohm's law again to determine R_2:

$\Delta V = IR$

$\Delta V = I_2 (R_1 + R_2)$

$\Delta V = I_2 R_1 + I_2 R_2$

$I_2 R_2 = \Delta V - I_2 R_1$

$R_2 = \frac{\Delta V - I_2 R_1}{I_2}$

$R_2 = \frac{(9V) - I_2 R_1}{I_2}$

R_1 and R_2 can be obtained by substituting the values of I_1 and I_2 into the above equations.

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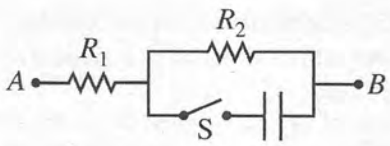

A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

Immediately after the switch is closed, the current through R1 is 0.9A, and that through R2 is zero, since the capacitor has zero resistance and its branch behaves like a short circuit. All the current (0.9A) goes through the switch too.

A long time after the switch is closed, the current through both R1 and R2 is 0.3A, since the capacitor has infinite resistance and its branch has zero current. Thus, the current through the switch is also zero.

ii. Calculate the values of R_1 and R_2.

$\Delta V = IR$

$9V = (0.9A) R_1$

$R_1 = 10\Omega$

$\Delta V = IR$

$9V = (0.3A)(R_1 + R_2)$

$9V = (0.3A)(10\Omega + R_2)$

$R_2 = 20\Omega$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

Let the potential difference across the capacitor be ΔV_c

$\Delta V_T = \Delta V_{R_1} + \Delta V_c$

$\Delta V_T = IR_1 + \Delta V_c$

$9V = (0.3A)(10\Omega) + \Delta V_c$

$\Delta V_c = 6V$

Question 2 continues on the next page.

GO ON TO THE NEXT PAGE.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

The third group's value of R_1 would be greater than the second group's. Since $\Delta V = IR$, the increase in total resistance from the internal resistance of the battery would reduce the measured value of the current, as the total potential difference remains constant. At the same time, the value of potential difference used in calculations is higher than actual because of internal resistance.

Because of $R = \frac{\Delta V}{I}$, ~~and~~ the potential difference higher than actual, and current lower than actual in calculations, the calculated value of R_1 would be higher than actual, the second group's value.

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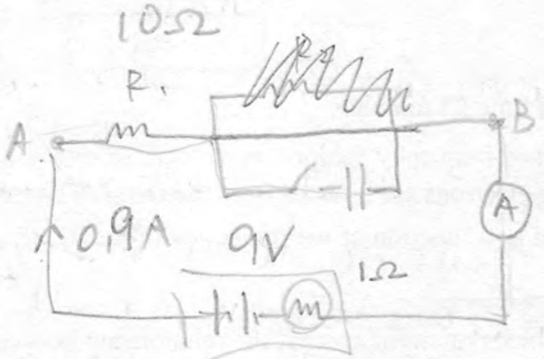

2nd.

$V = \mathcal{E} - IR_{internal}$.

$= IR\uparrow$

$R = \frac{V\uparrow}{I\downarrow}$

3rd.

$V = IR\uparrow$

$\uparrow V = I\, R_1$

$R_1 = \frac{\uparrow V}{\downarrow I}$

$V = IR$

$9V = I(1\Omega) + I(10\Omega)$

$I = 0.81\ldots$

calculated

$V = IR$

$9V = 0.81\, R$

$R = 11.1$

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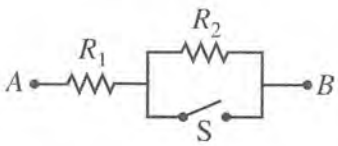
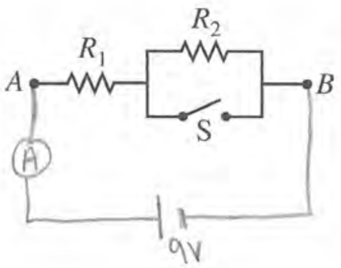


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

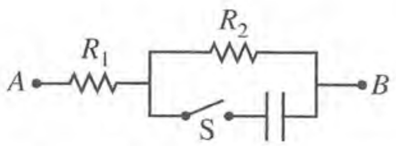
Complete the Diagram



Describe the Experiment

With the switch open, record the current read on the ammeter. This current should equal the total voltage (battery) divided by (Resistor 1 + Resistor 2). From the read current they can find what the total resistance is.

Now with the switch closed, record the current read on ammeter. This should equal total voltage (battery) divided by Resistor 1, since current follows the path of least resistance. From the read current they can find what resistance in Resistor 1 is equal to. Knowing the total resistance and resistance in Resistor 1, resistance in Resistor 2 can also be found from the difference, since they are in series.



A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

The current through resistor 1 immediately after the switch is closed would be .9 A, while in resistor 2 and the switch the current would add up to .9A since the current split. After a long time current would stop flowing through the switch since the capacitor is fully charged and the current in resistor 1 would be .3A as well as resistor 2 since they are practically in series.

ii. Calculate the values of R_1 and R_2.

$9V = (.3A)(R_T)$ $9V = (.9A)(R_1)$

$R_T = 30\Omega$ $\boxed{R_1 = 10\Omega}$

$R_T = R_1 + R_2$

$30 = 10 + R_2$

$\boxed{R_2 = 20\Omega}$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

$Q = VC$ $V = IR$

$V = (.3A)(20\Omega)$

$\boxed{V = 6V}$

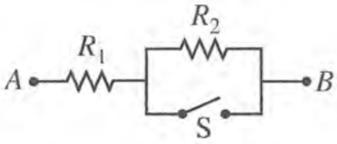
Question 2 continues on the next page.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

V=↓IR↑

The third group's value of R₁ would calculate out to be larger than of the second group's calculation of R₁. Because there is internal resistance within the battery, the circuit would then technically have a higher total resistance. Because a higher total resistance is present, a lower current will be present and read on the ammeter. Because they do not account for the internal resistance, it will make it seem as if there is more resistance in R₁ and R₂ than there actually is. So the 3rd group will have a higher calculated R₁ than R₁ of the second group.

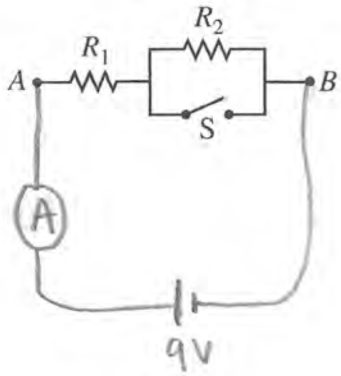


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



$I = \frac{\Delta V}{R}$

Describe the Experiment

To begin hook up the ammeter and battery to the circuit as shown. First, take a reading on the ammeter with the switch closed. Using $I = \frac{\Delta V}{R_1}$, with I being the reading on the ammeter and $\Delta V = 9$, determine the resistance of R_1. Then open the switch, and using the equation $I = \frac{\Delta V}{(R_1 + R_2)}$, solve for R_2 algebraically using the value found for R_1, I being the reading found on the ammeter the second time (with switch open), and $\Delta V = 9$.

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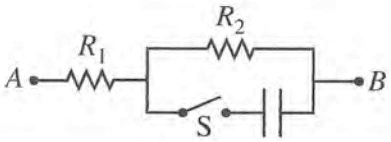

A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

The current through resistor 1 is the same as the current through the switch immediately after the switch is closed, while the current in resistor 2 is zero. A long time after the switch is closed, the current in resistor 1 is the same as in resistor 2, and the current through the switch is now zero.

ii. Calculate the values of R_1 and R_2.

$I = \frac{\Delta V}{R}$ $\quad .9 = \frac{9}{R_1}$ $\quad R_1 = \frac{9}{.9} = \boxed{R_1 = 10\Omega}$

$.3 = \frac{9}{10 + R_2}$ $\quad .3(10 + R_2) = 9$ $\quad 3 + .3R_2 = 9$

$.3R_2 = 6$

$/.3$

$\boxed{R_2 = 20\Omega}$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

~~$Q = \Delta V \cdot C$~~

$\frac{1}{2} Q \Delta V = \frac{1}{2} C (\Delta V)^2$

$\Delta U_E = q \Delta V$

$U_i = \frac{1}{2} C (\Delta V)^2$

$\frac{Q \Delta V}{(\Delta V)^2} = C$

$q \Delta V = \frac{1}{2} C (\Delta V)^2$

Question 2 continues on the next page.

GO ON TO THE NEXT PAGE.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

The third groups value of R_1 will be greater than the second group's value of R_1. Since the 3rd group's battery has internal resistance, this will result in the current (I) to be lower, since $I = \frac{\Delta V}{R}$. Since the 3rd group thinks their 9V battery is ideal, they will not take in account for the internal resistance, and treat it as if the internal resistance is added to the R_1 of the second group.

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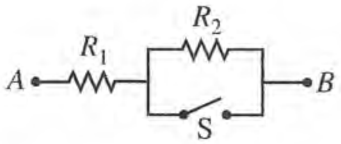
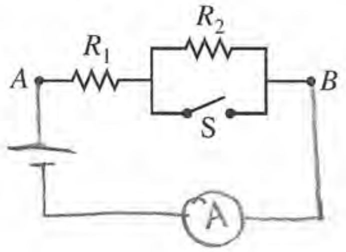


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points *A* and *B*. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



Describe the Experiment

First connect all components as shown in the diagram to the left. Then, open the switch and allow current to flow. Measure the current. Then, close the switch and measure the current once again. The first current is with both resistors, and the second current is with one resistor

Use:

$V = IR$

to calculate the resistance of the first resistor using the first current. Then calculate the resistance of both the resistors with the second current.

Use:

$R_{eq} = R_1 + R_2$

to find the resistance of the second resistor.

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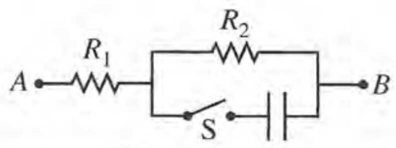

A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

The current through R_1 after the switch is closed will be 0.9A. There will be no current in R_2. After a long time, the current in both R_1 and R_2 will be 0.3 A. The current through R_1 decreased over time, but the current in R_2 increased over time.

ii. Calculate the values of R_1 and R_2.

$9 = 0.9 R_1$

$\boxed{R_1 = 10\,\Omega}$

$9 = 0.3 R_T$

$R_T = 30$

$R_1 + R_2 = R_T$

$10 + R_2 = 30$

$\boxed{R_2 = 20\,\Omega}$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

$IR = V$

$10 \cdot 0.3 = 3$

$9 - 3 = \boxed{6\text{ V}}$

Question 2 continues on the next page.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

The third groups value of R_1 will be greater than the second groups value of R_1. This is because they will think that the value of R_1 is actually inclusive of the internal resistance of the battery. They will think they are just added, because the two resistances are in series, and by $R_T = R_1 + R_2$, they will be added. They may also calculate the current to be less than anticipated, because of $V = IR$ and the inverse relationship between current and resistance. So, with an increase in resistance, there is a decrease in current.

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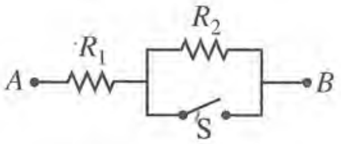
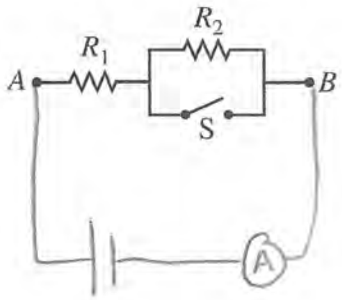


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



Describe the Experiment

Connect the Circuit as shown.

Then use the Ammeter to read the current when the switch is open. Divide 9V by the current to find the total resistance.

Then close the switch and record the new current, divide 9V by the new current to find the resistance of R_1, Subtract R_1 from the total resistance to find R_2.

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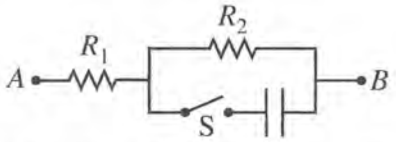

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(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

imediately after the switch is closed there is .9A current through the Switch Zero current through R_2 and .9A through R_1.

A long time after the switch is closed there is 0 current through the switch And an equal amount of current through resistors 1 & 2.

ii. Calculate the values of R_1 and R_2.

$R_2 = 20\,\Omega$

$\frac{9V}{.9A} = R_1 = 10\,\Omega$

$30 - 10 = 20$

$\frac{9V}{.3} = R_1 + R_2 = 30\,\Omega$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

$V = 0$

Question 2 continues on the next page.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

the 3rd group' R_1 is Smaller b/c the group was finding $R_1 + r$ when dividing $\mathcal{E}$ by current. So what they thought was R_1 was really R_{total} $(R_1 + r)$ and $R_{total} - r = R_1$.

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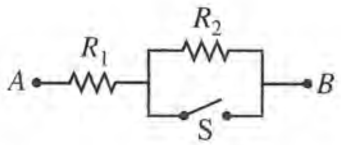
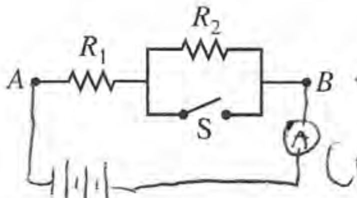


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



Describe the Experiment

First close switch S and take a measurement on the ammeter. No current will go through R_2 because it's in parallel with a wire of no resistance. Knowing voltage and current use the equation $V=IR$ to find the resistance of R_1. Then, open the switch S, now R_1 and R_2 are in series and are the only places for current to flow. measure the current, set up $V=IR$ and solve for R. R will be a combination of R_1 and R_2 since they are in series, so subtract R_1 from R to get R_2.

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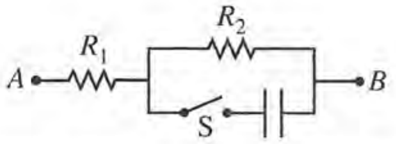
V=IR



A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

Initially the current through R_1 is .9A, after a long time it is .3A. The current of R_2 stays constant at .3A.

ii. Calculate the values of R_1 and R_2.

V = I R

9 = (.3)(R_1 + R_2)

30 = R_1 + R_2

9 = (.9)(R_1)

8.1 = R_1

21.9 = R_2

30 − 8.1 = R_2

21.9 = R_2

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

0 V

Question 2 continues on the next page.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

The third group would have a value of R_1 that is higher than that of the seconds group. This is because their total resistance is higher due to the resistors being the same but they have a battery with resistance. They would attribute this extra resistance to the resistors ~~to~~ so they would get a higher value than the second group.

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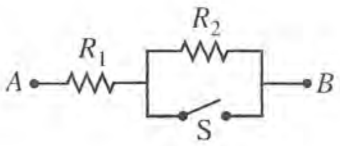
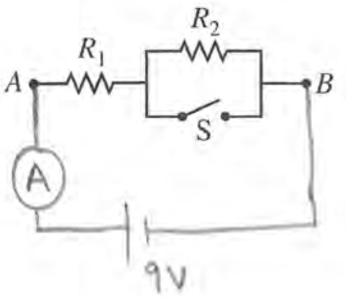


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points *A* and *B*. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



To find R_2:

$V_{battery} - V_1 = I R_2$

Describe the Experiment

1) Set up the circuit as shown in the diagram to the left.
2) To measure the total current of the circuit, I, read the number reading on the ammeter.
3) R_1 can be calculated using the voltage of the battery (since there is no voltage drop in the circuit before R_1) and the current, I, from the ammeter.
To find R_1: $V_{battery} = I(R_1 + R_2)$

4) Do not close the switch. Since we know the current, I, will all go to the branch where R_2 is located, since switch S is closed, we know the current in R_2. The voltage across R_2 is equal to the voltage of the battery minus the voltage drop of R_1, since voltage is equal in parallel.

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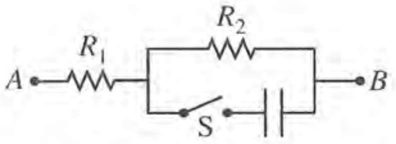

A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

Immediately After: $I_1 = I_S > I_2 = 0$

After a long time: $I_1 = I_2 > I_S = 0$

ii. Calculate the values of R_1 and R_2.

$V = 9\text{ V}$
$I = 0.3\text{ A}$

$V = IR$
$9 = (0.3)R_{eq}$
$R_{eq} = 30\ \Omega$

$R_{eq} = R_1 + R_2$

$V = IR$

$R_1 = 2\ \Omega$
$R_2 = 1\ \Omega$

$V = IR$
$9 = 0.9R$
$R = 10\ \Omega$

$\frac{V_1}{V_2} = \frac{I_1}{I_2} = \frac{0.9}{0.3} = \frac{R_2}{R_1}$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

$Q = VC$
$V = IR$
$V = (0.3)(1)$
$V = 0.3\text{ V}$

Question 2 continues on the next page.

GO ON TO THE NEXT PAGE.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

The third group's value of R_1 will be greater than the second group's value because the third group's value of R_1 will include the battery's internal resistance and the real resistance of the first resistor.

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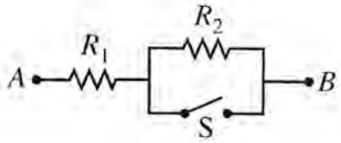
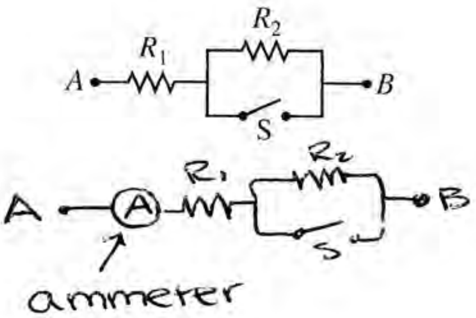


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

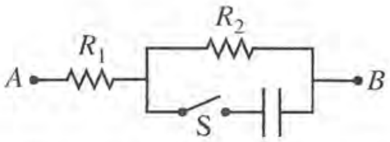
(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



Describe the Experiment

- The ammeter being placed in the beginning allows total current to be measured
- Since R_2 is placed in a parallel circuit, the amount of current to the parallel current is shared with the other branch based on resitivity
- By using $I = \frac{\Delta V}{R}$, resistance of the two resistors can be found because current and voltage is known



A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

- When the swith is immediately closed, R_2 recieves no current
- After a long period of time, R_2 receives all the current going into the parallel branches, making the capacitor's current zero
- Resistor 1 current remains constant

ii. Calculate the values of R_1 and R_2.

$V_1 = 3V$ $I_1 = .3A$ $R_1 = 10\Omega$
$V_2 = 6V$ $I_2 = .3A$ $R_2 = 20\Omega$
$V_T = 9V$ $I_T = .3A$ $R_T = 30\Omega$

Instant
$V_1 = 9V$ $I_1 = .9$ $R_1 = 10$
$V_2 = 0V$ $I_2 = 0$ $R_2 =$
$V_T = 9V$ $I_T = .9$ $R_T = 10$

$R_1 = 10\Omega$
$R_2 = 20\Omega$

$V = I \times R$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

The potential difference across the capacitor over a long period of time is zero

Question 2 continues on the next page.

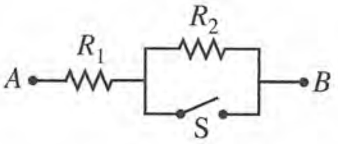
GO ON TO THE NEXT PAGE.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

-R_1 for the third group should have a greater resistance due to not calculating in the internal resistance of the battery

- the second group's voltage source does not have internal resistance so all resistance is within the circuit resistors



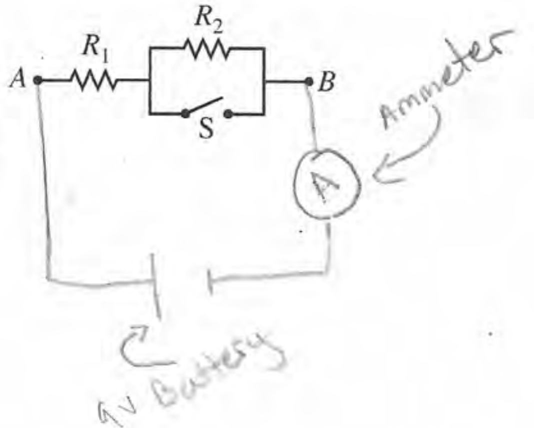
2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram

V / IR



Describe the Experiment

The battery is placed across from the Resistors and switch. The Ammeter is to the right of the battery so electricity flows to it last. You'll want it there so you get the correct current of the whole System* (current is constant in series) (switch open)

1.) Measure Amps + Find total resistance using V = IR (switch open)

2.) This time, close the switch + measure current. It will be different because it is now a parallel circuit

3.) You can now use the difference in currents to find the resistance of R_1 + R_2.

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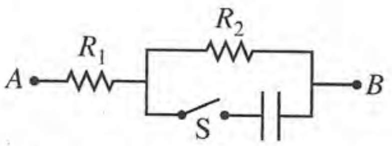

A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

Resistor 1 will have the largest current. This is because it doesn't have the a resistor before it & is directly linked to the battery. Resistor 2 will have a small current that continues to get smaller as the capacitor is allowed current. The switch will have a low current but it will continue to rise the longer the switch is closed. (Eventually, it will be constant.)

ii. Calculate the values of R_1 and R_2.

$V = IR$
$9 = .9R$
$\Delta R = 10$

$9 = .3R$
$R = 30$

$\Delta R = 10$

$R_1 =$

$R_2 =$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

The potential difference is still 9 volts. This is because voltage stays constant over a parallel circuit. Once the switch is closed it becomes a parallel circuit.

Question 2 continues on the next page.

GO ON TO THE NEXT PAGE.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

The value of R_1 as measured by the 3rd group would be larger. This is because when calculating the initial resistance that of the battery's internal resistance will be added to it because its existance was not known. Thus, it would be added on to the first resistor's resistance.

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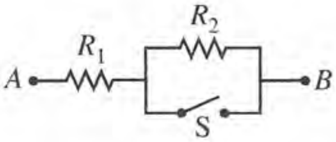
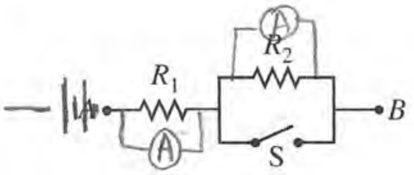


2. (12 points, suggested time 25 minutes)

Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

Complete the Diagram



Describe the Experiment

The battery would be placed in front of R_1 and the Ammeter would be placed around the resistors (one end in front and one end behind the resistor). Then you would turn on the battery and find the current running through the resistors (I). You would then use the equation $I = \frac{\Delta V}{R}$ where I is the measurements from the ammeter and 9V from the battery. $\frac{1}{R}$ is your resistance in ohms.

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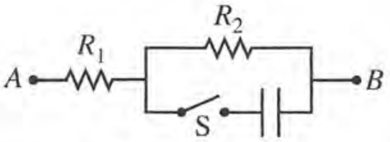


A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

The current through resistor 1 is the same in both circumstances, but resistor 2 has decreased current after the circuts been closed for a long time. The current through the switch increased when the switch is closed for a long time.

ii. Calculate the values of R_1 and R_2.

$.3\,A = \frac{9v}{R_?}$

$R_{tot} = \frac{1}{30}\,\Omega$

$\frac{1}{30} + \frac{1}{30} = \frac{1}{15}$

$R_1 = \frac{1}{.15}\,\Omega$

$.9A = \frac{9v}{R_{tot}}$

$R_{total} = \frac{1}{10}\,\Omega$

$R_2 = \frac{1}{30}\,\Omega$

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

The potential difference remains constant at 9 volts.

Question 2 continues on the next page.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

R1 would be more because they are calculating the total Resistance which includes the resistance from the battery.

Question 2

Sample Identifier: P2 Q2 A
Score: 12

- a) Full credit for diagram and experimental design, 4pts
- b(i) Full credit for description of current before and after through all three elements, 3pts
- b(ii) Correct resistance values, 2pts
- b(iii) Correct calculation of the potential difference across the capacitor and unit, 1pt
- c) Correct description of the higher calculated resistance and referencing the lower current, 2pts

Sample Identifier: P2 Q2 B
Score: 11

- a) Full credit for diagram and experimental design, 4pts
- b(i) 2pts for describing the current through R1 and the switch but is vague about R2
- b(ii) Correct resistance values, 2pts
- b(iii) Correct calculation of the potential difference across the capacitor and unit, 1pt
- c) Correct description of the higher calculated resistance and referencing the lower current, 2pts

Sample Identifier: P2 Q2 C
Score: 10

- a) Full credit for diagram and experimental design, 4pts
- b(i) 2pts for describing the current through R2 going from zero to something and the current through the switch going from something to zero but no credit is earned because they do not say if the current through R1 goes up, down or stays the same in magnitude
- b(ii) Correct resistance values, 2pts
- b(iii) No credit
- c) Correct description of the higher calculated resistance and referencing the lower current, 2pts

Sample Identifier: P2 Q2 D
Score: 9

- a) 2pts for the diagram and measuring the current with the switch open and closed, but they mix up which current to use for R1 and R2 so no credit for those two points
- b(i) 2pts for describing current through R1 and R2 but no mention of current through the switch
- b(ii) Correct resistance values, 2pts
- b(iii) Correct calculation of the potential difference across the capacitor and unit, 1pt
- c) Correct description of the higher calculated resistance and referencing the lower current, 2pts

Sample Identifier: P2 Q2 E
Score: 8

- a) Full credit for diagram and experimental design, 4pts
- b(i) 2pts for describing R2 going from zero to some current and the current through the switch going from 0.9A to zero. They are vague if the current in R1 increases or decreases
- b(ii) 2pts for correct resistance values
- b(iii) No credit
- c) No credit for stating the resistance would be less

Sample Identifier: P2 Q2 F
Score: 7

- a) Full credit for diagram and experimental design, 4pts
- b(i) 1pt for saying the current in R1 goes from 0.9A to 0.3A
- b(ii) 1pt for correct calculation of R2 from incorrect calculation of R1, units not required for this part
- b(iii) No credit
- c) 1pt for stating the total resistance would be higher but no mention of current decreasing

Sample Identifier: P2 Q2 G
Score: 5

- a) 1pt for the diagram only, they never close the switch then measure current and the current with the switch open will not allow them to calculate R1
- b(i) 2pts for accurate descriptions of the current through the switch from something greater than zero to zero and R2 going from zero to something greater than zero. A change through R1 is unclear
- b(ii) No credit
- b(iii) 1pt for substituting the incorrect R2 into the correct equation and unit
- c) 1pt for stating the total resistance would be higher but no mention of current decreasing

Sample Identifier: P2 Q2 H
Score: 4

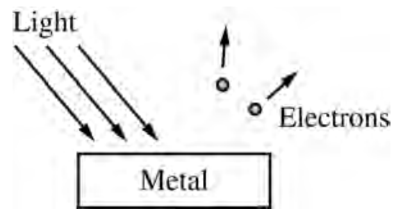
- a) No credit for incorrect diagram that is not a closed loop and the experimental design will not lead to values of R1 and R2
- b(i) 1pt for correctly comparing the current in R2
- b(ii) 2pts for correct resistance values
- b(iii) No credit
- c) 1pt for stating the resistance would be higher but no mention of the current

Sample Identifier: P2 Q2 I
Score: 3

- a) 2pts for the correct diagram and for measuring current when the switch is open and closed but no credit for incorrect data analysis
- b(i) No credit for not describing what happens before and after the capacitor charges
- b(ii) No credit, 10 is calculated but it is unclear if it is R1
- b(iii) No credit
- c) 1pt for stating the resistance would be higher but no explanation of why the current date would indicate that

Sample Identifier: P2 Q2 J
Score: 1

- a) No credit for non-looped circuit, the calculation does not indicate what R is determined and the switch is never closed
- b(i) No credit
- b(ii) No credit
- b(iii) No credit
- c) 1pt for indicating the resistance would be higher but no mention of current measurements

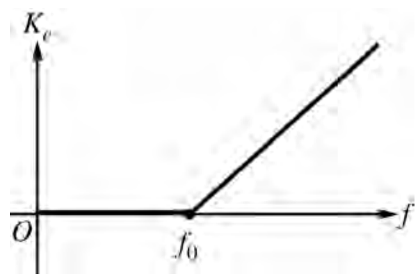


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

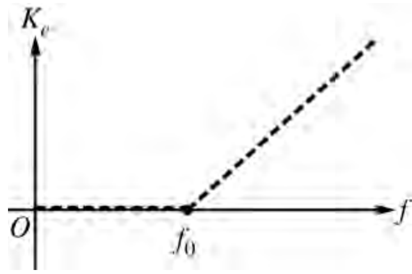
(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.

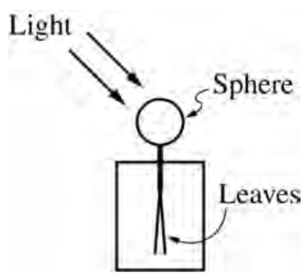


ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

Question 3 continues on the next page.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

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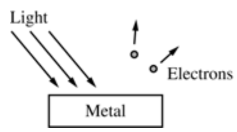
Question 3

12 points total **Distribution of points**

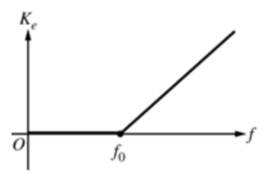


Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i) LO 5.B.4.2, SP 1.4, 2.1, 2.2; LO 6.F.3.1, SP 6.4
3 points

Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



For indicating that A represents the slope or the rate of change of K_e as a function of f, and equals Planck's constant		1 point
For indicating that $-B$ is the intercept with the K_e axis and equals the minimum energy needed to release an electron from the metal (the work function)		1 point
For indicating that f_0 is the minimum frequency that will release an electron from the metal (the cutoff or threshold frequency)		1 point

ii) LO 6.F.3.1, SP 6.4
1 point

Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

For indicating that the horizontal portion of the graph represents frequencies of light whose energy is insufficient to eject an electron		1 point

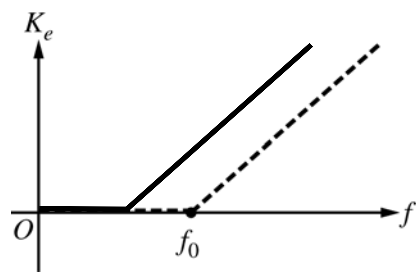
Question 3 (continued)

Distribution of points

(a) (continued)

iii) LO 6.F.3.1, SP 6.4
3 points

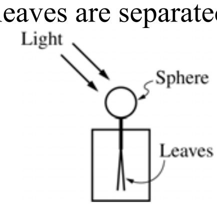
A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



For drawing a line that is parallel to the given line		1 point
For drawing the horizontal intercept on either side of f_0 with the line ending at the horizontal axis (The horizontal segment does not have to be drawn.)		1 point
For indicating that the K_e or f intercept changes because the work function or the frequency at which electrons can be emitted is different		1 point

(b)

The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i) LO 1.B.1.2, SP 6.4, 7.2, LO 4.E.3.3, SP 6.4; LO 6.F.3.1, SP 6.4
2 points

Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

For indicating that the UV light causes electrons to be ejected from the electroscope		1 point
For indicating the electroscope becomes less negatively charged, causing the leaves to move closer together		1 point

Question 3 (continued)

Distribution of points

(b) (continued)

ii) LO 6.F.1.1, SP 6.4, 7.2, LO 6.F.3.1, SP 6.4
1 point

Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

For indicating that the green light frequency or energy per photon is too low to eject electrons		1 point

(c) LO 6.F.3.1, SP 6.4
2 points

The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

For indicating that the increase in brightness causes an increase in the number of photons in the beam or increases the amplitude of the wave		1 point
For indicating that the leaves would not separate because the energy per photon or frequency of the light remains the same		1 point
The particle nature of light (photons) must be discussed to receive full credit.		

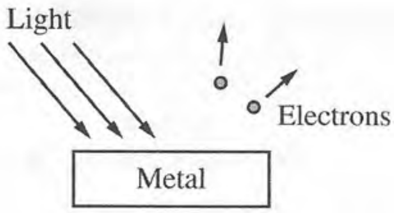
LO 1.B.1.2: The student is able to make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits. **[SP 6.4, 7.2**]

LO 4.E.3.3: The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors. **[SP 1.1, 1.4, 6.4]**

LO 5.B.4.2: The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. **[SP 1.4, 2.1, 2.2]**

LO 6.F.1.1: The student is able to make qualitative comparisons of the wavelengths of types of electromagnetic radiation. **[SP 6.4, 7.2**]

LO 6.F.3.1: The student is able to support the photon model of radiant energy with evidence provided by the photoelectric effect. **[SP 6.4**]

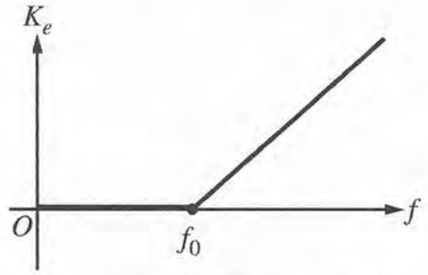


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



A is represented by the slope of the graph
B is represented by the y-intercept of the graph

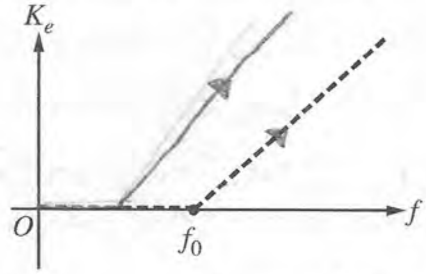
A is equal to planck's constant and determines the energy of a photon given its frequency
B is the work fuction, or amount of energy required to release an electron from the nucleus of one of the metal atoms.
fo is the minimum frequency required to have enough energy to overcome the work fuction.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

The horizontal section represents the range of frequencies that don't have enough energy to overcome the work fuction, therefore the electron does not have enough energy to break away from the nucleus. Since the electron is never emmited, Ke cannot be measured.

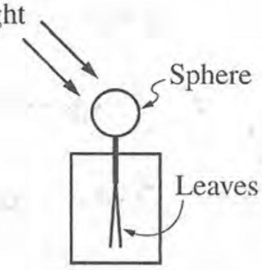
GO ON TO THE NEXT PAGE.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



The horizontal section for the graph of a different metal could be different because it could have a lower work fuction.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

Due to the photoelectric effect, when light hits the sphere, some electrons in the sphere absorb enough energy from the photons to be emmited. With less total electrons, there is less total negative charge, reducing the repulsive electrostatic force between the leaves, reducing their seperation.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

The UV light has a higher frequency than the green light, therefore higher energy. The green light does not give the electrons enough energy to overcome the work function of the metal, or energy required to emmit the electrons. Therefore no charge is lost because no electrons are lost. The UV light has enough energy to overcome the work function.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

When the brightness of the green light is increased its intensity is increased, meaning more photons are released per unit area. The increase in brightness would not result in movement of the leaves. The change in intensity only changes the amount of photons present and does not change the energy per photon. Each photon would still lack the energy to overcome the work function, meaning no electrons would be released, meaning the leaves wouldn't move.

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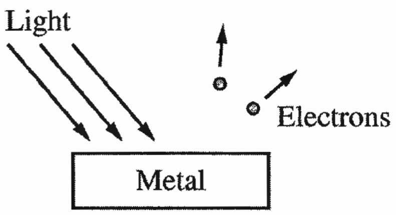
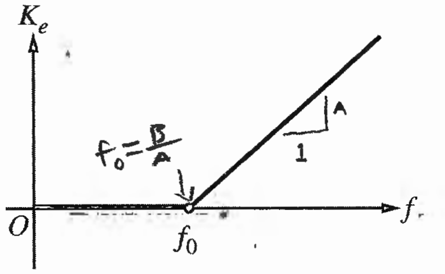


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \le f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



B = A×f₀, the energy at the point where the graph starts to go up

A is the slope of the graph

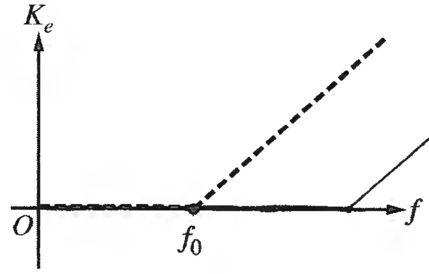
B is the work function of the metal. A is Planck's constant, which relates the frequency of a photon to its energy in the equation E = hf, where h = A = Planck's constant. f_0 is the maximum frequency of the light at which no electrons will be emitted from the metal.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

If f is in that horizontal section, the energy of the photons will be less than the work function of the metal, so no electrons will be emitted, so the kinetic energy would be 0.

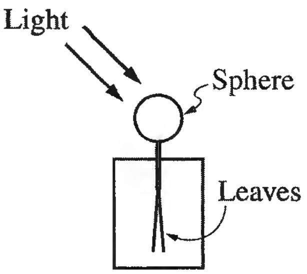
GO ON TO THE NEXT PAGE.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



The horizontal section of the graph is longer for the second metal because it has a larger work function (if it's a smaller work function the horizontal part will be shorter). The photons hitting the metal must have a higher frequency before electrons are emitted.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

Photons strike the sphere with high energy (frequency), causing it to emit electrons because of the photoelectric effect. When negatively charged electrons are emitted, the electroscope moves toward 0 charge. There is less electric repulsive force between the two leaves, so gravity pulls them closer together.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

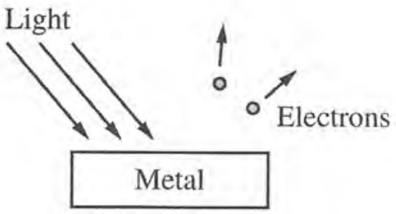
Green light has a lower frequency than UV light does. Its photons do not carry enough energy to surpass the work function of the metal, so no electrons are emitted. The electroscope retains its charge.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

The number of photons in the green light changes. However, their frequency does not. Since energy is proportional to frequency, each photon has the same energy as before. Therefore, they will still not surpass the work function of the metal, and the leaves will not move.

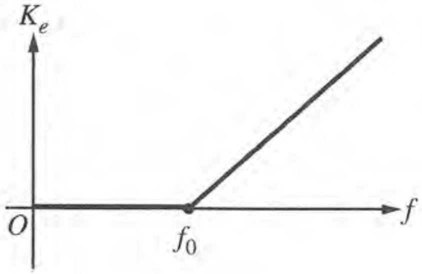


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



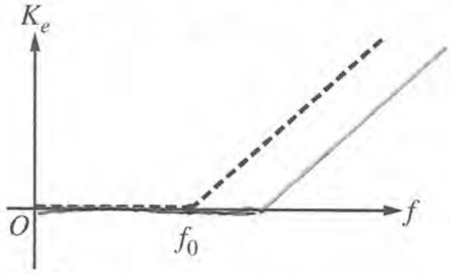
AF - B = KE

- B is the y intercept of the function if AF=B+Ke extended to the origin. It corresponds to the work function of the metal.
- A is the slope of the graph for f > fo, and corresponds to planks constant
- Fo is the threshold frequency for electrons to be emitted from the metal as you shine the light on the metal.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

There is no kinetic energy in the electrons as the frequencys of the light are below the threshold frequency, and thus, no electrons are being emitted from the metal. The metal's threshold frequency is determined by its work function. As no electrons are emitted, thier KE = 0.

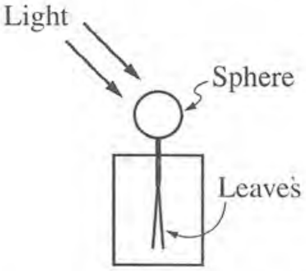
iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



The threshold frequency for metal 2 is greater as it has a larger work function.

-If you extended the linear increasing parts of the graph to the origin, the magnitude of the y intercept would be greater for the 2nd metal

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

The light shining on the sphere is above the sphere's threshold frequency, causing electrons to be emitted from the sphere. As a result, the sphere becomes less negatively charged and there is less repulsive electric force between the leaves, bringing them closer together

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

The wavelength of UV light is smaller, causing it to have a greater frequency by the equation $f = \frac{c}{\lambda}$. Therefore, green light has a smaller frequency which is below the threshold frequency necessary to emit electrons. For the green light, $\phi > hf$, and for the UV rays, $hf > \phi$.

Question 3 continues on the next page.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

- The amplitude of the wave is increased as brightness increases
- The brighter green light would have no effect on the leaves as, in order for the leaves to move, there needs to be a change in electric charge in the sphere. Increasing intensity of the light has no effect on frequency, as intensity only affects the rate of collisions, not the frequency. Because the green light is still below the necessary threshold frequency to emit electrons from the metal, the charge would remain the same, and the leaves would not move.

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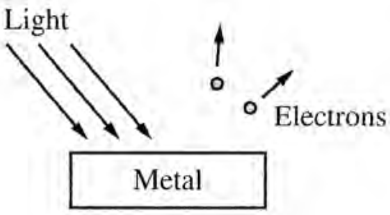


$K_{max} = hf - \phi$

$hf = K_{max} + \Phi$

$K = hf - \phi$

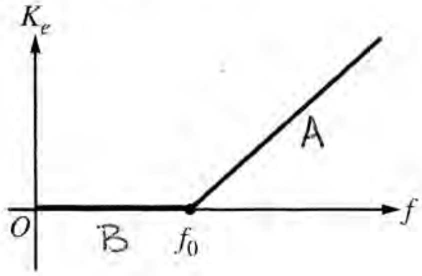
$y = mx + b$

3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



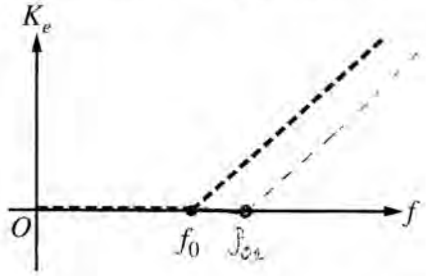
A is Planck's constant and B is the work function. f_0 is the threshold frequency at which electrons emit.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

The horizontal section is the ~~time~~ frequencies before the threshold frequency where the maximum kinetic energy is not enough to emit electrons.

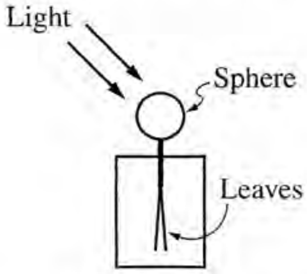
GO ON TO THE NEXT PAGE.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



A different metal with a different threshold frequency could be used. My graph shows the second metal with a greater threshold frequency.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

The leaves detect excess charge. When the UV light shines on the sphere, electrons are ~~emmit~~ emitted so party of the excess negative charge leaves, making the electroscope closer to the neutral position.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

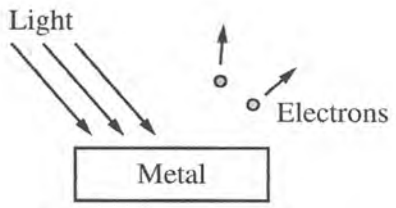
UV light has a higher frequency than green light. The green light does not have the threshold frequency to emit electrons, so the electroscope stays negatively charged.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

The velocity of the green light changes when its brightness is increased. Shining the brighter green light would not result in movement of the leaves. Intensity ~~de~~ does not cause electrons to emit, the green light still does not have the threshold frequency for the particular metal.

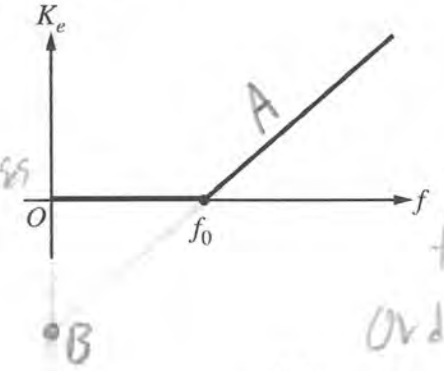


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \le f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



• A is the slope of $\frac{Ke}{f}$, as frequency increases so does the maximum kenetic energy.

f_0 is the frequency that the light needs to be greater than in order to give the electrons kenetic energy.

• B is the y intercept of the line after f_0 if you drew a line with slope A to the y-axis. It is used to position where f_0 is on the graph.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

Until the frequency of light is greater than f_0, the electrons in the panel will not get enough energy to escape and move to have kenetic energy. Energy of light is directly related to frequency.

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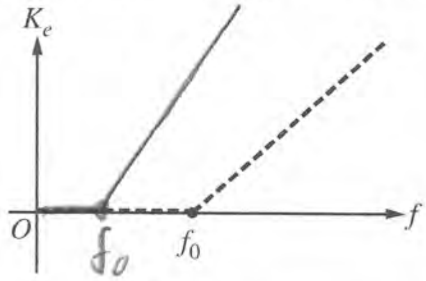
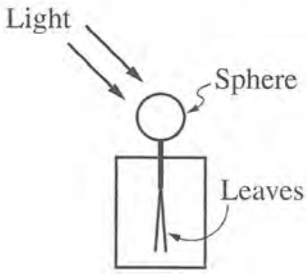
iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



for the new metal the required frequence to give the electrons kenetic energy and free them is less than for the first metal as indicated by how the New fo is sooner on the graph then the old one.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

UV light has lots of energy so it makes electrons on the sphere leave. Since all of the components are conductors, the Leaves then also loose some negative charge and the repelling forces decrease This causes the Leaves to fall closer together.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

UV light has more energy then green light so the green light most likly doesn't have a high enough frequency to give the electron kenetic energy and break free so the leaves remain negativly charged and continue to repel eachother with the same force.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

When the brightness of the green light increases, It means that amount of photons carrying green light is also increasing. The brighter green light has the ability to make the leaves move closer together. This is because the electrons are now being shot with photons more often. even though they have the same energy as before per photon, the increase in the number of times the electrons are hit causes them to gain enough energy to be released and move around. This causes the charge in the leafes to decrease and they start to come together now that the green light is capable of providing as much energy as the UV light.

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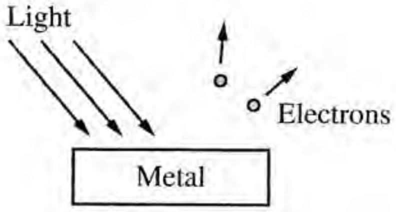


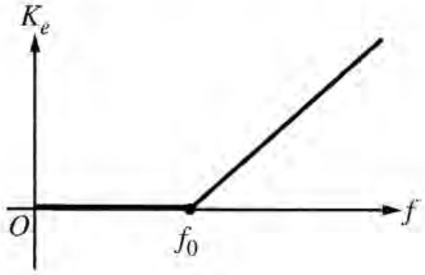
3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.

KE = hf − ~~θ~~
hf = θ + KE
Af = B + KE
A corresponds to Planck's constant (4.14 E−15 eV·s)
B corresponds to the work function.

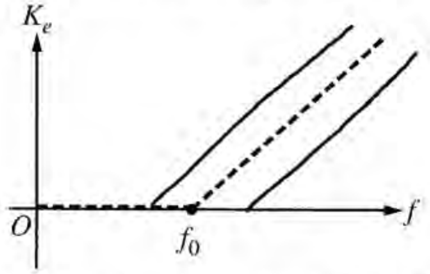


f_0 is the lowest frequency (fundamental frequency) at which electrons are emitted from the metal.
θ (work function) is characteristic to the metal, and represents the work required for electrons to be emitted.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

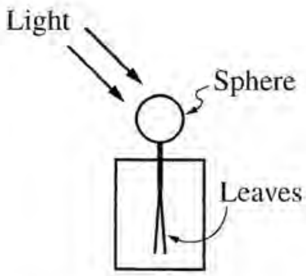
The physical meaning of the horizontal section of the graph is it is the portion at which there was no ke or electrons emitted from the metal bc the monochromatic light was $f < f_0$.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



Key difference: the y-intercept or work function (σ)
different metal - different work function.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

The UV light excites the charges present on the sphere. positive charges are forced down one leaf, and negative charges down the other. This causes an electrostatic force to bring the leaves closer together.

e^- emitted, p^+ take their place, $e^- + p^+$ attract.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

green light does not have a f as high as UV light; therefore, it must've not reached the threshold f required for the electroscope leaves to move.

e^- not emmited, p^+ can't take their place, $e^- + e^-$ repel.

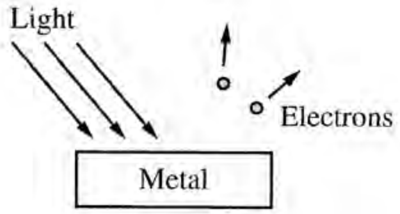
Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

When ~~[illegible]~~ brightness is increased the density or the # of green light particles increase.

The brighter green light would still NOT result in movement of the leaves, because the frequency is constant and still insufficient to be able to do so. and overcome the work function,



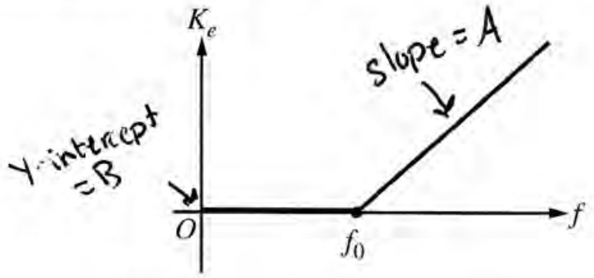
3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.

$K_e = Af - B$



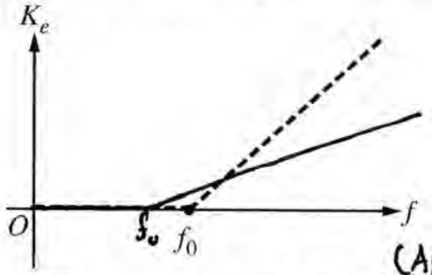
f_0 is the threshold frequency required for the electrons to be emitted from the metal. A is the ~~mathematical relationship~~ number showing how much K_e the electrons will have based on the frequency. B is the lowest amount of kinetic energy an electron could have.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

That section of the graph is depicting how no electrons are emitted (and thus will have no K_e) until they reach a certain frequency, so it is all frequencies before the threshold frequency required to be emitted.

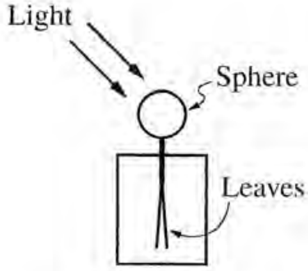
GO ON TO THE NEXT PAGE.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



One difference is the slope (A value), meaning that the emitted electrons will have ~~less kinetic energy~~ a different amount of Kinetic energy based on their frequency (other than at one ~~point~~ freq. where they intersect).

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

Because UV light has the frequency that is needed for this metal to emit electrons, and because electrons are being emitted, the overall negative charge lessens, so the repelling force ~~can~~ between the leaves weakens.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

Because green light has a different λ than UV light, and ~~because~~ $f = \frac{v}{\lambda}$, assuming that the light is travelling through the same medium, then the frequencies of the light will be different, so the ~~photoelectric effect won't take place~~ electrons won't be emitted and the leaves won't move.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

No, ~~the~~ the aspect that is affected is amplitude when the green light is increased, and the ~~frequency~~ amplitude of the waves does not affect the frequency, so ~~not~~ the light still wouldn't have the right frequency, ~~and~~ so no electrons would be emitted so the leaves wouldn't move.

GO ON TO THE NEXT PAGE.

THIS PAGE MAY BE USED FOR SCRATCH WORK.

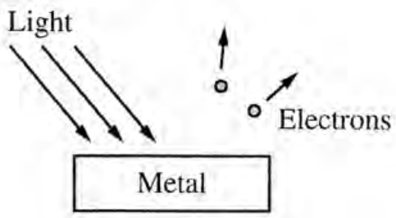
$\Delta V = \frac{I \Delta t}{C}$

$C = \frac{I \Delta t}{\Delta V}$

$I = \frac{\Delta Q}{\Delta t}$

$\Delta Q = I \Delta t$

GO ON TO THE NEXT PAGE.



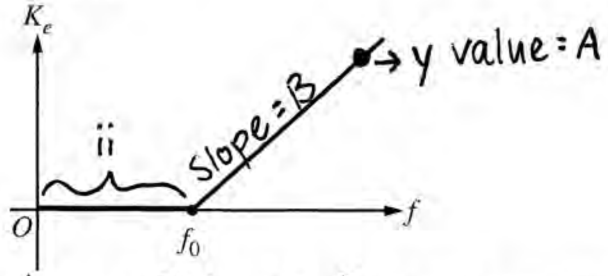
3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

$y = mx + b$

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



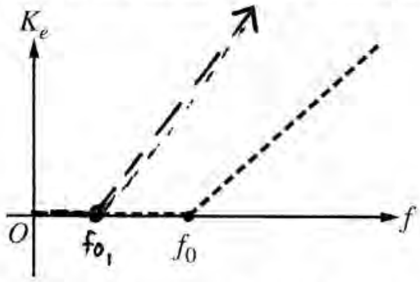
f_0 is the lowest possible ~~en~~ frequency needed to emit an electron ~~with~~ from the metal. A is the maximum kinetic energy (K_{max}) of a given-off electron, and B is the frequency (minimum) needed to emit an electron of a given energy.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

The light frequency is too low to emit electrons from the metal, which is why the section is horizontal; K_e is zero for the very same reason.

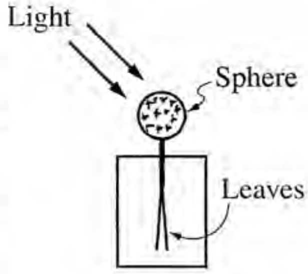
GO ON TO THE NEXT PAGE.

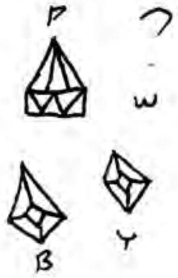
iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



The second metal can begin emitting electrons at lower light frequencies than the 1st metal.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.





i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

Charge is transferred between the leaves. As one becomes more positive and the other becomes more negative, they become electrically attracted to each other due to their opposing signs.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

UV light has a greater amount of energy in it than green light does; green light doesn't have enough energy to make the leaves move, but UV light does.

Question 3 continues on the next page.

I'm becoming more depressed as I do this. Help me.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

When the green light's brightness increases, its intensity (force over a given area) does too. It would not make the leaves move because while the force becomes more focused (so to say), its true, ultimate quantity does not increase. Having more green light in an area won't make the light turn blue, purple, or ultraviolet - it will remain green, just with more of it present.

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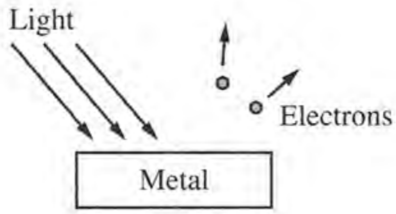
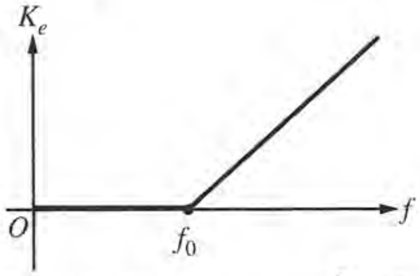


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \le f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.



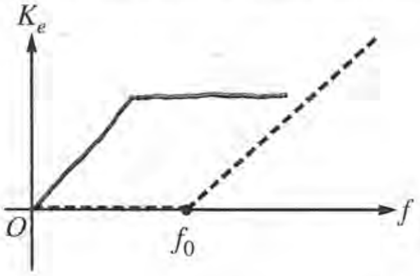
The horizontal piece is B and the sloped line is A. A is the constant of reflection, B is the minimum level of f needed to successfully release energy, f_0 is the spot where the frequency becomes high enough to emit charged particles.

ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

When the frequency times constant A is less than constant B. The energy being shown on the metal is too low to meet the allotted value of reflection

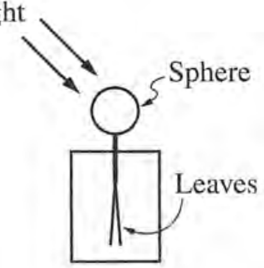
GO ON TO THE NEXT PAGE.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



This metal reflects energy up to a certain frequency when it starts absorbing it, may be lead

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens. The high frequency of charged particles interact with the sphere. The protons that are not being reflected like the electrons are being absorbed.

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.
The green light has a lower frequency than UV light so there are not as many protons coming in.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

The Magnitude of the light wave changes not the frequency So there will be no change on the electroscope because the electroscope reacts by the number of molecules rather than the individual magnitude of each one.

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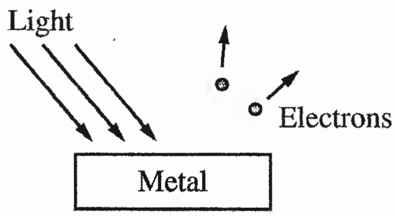


3. (12 points, suggested time 25 minutes)

Monochromatic light of frequency f shines on a metal, as shown above. The frequency of the light is varied, and for some frequencies electrons are emitted from the metal. The maximum kinetic energy K_e of the emitted electrons is measured as a function of the frequency of the light.

(a)

hf → photons

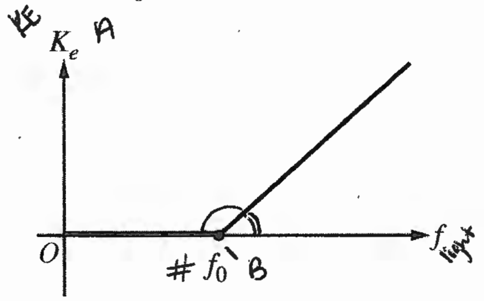
i. Based on conservation of energy, the relationship between K_e and f is predicted to be $Af = B + K_e$ when $f > f_0$ and $K_e = 0$ when $f \leq f_0$, where A and B are positive constants. A graph of this relationship is shown below. Indicate which aspects of the graph correspond to A and B. Also, explain the physical meaning of A, B, and f_0.

$\phi = E - KE$

$K_{max} = hf - \phi$

$hf = K_{max} + \phi$

$Af = K_e + B$



A → Planck's constant ($\frac{1}{s}$)

B → work function

~~Energy~~ minimum energy required

if $K_{max} = 0$,

$E = \phi$

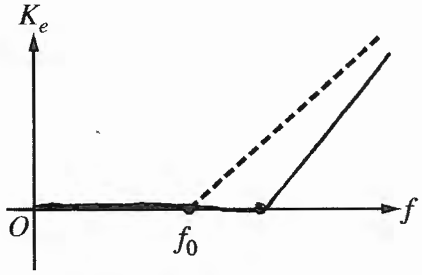
ii. Explain the physical meaning of the horizontal section of the graph between the origin and f_0.

~~Along that line is complete internal reflection.~~

The line shows the frequencies where the kinetic Energy would be zero.

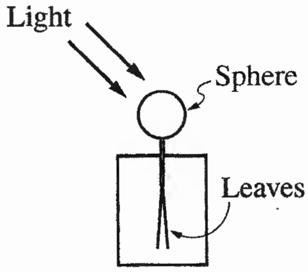
GO ON TO THE NEXT PAGE.

iii. A second metal with different properties than the first metal is now used. On the figure below, the dashed lines are the same lines shown in the previous graph. Sketch lines on the figure below that could represent the data for the second metal. Explain one difference between the two graphs.



The frequency at which the KE would be zero is greater for the second metal.

(b) The figure below shows an electroscope. A sphere is connected by a vertical bar to the leaves, which are thin, light strips of material. The sphere, leaves, and bar are all made of metal. The electroscope initially has a negative charge, so the leaves are separated.



i. Ultraviolet (UV) light shines on the sphere, causing the leaves of the electroscope to move closer together. Explain why this happens.

The frequency is higher, experiences constructive interference with each wavelength

ii. Green light then shines on an identical negatively charged electroscope. No movement of the leaves is observed. Explain why the green light does not make the leaves move, while the UV light does.

The green light has a smaller affect on the frequency of the electroscope

Question 3 continues on the next page.

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(c) The brightness of the green light is increased until the intensity (power per unit area) is the same as that of the UV light. What aspect of the green light changes when its brightness is increased? Would shining the brighter green light on the electroscope result in movement of the leaves? Explain why or why not.

$\uparrow Power = \frac{\uparrow \Delta E}{t} = \frac{\uparrow W}{t}$

Question 3

Sample Identifier: P2 Q3 A
Score: 12

ai:
- 1pt: A represents slope and Planck's constant
- 1pt: B represents y-intercept and work function
- 1pt: f_o represents minimum frequency to eject electrons

aii:
- 1pt: Line represents frequencies with inadequate energy to overcome work function and eject electrons

aiii:
- 1pt: Line is drawn parallel to line on figure (barely acceptable)
- 1pt: Line has a smaller x-intercept
- 1pt: Explained that the different x-intercept is due to a lower work function

bi:
- 1pt: UV light causes electrons to be emitted from sphere
- 1pt: Less negative charge on electroscope is indicated by leaves moving closer together because of reduced Coulomb force

bii:
- 1pt: Photons of green light have less energy than that of UV light which is not enough to emit electrons

c:
- 1pt: Increased intensity means the wave has more photons
- 1pt: Leaves do not move because the energy per photon is still too low for electron emission

Sample Identifier: P2 Q3 B
Score: 11

ai:
- 1pt: A represents slope and Planck's constant
- 1pt: f_o represents maximum frequency which does not eject electrons
- Does not relate B to correct aspect of the graph

aii:
- 1pt: Line represents frequencies with energy less than the work function that cannot eject electrons

aiii:
- 1pt: Line is drawn parallel to line on figure
- 1pt: Line has a greater x-intercept
- 1pt: Explained that the different x-intercept is due to a larger work function

bi:
- 1pt: UV light causes electrons to be emitted from sphere
- 1pt: Less negative charge on electroscope is indicated by leaves moving closer together because of reduced Coulomb force

bii:
- 1pt: Green light has a lower frequency and the photons lack the energy to overcome work function and emit electrons

c:
- 1pt: Increased intensity means the wave has more photons per unit area
- 1pt: Leaves do not move because the energy per photon is still inadequate for electron emission

Sample Identifier: P2 Q3 C
Score: 10

ai:
- 1pt: A represents slope and Planck's constant
- 1pt: B represents y-intercept and work function
- 1pt: f_o represents cutoff frequency or minimum frequency to eject electrons

aii:
- 0 pt: did not specifically discuss the energy being responsible for no electrons being emitted

aiii:
- 1pt: Line is drawn parallel to line on figure
- 1pt: Line has a greater x-intercept
- 1pt: Explained that the different x-intercept is due to a greater work function

bi:
- 1pt: UV light causes electrons to be emitted from sphere
- 1pt: Less negative charge on electroscope is indicated by leaves moving closer together

bii:
- 1pt: Green light has a greater wavelength or lower frequency which does not have enough energy to emit electrons

c:
- Increased intensity means the wave has greater amplitude
- 1pt: Leaves do not move because the energy per photon is still inadequate for electron emission
- Note: only one point was awarded for part c because the particle nature of light was not discussed.

Sample Identifier: P2 Q3 D
Score: 9

ai:
- 1pt: f_o represents threshold frequency to eject electrons
- Did not relate A or B to aspects of the graph

aii:
- 1pt: Line represents frequencies below the threshold frequency with inadequate energy to eject electrons

aiii:
- 1pt: Line is drawn parallel to line on figure
- 1pt: Line has a greater x-intercept
- 1pt: Explained the greater x-intercept is due to a larger threshold frequency

bi:
- 1pt: UV light causes electrons to be emitted from sphere
- 1pt: Part of excess negative charge leaves indicated by leaves moving closer together

bii:
- 1pt: Green light has a lower frequency which is below the threshold frequency to emit electrons

c:
- 1pt: Leaves do not move because the frequency is still below the threshold frequency for electron emission
- Did not correctly relate intensity to a property of the light

Sample Identifier: P2 Q3 E
Score: 8

ai:
- 1pt: f_o represents cutoff frequency or minimum frequency to eject electrons
- Did not relate A or B to physical properties

aii:
- 1pt: Line represents frequencies below the threshold frequency with inadequate energy to eject electrons

aiii:
- 1pt: Line has a smaller x-intercept
- 1pt: Explained that the smaller x-intercept is due to a smaller cutoff frequency
- New line is not parallel to line on figure

bi:
- 1pt: UV light causes electrons to be emitted from sphere
- 1pt: Less negative charge on electroscope is indicated by leaves moving closer together

bii:
- 1pt: Green light has a lower frequency which is below the cutoff frequency to emit electrons

c:
- 1pt: Increased intensity means the wave has more photons per unit area
- Incorrectly says leaves move

Sample Identifier: P2 Q3 F
Score: 7

ai:
- 1pt: f_o represents cutoff frequency or minimum frequency to eject electrons
- Did not relate A or B to aspects of the graph

aii:
- Just described graph, did not mention energy

aiii:
- 1pt: Lines drawn parallel to line on figure
- 1pt: Lines have different (non-zero) x-intercepts
- 1pt: Explained that the different x-intercepts are due to different work functions

bi:
- Incorrect description of the change in charge

bii:
- 1pt: Green light has a lower frequency which does not reach the threshold to emit electrons

c:
- 1pt: Increased intensity means the wave has more light particles
- 1pt: Leaves do not move because the frequency is still inadequate for electron emission

Sample Identifier: P2 Q3 G
Score: 5

ai:
- 1pt: f_o represents threshold frequency to eject electrons
- A identified with slope, but not with Planck's constant
- B incorrectly identified

aii:
- Just described graph, did not mention energy

aiii:
- 1pt: Line has a smaller x-intercept
- Slopes not the same, and prose just describes the graph

bi:
- 1pt: UV light causes electrons to be emitted from sphere
- 1pt: Less negative charge on electroscope is indicated by leaves moving closer together

bii:
- Says green light's wavelength is different instead of higher

c:
- Increased intensity means the wave has more photons or greater amplitude
- 1pt: Leaves do not move because the energy per photon is still inadequate for electron emission
- Note: only one point was awarded for part c because the particle nature of light was not discussed.

Sample Identifier: P2 Q3 H
Score: 4

ai:
- 1pt: f_o represents minimum frequency to eject electrons
- A and B are not correctly identified

aii:
- Just described graph, did not mention energy

aiii:
- 1pt: Line has a smaller x-intercept
- 1pt: Explained that the different x-intercept is because electrons can be emitted at lower frequencies
- New line is not parallel to original

bi:
- Incorrect description of the change in charge

bii:
- Does not describe anything about charge

c:
- 1pt: Leaves do not move because the energy per photon is still inadequate for electron emission
- Incorrect description of how the properties of the light change

Sample Identifier: P2 Q3 I
Score: 3

ai:
- 1pt: f_o represents minimum frequency to eject electrons
- A and B are not correctly identified

aii:
- Incorrect description

aiii:
- 1pt: Line is drawn parallel to line on figure
- Intercept at zero not realistic, description incorrect

bi:
- Incorrect description of the change in charge

bii:
- Incorrect description

c:
- 1pt: Leaves do not move because frequency does not change and is still too low to change charge on electroscope

Sample Identifier: P2 Q3 J
Score: 1

ai:
- A and B are not correctly identified with aspects of the graph
- f_o id not described

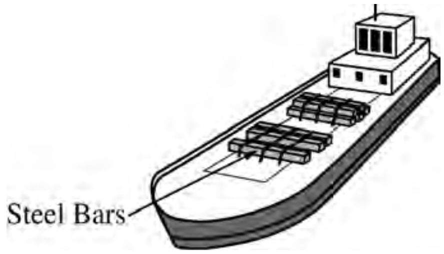
aii:
- Just described graph, did not mention energy

aiii:
- 1pt: Line has a greater x-intercept
- Line is not parallel and prose just describes graph

bi:
- Incorrect description

bii:
- Incorrect description

c:
- No description



4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

GO ON TO THE NEXT PAGE.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \text{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

GO ON TO THE NEXT PAGE.

Question 4

10 points total **Distribution of points**

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) LO 1.E.1.2, SP 6.4; LO 3.B.2.1, SP 1.1, 1.4, 2.2; LO 5.B.10.1, SP 2.2
4 points

Derive an expression for the maximum number *N* of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

For equating the correct forces acting on the boat-steel system - gravity (weight) and the buoyant force		1 point
For correctly calculating the weight of the boat-steel system		1 point
$W_{system} = (M_b + N_{steel}\rho_{steel}V_{steel})g$, where *N* is the number of steel beams (must clearly use mass of boat)		
For correctly calculating the buoyant force		1 point
$F_b = \rho_{water} g V_b$		
For algebraic manipulation of the equations to get an expression for the number of beams consistent with the equations for weight and buoyant force		1 point
$(M_b + N\rho_{steel}V_{steel})g = \rho_{water} g V_b$		
$N = (\rho_{water}V_b - M_b)/\rho_{steel}V_{steel}$		

(b) LO 6.C.1.1, SP 6.4, 7.2; LO 6.E.1.1, SP 6.4, 7.2; LO 6.E.3.3, SP 6.4, 7.2
4 points

The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

The constructive interference is between light reflected from the air-oil interface and light reflected from the oil-water interface.		
For indicating that the green appearance is the result of interference of light from two waves		1 point
For indicating that there is a phase shift due to one of the reflections		1 point
For indicating that the wavelength of the light is different in air and oil		1 point
For indicating that there is a path length difference of the light reflected from the two surfaces		1 point

Question 4 (continued)

Distribution of points

(c) LO 5.F.1.1, SP 2.2, 7.2
2 points

Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \text{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

For an attempting to apply the principle of continuity		1 point
$A_{wide}v_{wide} = A_{narrow}v_{narrow}$		
$(60\ \text{m})(\text{depth})(5\ \text{km/hr}) = (30\ \text{m})(\text{depth})(v_{narrow})$		
For correctly calculating the speed		1 point
$v_{narrow} = 10\ \text{km/hr}$		

LO 1.E.1.2: The student is able to select from experimental data the information necessary to determine the density of an object and/or compare densities of several objects. **[SP 4.1, 6.4**]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. **[SP 1.1, 1.4, 2.2]**

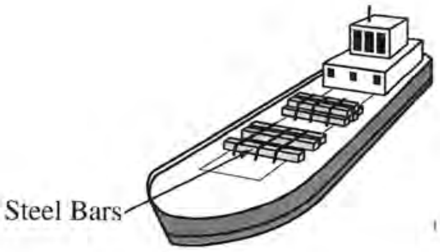
LO 5.B.10.1: The student is able to use Bernoulli's equation to make calculations related to a moving fluid. **[SP 2.2**

LO 5.F.1.1: The student is able to make calculations of quantities related to flow of a fluid, using mass conservation principles (the continuity equation). **[SP 2.1, 2.2, 7.2**]

LO 6.C.1.1: The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves. **[SP 6.4, 7.2]**

LO 6.E.1.1: The student is able to make claims using connections across concepts about the behavior of light as the wave travels from one medium into another, as some is transmitted, some is reflected, and some is absorbed. **[SP 6.4, 7.2**]

LO 6.E.3.3: The student is able to make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. **[SP 6.4, 7.2]**



4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$$F_b = F_{w_{boat}} + F_{steel}$$

$$\rho_{water} V_b \, g = M_b \, g + \rho_{steel} V_{steel} N g$$

$$N = \frac{\rho_{water} V_b - M_b}{\rho_{steel} V_{steel}}$$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

The oil floats on the water and because its index of refraction is greate than air, light that reflects off of the oil is phase shifted by half a wavelength. Some light travels into the oil and is refracted more downward due to higher index of refraction than air. This light reflects off of the bottom of the oil laye and is not phase shifted as the water has a higher index of refraction than the oil, the light then travels back up and refracts out of the oil at the same angle as the light was reflected off the top of the oil. The light reflected from both processes is constructive at the green wavelength because the distance it took the light to travel considering its lessened green light wavelength through the oil phase shifted it half a wavelength to match the green light reflected off the oil.

GO ON TO THE NEXT PAGE.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

d = depth (m)

$$V_1 A_1 = V_2 A_2$$

$$V_2 = \frac{V_1 A_1}{A_2} = \frac{(5)(d)(60)}{d\,(30)} = \boxed{10 \text{ km/hr}}$$

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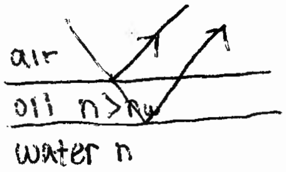

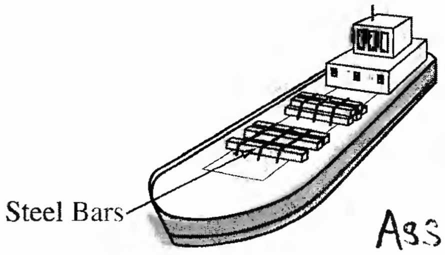

Assume ρ_w is ρ_{water}
ρ_s is ρ_{steel}

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(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$F_B = F_g \quad F_B = \rho_w V_b g = mg \quad m = M_b + V_s \rho_s N$

$\rho_w V_b = M_b + V_s \rho_s N$

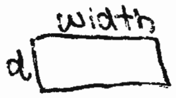
$$N = \frac{\rho_w V_b - M_b}{V_s \rho_s}$$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

When light enters a new medium, it refracts, or changes it direction. When light ~~...~~ reflects off the oil, it ~~...~~ experience a path difference of $\frac{1}{2}\lambda$. This is because oil has a greater n than air. When the light that passes through the oil and reflects off the oil-water interface, it does not shift $\frac{1}{2}\lambda$ since $n_{oil} > n_{water}$. Thus, destructive interference causes all colors except green to be visible. Because of green's ~~wavelength~~ frequency, it undergoes constructive interference, making the green light even bright and more visible. Green light rays all experience the same path difference, so →*

GO ON TO THE NEXT PAGE.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

$VA = VA$ Assume rectangular river 

$A = wd$

$V_1 w_1 d = V_2 w_2 d$

$V_1 w_1 = V_2 w_2$

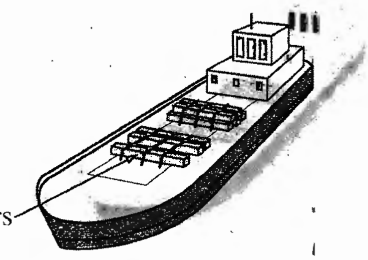
$$\frac{60 \text{ m}}{1} \times \frac{5000 \text{ m}}{1 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 83.\bar{3}$$

$83.\bar{3} = V_1 w_1$

$83.\bar{3} \text{ m/s} = 30 V_2$

$V_2 = 2.78 \text{ m/s}$

* b.) the green light constructively interferes with itself, ~~and~~ which is why the oil appears green.



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(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

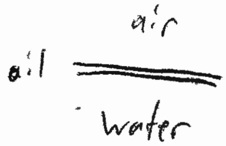
$\Sigma F_y = 0 \quad -mg + g\rho_{water}(V_b) = 0 \Rightarrow g\rho_{water}(V_b) = mg$

$m = M_b + M_s, \quad M_s = V_{steel}\rho_{steel} N$

$g\rho_{water}(V_B) = g(M_b + V_{steel}\rho_{steel}N) \Rightarrow g\rho_{water}V_B - gM_b = gV_{steel}\rho_{steel}N$

$\boxed{N = \dfrac{g\rho_{water}V_B - gM_b}{gV_{steel}\rho_{steel}}}$ ~~with ρ_{water} 1000 $\frac{kg}{m^3}$~~, g cancels, $\Rightarrow$ $\boxed{N = \dfrac{\rho_{water}V_B - M_b}{V_{steel}\rho_{steel}}}$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.



The light from the sun (or another light source) will hit the oil and some light will refract while some refracts. Now, some of the refracted light reflects at the water-oil barrier. ~~So, there are~~ Some of this light then refracts at the oil-air boundary. ~~The~~ This light, and that ~~inter~~ initially reflected, will be seen by the captain. ~~At~~ ~~The dis~~ There ~~is a distn~~ is an extra distance traveled by some of the light such that $x = \lambda m$, (λ is the wavelength of green light and ~~me~~ m is an ~~inter ge~~ integer.

GO ON TO THE NEXT PAGE.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr . Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

$Q_1 = Q_2$, $Q = Av$, $A = wh$

$A_1 v_1 = A_2 v_2$

depth = h, constant so $h_1 = h_2$

$w_1 h_1 v_1 = w_2 h_2 v_2$

$w_1 h_1 v_1 = w_2 h_2 v_2$

$w_1 v_1 = w_2 v_2$

$w_1 = 60 m$

$w_2 = 30 m$

$v_1 = 5 km/hr$

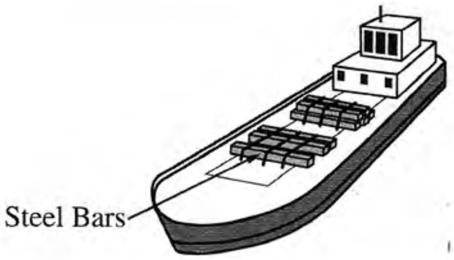
$(60m)(5 km/hr) = (30m) v_2$

$v_2 = \frac{(60m) \cdot 5 km/hr}{30 m} = 2 \cdot 5 km/hr$

$v_2 = 10 km/hr$

4.b cont

This means that the initally reflected green light waves are in phase with the others, so they interfer constructively. This will only be true of wavelengths with ~~x = λ m~~ x = λ m, so, the green is more noticable than colors without this this inter



$mg \neq \rho V g$

$F_B = \rho V g$

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(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$$(M_b + N(\rho_{steel} V_{steel}))g = \rho V_b g$$

$$N(\rho V) = \rho_{water} V_b - M_b$$

$$N = \frac{\rho_{water} V_b - M_b}{(\rho V)_{steel}}$$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

Constructive interference happens when two wavelength peaks coincide on one another to create a greater peak. Now, adding the oil to the surface of the water changes the direction of light waves exiting the ocean as well as those bouncing off the oil. These wavelengths creating constructive interference no doubt create waves of the right orientation to appear green to the captain's eyes.

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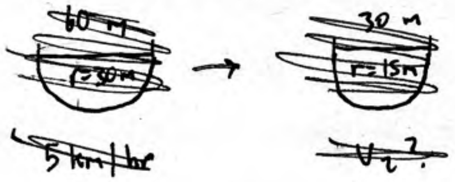
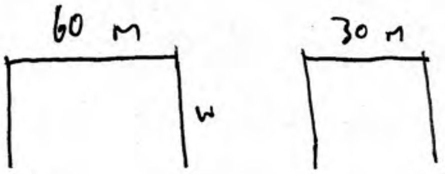
(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr . Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

$A_1 v_2 = A_2 v_2$



~~$\frac{\pi}{2}(30^2)\, 5\ \text{km/hr} = \frac{\pi}{2}(15^2) v_2$~~ ~~$A = \frac{\pi}{2} r^2$~~

~~$v_2 = \frac{30^2 \cdot 5}{15^2} = 20$~~



~~$V_2 = 20$ km/hr~~

$A = l \cdot w$

$(60 \cdot w)\, 5\ \text{km/hr} = (30 \cdot w) v_2$

Actual answer

$V_2 = 10$ km/hr

$\frac{60 \cdot 5}{30} = v_2$

$V_2 = 10$

wrote it again to be clearer

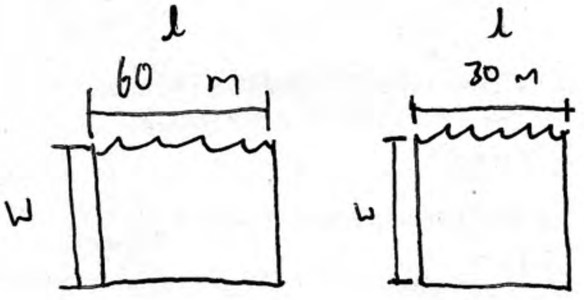
$A_1 v_1 = A_2 v_2$

$(60\ \text{m} \cdot w)\, 5\ \text{km/hr} = (30\ \text{m} \cdot w) v_2$

$60 \cdot 5 = 30 v_2$

$V_2 = \frac{300}{30} = 10$

$V_2 = 10$ km/hr



$A = l \cdot w$

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$F_B = \rho_{fluid} V g$

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(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$F_b - mg = \Sigma F = 0 \quad F_b = mg$

$\rho V g = mg$ (fluid; boat+bars)

↑F_B ↓mg

Bar − $\rho_{steel} \cdot V_{steel} = m$

$\rho_{water} (V_b) g = (M_b + N \rho_{steel} V_{steel}) g$

$\rho_{water} = M_b + N \rho_{steel} V_{steel}$

$\rho_{water} - M_b = N \rho_{steel} \cdot V_{steel}$

$$N = \frac{\rho_{water} - M_b}{\rho_{steel} \cdot V_{steel}}$$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

Since light seen by an observer above the water would pass through the air, oil, and then the water, the senaro would be destructive, or light would experience a $\frac{1}{2}\lambda$ flip when exiting these laters, Since $n_{air} < n_{water} < n_{oil}$. For a destructive scenario, constructive interference would take place in a wavelength with a $\frac{1}{2}\lambda$ shift. The light hitting the oil in the certain area appears green because that is the max wavelength w/ a $\frac{1}{2}$ wavelength shift.

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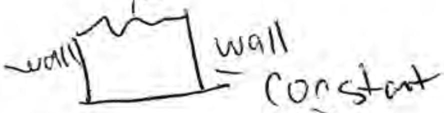
(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr . Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

- depth same - ~~dont need to take into~~ account
- both have air pressure extertod dont need to take into ~~acco~~ account
- ~~same density dont take into account~~

use cross sectional area — so use $AU = AU$

use d as depth constant

$A = \text{width} \cdot d$



$\frac{5 km}{1 hr} \cdot \frac{1000 m}{1 km} \cdot \frac{1 hr}{60 min} \cdot \frac{1 min}{60 sec} = 1.39 \text{ m/s} = 5 \frac{km}{hr}$ initial velocity

$60 \cdot d \cdot 1.39 = 30 \cdot d \cdot U$

$\frac{60 \cdot 1.39 = 30U}{30}$

$V = 2.78 \text{ m/s}$

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(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$$F_b = \rho_w V_b g = (m_s g) N$$

$$\rho_{steel} = \frac{m_{steel}}{V_{steel}}$$

$$\rho_w V_b g = (\rho_{steel} \cdot V_{steel}) g N$$

$$m_{steel} = \rho_s V_s$$

$$N = \frac{\rho_{water} V_{boat}}{\rho_{steel} \cdot V_{steel}}$$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

When the light is traveling in oil, some of the light reflects instead of going into water + interference patterns occur at the surface which gives it a green color. Since $n_{oil} > n_w$, the constructive interference occurs at $\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$ & so on.

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1.382 m/s

P2 Q4 F p2

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$A_1 v_1 = A_2 V_2$

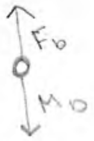
$A = \frac{1}{2} A_{circle}$

$A_1 = \frac{1}{2}(\pi(30)^2) = 1413.72 \ m^2$

$A_2 = \frac{1}{2}(\pi(15)^2) = 353.43 \ m^2$

$1413.72(5) = 353.43 \ v_2$

$V_2 = 20 \ km/hr$



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(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$\frac{m}{V}$

$F_b = \rho V g$ $\quad (M_b + (\rho \cdot V_{steel}))\cdot 10$ $\quad$ Mass beams $= \rho_{steel} \cdot V_{steel}$

$F_b = \rho_{water} V_b \cdot 10$

$10 \cdot M_b(N(\rho \cdot V_{steel})) = \rho_{water} V_b \cdot 10$

$$N = \left(\frac{\rho_{water} \cdot V_b}{M_b \cdot \rho_{steel} \cdot V_{steel}}\right)$$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

Since light from the sun is going through a more dense (oil) to less dense (water) material, light gets deflected away from the normal. that being said, the oil refracts water differently than the water, which will result in a different frequency of light, and therefore a different color.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr . Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

A·V = A·V

$(\pi)(30)^2 \cdot (5) = (\pi)(15)^2 \cdot V$

1414137.2 = 706.9 · V

V = 20 km/hr

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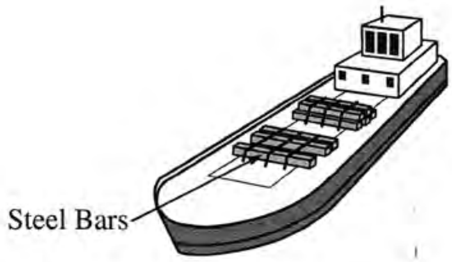

4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$F_B - mg = 0$

$m = M_b + N(\rho_{steel} \times V_{steel})$

$F_B = \rho V_b g$

$\rho_{water} V_b g - M_b + N(\rho_{steel} \times V_{steel}) g = 0$

$\rho_{water} V_b - (M_b + N(\rho_{steel} \times V_{steel})) = 0$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

The angle the captain is looking @ is changing between 3 medium one is air so $1 \sin\theta = 1.8 \sin\theta$ then the other is oil to water $1.8 \sin\theta = 1.4 \sin\theta$

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr . Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

$\frac{5 km}{hr} \cdot \frac{1000 m}{1 km} = \frac{5000 m}{hr}$

$\frac{60 m \; hr}{5000 m} = \frac{30 m}{?} = 2500 \frac{m}{hour}$ or $2.5 \frac{km}{hour}$

~~5000m / hr = 60m / hr~~

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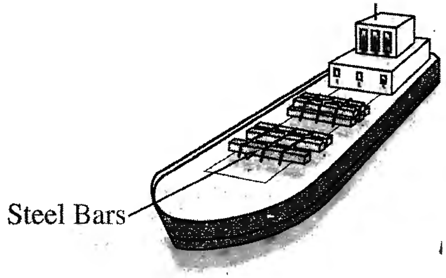

4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

~~$V_b + V_{steel} = V_{total}$~~ $V_{steel} < V_{boat}$

$P_{water} > P_{steel}$

In order to hold N steel beams, the volume of steel must be less than the volume of the boat and the total density must be less than the density of water.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

Due to a greater index of refraction in oil than in water, light will have a harder time getting through and therefore will make it have a green appearance.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

$A_1V_1 = A_2V_2$

$A_1 = 60\text{ m}$

$V_1 = 5\text{ Km/hr}$

$A_2 = 30\text{ m}$

$60\text{ m} \times 5\text{ Km/hr} = 30\text{ m}\ V_2$

$\frac{300}{30\text{m}} = \frac{30\text{m}\ V_2}{30\text{m}}$

$V_2 = 10\text{ Km/hr}$

The speed of water in the narrow section is 10 Km/hr.

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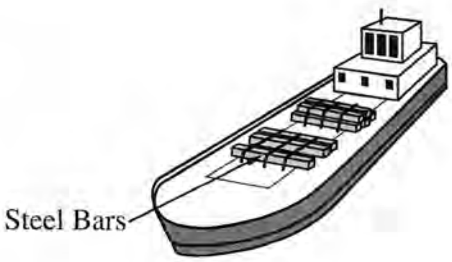

4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

$N = \rho_s V g$

$N = \rho_{steel} V (ma)$?

$n(\sin\theta) = n_2(\sin\theta_2)$

$10(\sin 60) = 5(\sin\theta_2)$

$1.7321 = \sin\theta_2$

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

with the small amount of oil in the water, the angle that the light hits the water at is what creates the green color. And, we know that the index of Refraction for oil is greater than the index of Refraction for the water. we know that the angle that the light will be going at will be just enough to refract the light and make it appear green.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of 5 km/hr . Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

$5\,\frac{km}{hr} \times \frac{1000\,m}{1\,km} \times \frac{1\,hr}{60\,min} \times \frac{1\,min}{60\,s}$

$A_1 V_1 = A_2 V_2$

$(\pi 60^2)(5\,km/hr) = (\pi 30^2)(?)$

$(\pi 60^2)(13.889\,m/s) = (\pi 30^2)(V_2)$

$11309.734(13.889) = (2827.43)(V_2)$

$157080.896 = 2827.43$

$V_2 = 55.56\,m/s$

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Question 4

Sample Identifier: P2 Q4 A
Score: 10
a:
- 1pt: started by equating forces
- 1pt: correctly identified weight of boat-steel system
- 1pt: correctly identified the buoyant force
- 1pt: algebraic manipulation for N

b:
- 1pt: identified interference of two waves
- 1pt: indicated there was a phase shift from the reflection(s)
- 1pt: discussed a path length difference for the two waves
- 1pt: indicated a different wavelength in the oil (λ_{oil})

c:
- 1pt: applied continuity equation
- 1pt: correctly calculated speed

Sample Identifier: P2 Q4 B
Score: 9
- 1pt: started by equating forces
- 1pt: correctly identified weight of boat-steel system
- 1pt: correctly identified the buoyant force
- 1pt: algebraic manipulation for N

b:
- 1pt: identified interference of two waves
- 1pt: describes different paths for two waves, implying path length difference
- 1pt: stated a phase shift of the wave(s) at reflection
- did not indicate a different wavelength in oil

c:
- 1pt: applied continuity equation
- 1pt: correctly calculated speed in m/s

Sample Identifier: P2 Q4 C
Score: 8
a:
- 1pt: started by equating forces
- 1pt: correctly identified weight of boat-steel system
- 1pt: correctly identified the buoyant force
- 1pt: algebraic manipulation for N

b:
- 1pt: identified interference of two waves
- 1pt: described a path length difference
- no phase shift or different wavelength in oil

c:
- 1pt: applied continuity equation
- 1pt: correctly calculated speed

Sample Identifier: P2 Q4 D
Score: 7
a:
- 1pt: started by equating forces
- 1pt: correctly identified weight of boat-steel system
- 1pt: correctly identified the buoyant force
- 1pt: algebraic manipulation for N

b:
- 1pt: identified interference of two waves
- no mention of phase shift, different wavelength in oil, or path length difference

c:
- 1pt: applied continuity equation
- 1pt: correctly calculated speed

Sample Identifier: P2 Q4 E
Score: 6
a:
- 1pt: started by equating forces – free body diagram
- 1pt: correctly identified weight of boat-steel system
- 1pt: correctly identified the buoyant force
- Incorrect algebraic manipulation for N

b:
- 1pt: indicated there was a phase shift from the reflection(s) - "flip"
- no mention of two waves to interact, different wavelength in oil, or path length difference

c:
- 1pt: applied continuity equation
- 1pt: correctly calculated speed

Sample Identifier: P2 Q4 F
Score: 5
a:
- 1pt: started by equating forces
- 1pt: correctly identified the buoyant force
- 1pt: algebraic manipulation for N
- neglected mass of boat

b:
- 1pt: identified interference of two waves
- The last sentence implies a phase shift, but the wording is not clear enough
- no mention of different wavelength in oil or path length difference

c:
- 1pt: applied continuity equation
- used area of a circle instead of rectangle

Sample Identifier: P2 Q4 G
Score: 4
a:
- 1pt: Equated forces
- 1pt: correctly identified the buoyant force
- 1pt: algebraic manipulation for N
- total mass of steel bars incorrect

b:
- only discusses refraction

c:
- 1pt: applied continuity equation
- used area of a circle instead of rectangle

Sample Identifier: P2 Q4 H
Score: 3
a:
- 1pt: started with force equation
- 1pt: correctly identified weight of boat-steel system
- 1pt: correctly identified the buoyant force
- did not manipulate equation to get expression for N

b:
- Snell's law not relevant to the required explanation

c:
- Only used dimensional analysis

Sample Identifier: P2 Q4 I
Score: 2
a:
- to earn credit, the density comparison should be between water and the system, not between water and steel

b:
- incorrect explanation

c:
- 1pt: applied continuity equation
- 1pt: correctly calculated speed

Sample Identifier: P2 Q4 J
Score: 1
a:
- no correct work

b:
- Snell's law not relevant to the required explanation

c:
- 1pt: applied continuity equation
- used area of a circle instead of rectangle