CollegeBoard
Advanced Placement Program

AP® Physics B
2005 Sample Student Responses

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1A

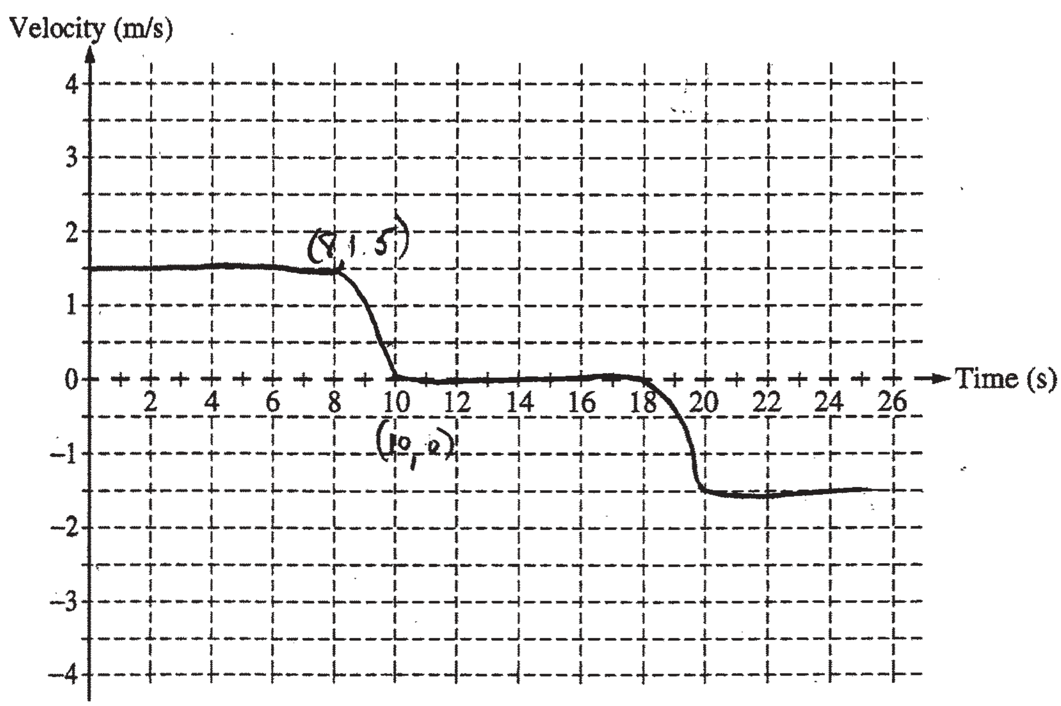
PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested time is about 11 minutes for answering each of questions 1-2 and 5-7, and about 17 minutes for answering each of questions 3-4. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.

1. (10 points)

The vertical position of an elevator as a function of time is shown above.

(a) On the grid below, graph the velocity of the elevator as a function of time.



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(b)

i. Calculate the average acceleration for the time period $t = 8$ s to $t = 10$ s.

$$\frac{0-1.5}{10-8} = \frac{-1.5}{2} = \boxed{-.75 \, m/s^2}$$

ii. On the box below that represents the elevator, draw a vector to represent the direction of this average acceleration.

(c) Suppose that there is a passenger of mass 70 kg in the elevator. Calculate the apparent weight of the passenger at time $t = 4$ s.

$W = mg$

$w = (70)(9.8)$

$\boxed{w = 686 \, N}$

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1B

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested time is about 11 minutes for answering each of questions 1-2 and 5-7, and about 17 minutes for answering each of questions 3-4. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.

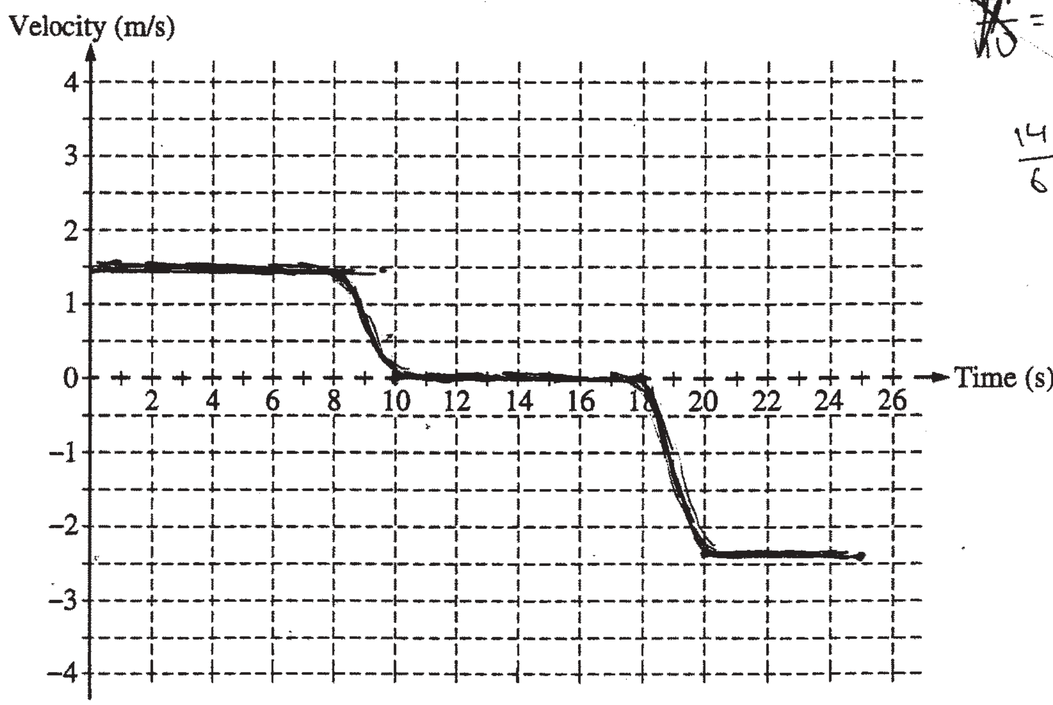
1. (10 points)

The vertical position of an elevator as a function of time is shown above.

(a) On the grid below, graph the velocity of the elevator as a function of time.

$\frac{12}{8} = 1.5$ m/s

$\frac{14}{6}$



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(b)

i. Calculate the average acceleration for the time period $t = 8$ s to $t = 10$ s.

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$14m = 12m + 1.5m/s(2s) + \frac{1}{2}a(2)^2$

$14m = 12m + 3m + 2a$

$14m = 15m + 2a$
$-15m \quad -15m$

$\frac{-1m}{2} = \frac{2a}{2}$

$a = -\frac{1}{2} m/s^2$ or $-.5 m/s^2$

ii. On the box below that represents the elevator, draw a vector to represent the direction of this average acceleration.

(c) Suppose that there is a passenger of mass 70 kg in the elevator. Calculate the apparent weight of the passenger at time $t = 4$ s.

$F = ma = 70kg(9.8m/s^2) = 686N$

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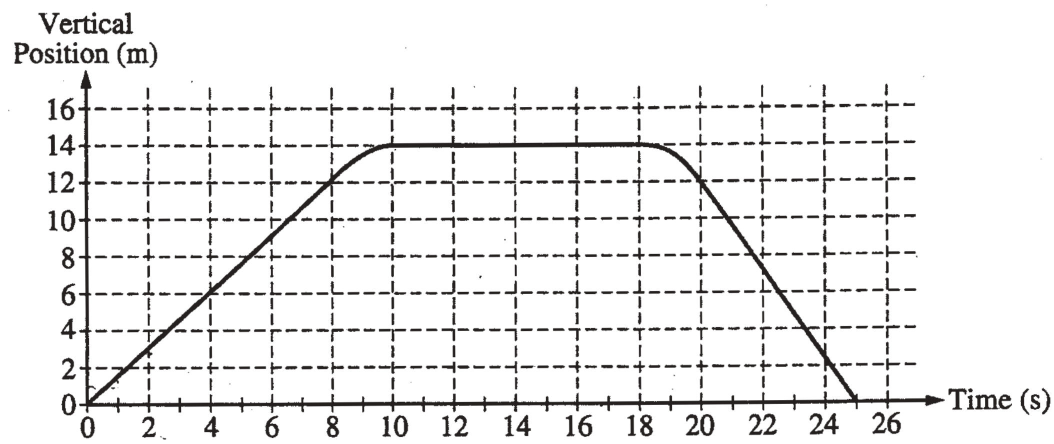
1C

PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested time is about 11 minutes for answering each of questions 1-2 and 5-7, and about 17 minutes for answering each of questions 3-4. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



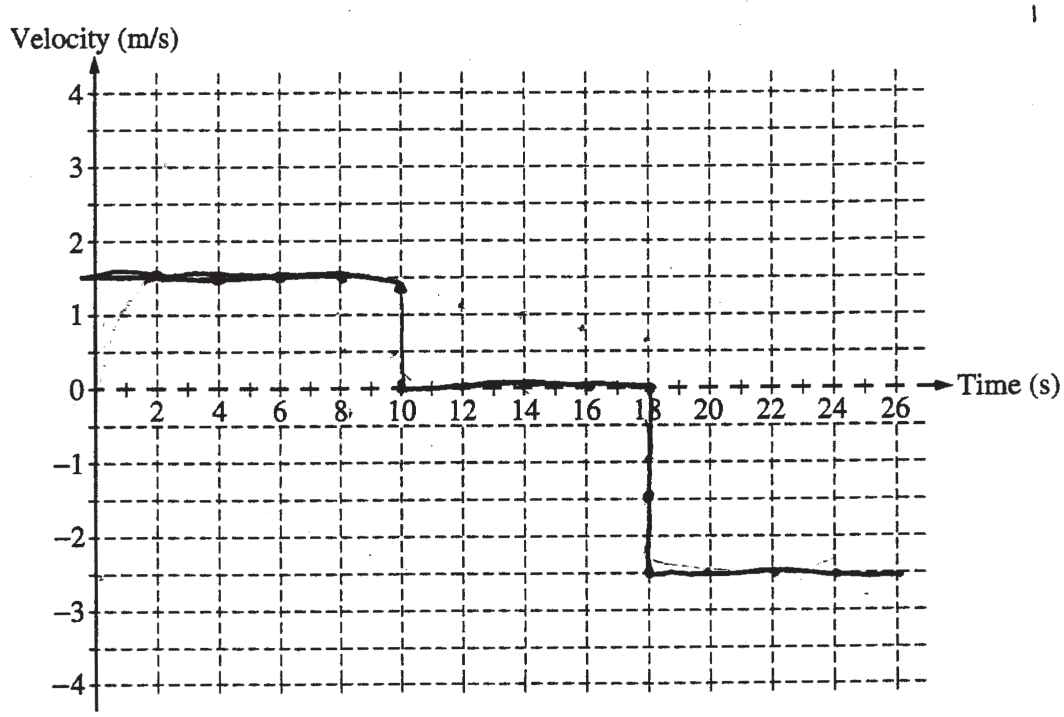
1. (10 points)

The vertical position of an elevator as a function of time is shown above.

$V = \frac{\Delta y}{t}$

(a) On the grid below, graph the velocity of the elevator as a function of time.

$\frac{9}{6}$ $\frac{1}{1}$ $\frac{3}{2}$ $\frac{6}{4}$



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(b)

i. Calculate the average acceleration for the time period $t = 8$ s to $t = 10$ s.

$a = \frac{v}{t}$ $\quad \bar{a} = \frac{\frac{1.5\,m/s}{8\,s} + \frac{1.5\,m/s}{9\,s} + \frac{0}{10\,s}}{3}$

$\bar{a} \approx .12\,m/s^2$

ii. On the box below that represents the elevator, draw a vector to represent the direction of this average acceleration.

(c) Suppose that there is a passenger of mass 70 kg in the elevator. Calculate the apparent weight of the passenger at time $t = 4$ s.

$\Sigma F_y = FN - mg = ma$

$mg = -ma + FN$

$mg = -(70\,kg)(.375\,m/s^2) + FN$

$mg = -26.25 + FN$

$mg = 105\,N$

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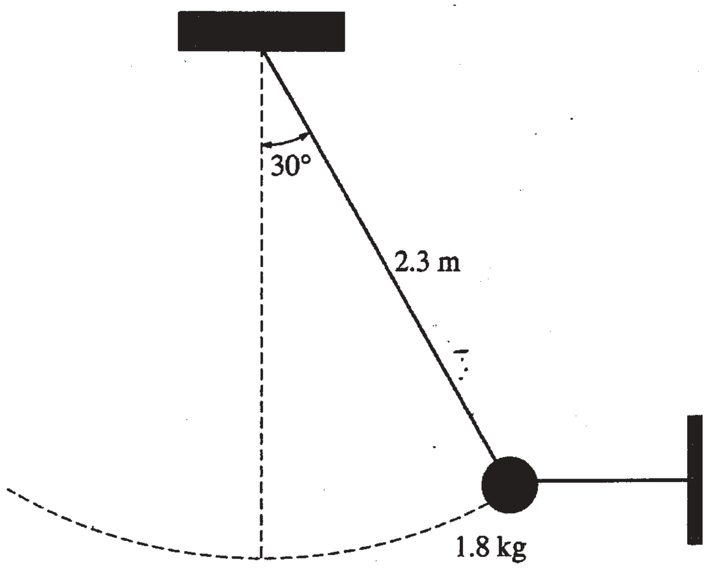
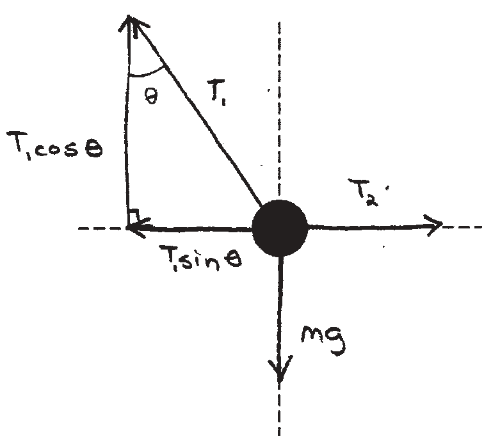


2. (10 points)

A simple pendulum consists of a bob of mass 1.8 kg attached to a string of length 2.3 m. The pendulum is held at an angle of 30° from the vertical by a light horizontal string attached to a wall, as shown above.

(a) On the figure below, draw a free-body diagram showing and labeling the forces on the bob in the position shown above.



(b) Calculate the tension in the horizontal string.

$mg = T_1 \cos\theta$

$(1.8)(9.8) = T_1 \cos 30°$

$T_1 = 20.37$ Nt

$T_2 = T_1 \sin\theta$

$T_2 = (20.37)(\sin 30°)$

$T_2 = 10.18$ Nt

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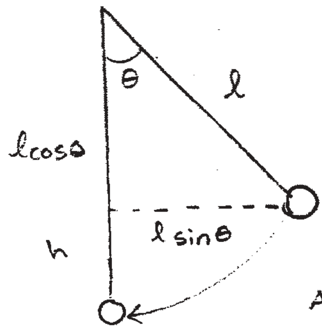
(c) The horizontal string is now cut close to the bob, and the pendulum swings down. Calculate the speed of the bob at its lowest position.



$\ell = 2.3 \text{ m}$

$\ell \cos\theta = 1.99 \text{ m}$

$h = 2.3 - 1.99$
$= 0.308 \text{ m}$

At starting position:

$TE = KE + PE$

$TE = \frac{1}{2}mv^2 + mgh$

at rest, $KE = 0$

$TE = mgh = (1.8)(9.8)(0.308)$

$TE = 5.4 \text{ J}$

At lowest position:

$TE = KE + PE$ → PE = 0, there is no more height

$TE = KE$

$KE = 5.4$

$KE = \frac{1}{2}mv^2$

$5.4 = \frac{1}{2}(1.8)v^2$

$v = 2.46 \text{ m/s}$

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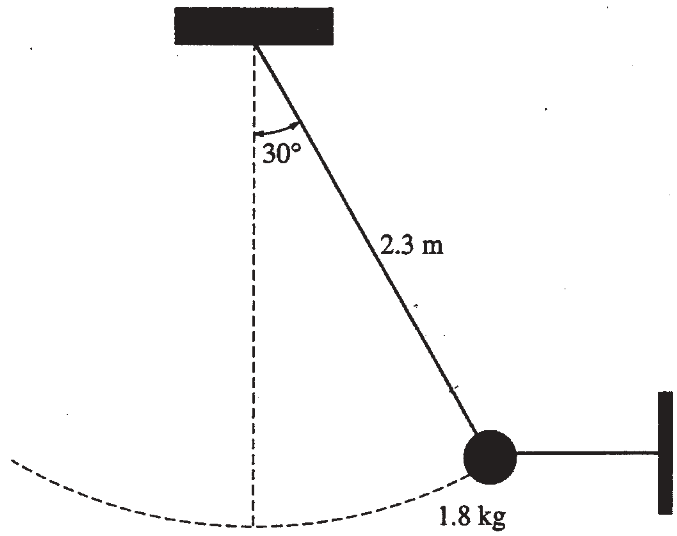
2B



2. (10 points)

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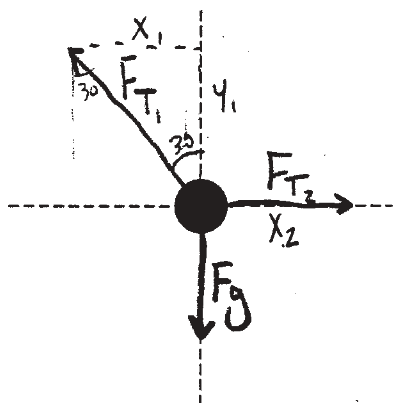
(a) On the figure below, draw a free-body diagram showing and labeling the forces on the bob in the position shown above.



(b) Calculate the tension in the horizontal string.

$F_g = 1.8 \cdot 9.8 = 17.64$

$F_g = Y_1$

$\cos 30 = \frac{Y_1}{F_{T_1}}$

$.866 F_{T_1} = 17.64$

$F_{T_1} = 20.37$

GO ON TO THE NEXT PAGE.

2B

(c) The horizontal string is now cut close to the bob, and the pendulum swings down. Calculate the speed of the bob at its lowest position.

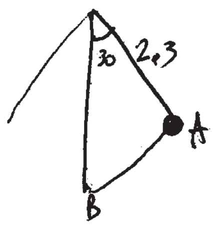
$$T_p = 2\pi\sqrt{\frac{l}{g}}$$

$$T_p = 2\pi\sqrt{\ }$$

$$T_p = .97\pi$$

$$1/T_p = f$$

$$f = 1.03\ Hz$$



1.03 oscillations/second, meaning it gets to the low point in $f/2$ = .516 seconds.

~~Arc~~ Length of arc AB = $\frac{30}{360} \cdot 2\pi \cdot 2.3$ = 1.2 ~~seconds~~ meters

1.2 meters in .516 seconds means

$\bar{V} = 2.33\ m/s$

because $V_0 = 0$, $V_{max} = 2\bar{V} - V_0 = 4.67$

$V_{max} + V_{min} = \bar{V}$

$V_{max} = 4.67\ m/s$

$\sqrt{x_1^2 + y_1^2} = F_{T_1}$

$\sqrt{x_1^2 + 311.17} = 414.94$

$X_1 = 10.19\ N$

$X_1 = X_2 = F_{T_2} = 10.19\ N$

~~X_2~~ =

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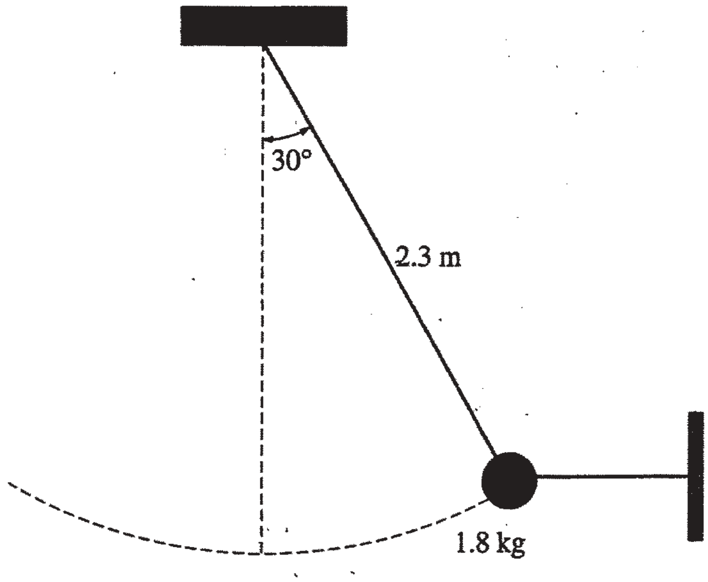

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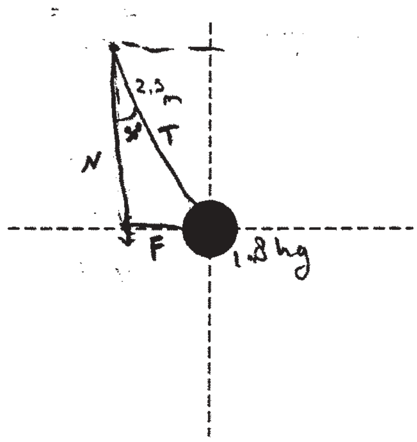

(b) Calculate the tension in the horizontal string.

$T = f \sin\theta$

$T = (1.8\,kg)(9.8\,m/sec^2)\sin 30°$

$T = 8.82\,n$

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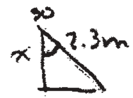
2C

(c) The horizontal string is now cut close to the bob, and the pendulum swings down. Calculate the speed of the bob at its lowest position.



$PE = KE$

$mgh = \frac{1}{2} m v^2$

$(1.8 kg)(9.8 m/sec^2)(.31 m) = \frac{1}{2}(1.8 kg) v^2$

$5.47 \frac{kg \cdot m^2}{sec^2} = .9 kg\, v^2$

$V = 2.46 m/sec^2$

$\cos 30° = \frac{x}{2.3m}$

$x = 1.99$

$2.3m - 1.99m = .31m$

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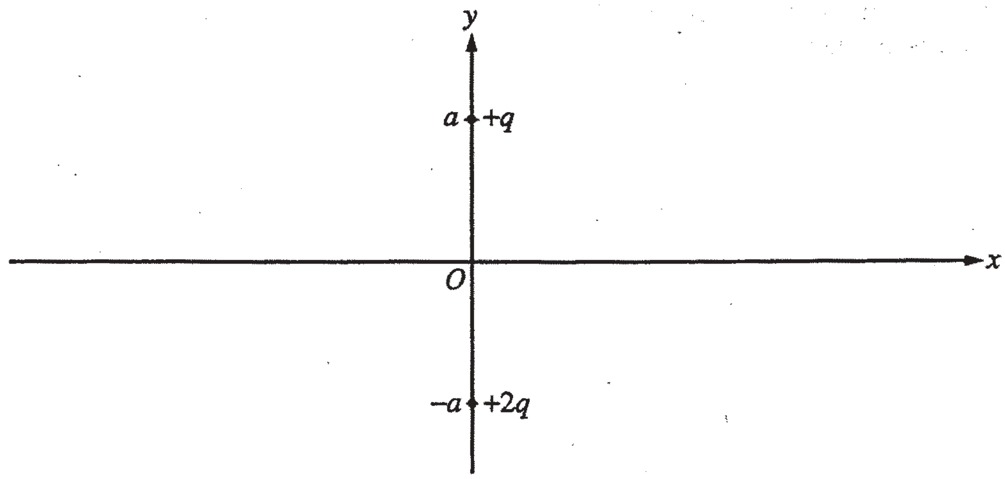

3. (15 points)

Two point charges are fixed on the y-axis at the locations shown in the figure above. A charge of $+q$ is located at $y = +a$ and a charge of $+2q$ is located at $y = -a$. Express your answers to parts (a) and (b) in terms of q, a, and fundamental constants.

(a) Determine the magnitude and direction of the electric field at the origin.

$E = \frac{kq}{r^2}$

$E_a = \frac{kq}{a^2}$ downwards $= \frac{-kq}{a^2}$

$E_{-a} = \frac{2kq}{(-a)^2}$ upwards $= \frac{2kq}{a^2}$

(Electric field is a vector)

$E_a + E_{-a} = \frac{-kq}{a^2} + \frac{2kq}{a^2} = \boxed{\frac{kq}{a^2}}$

(b) Determine the electric potential at the origin.

$V = \frac{kq}{r}$

$V_a = \frac{kq}{a}$

$V_{-a} = \frac{2kq}{|-a|} = \frac{2kq}{a}$

Electric potential is a scalar quantity

$V_a + V_{-a} = \frac{kq}{a} + \frac{2kq}{a} = \boxed{\frac{3kq}{a}}$

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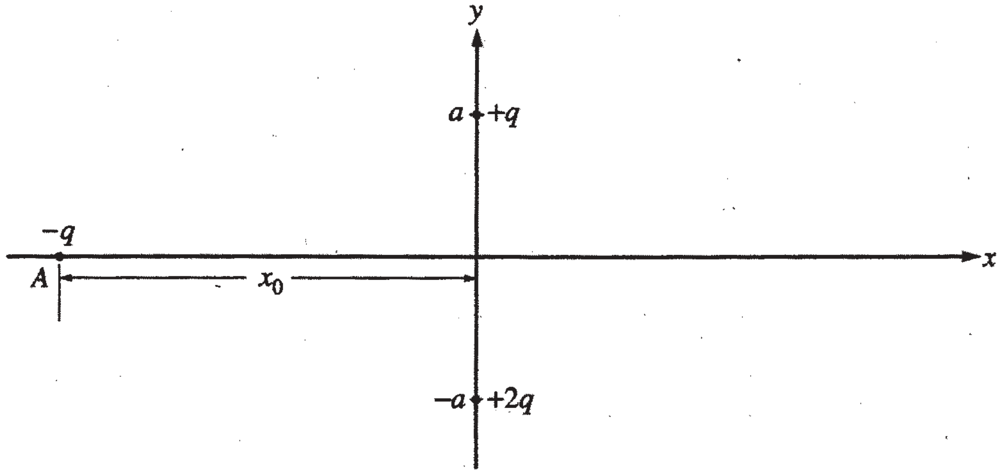
A third charge of $-q$ is first placed at an arbitrary point A $(x = -x_0)$ on the x-axis as shown in the figure below.



(c) Write expressions in terms of q, a, x_0, and fundamental constants for the magnitudes of the forces on the $-q$ charge at point A caused by each of the following.

i. The $+q$ charge

$F = \frac{kq_1q_2}{r^2}$

$r = \sqrt{x_0^2 + a^2}$

$F = \frac{k(q)(-q)}{(\sqrt{x_0^2+a^2})^2} = \frac{-kq^2}{x_0^2+a^2}$

$|F| = \boxed{\frac{kq^2}{x_0^2+a^2}}$

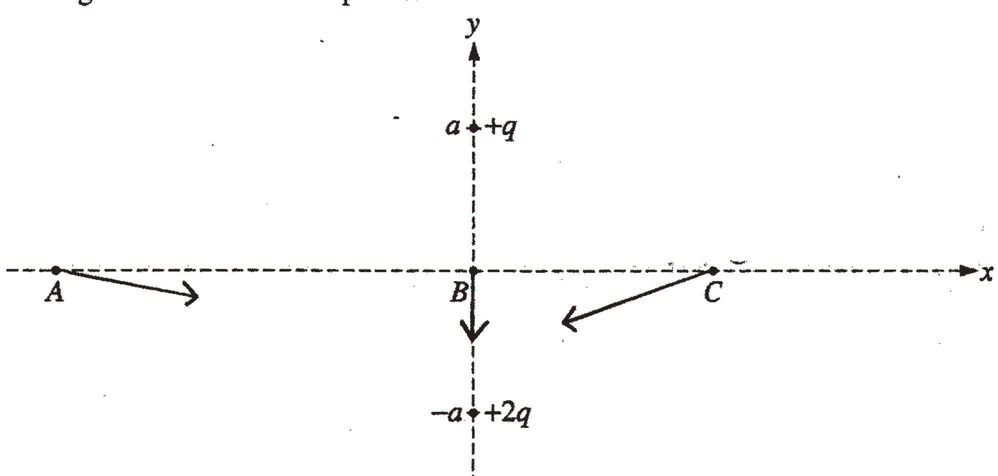
ii. The $+2q$ charge

$F = \frac{kq_1q_2}{r^2}$

$r = \sqrt{x_0^2 + (-a)^2}$

$F = \frac{k(2q)(-q)}{(\sqrt{x_0^2+a^2})^2} = \frac{-2kq^2}{x_0^2+a^2}$, $|F| = \boxed{\frac{2kq^2}{x_0^2+a^2}}$

(d) The $-q$ charge can also be placed at other points on the x-axis. At each of the labeled points (A, B, and C) in the following diagram, draw a vector to represent the direction of the net force on the $-q$ charge due to the other two charges when it is at those points.



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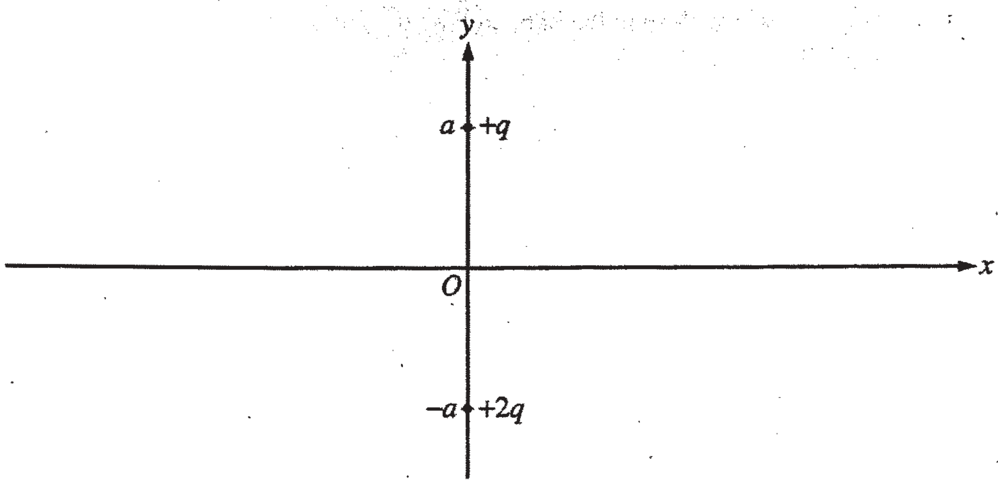

3. (15 points)

Two point charges are fixed on the y-axis at the locations shown in the figure above. A charge of $+q$ is located at $y = +a$ and a charge of $+2q$ is located at $y = -a$. Express your answers to parts (a) and (b) in terms of q, a, and fundamental constants.

(a) Determine the magnitude and direction of the electric field at the origin.

$$E = \frac{kq}{r^2}$$

$$= \frac{kq}{a^2} + \frac{k(2q)}{(-a)^2}$$

up

(b) Determine the electric potential at the origin.

$$V = \frac{kq}{r}$$

$$V = \frac{k(q)}{a} + \frac{k(2q)}{-a}$$

$$V = \frac{kq}{a} - \frac{2kq}{a}$$

$$V = -\frac{kq}{a}$$

V

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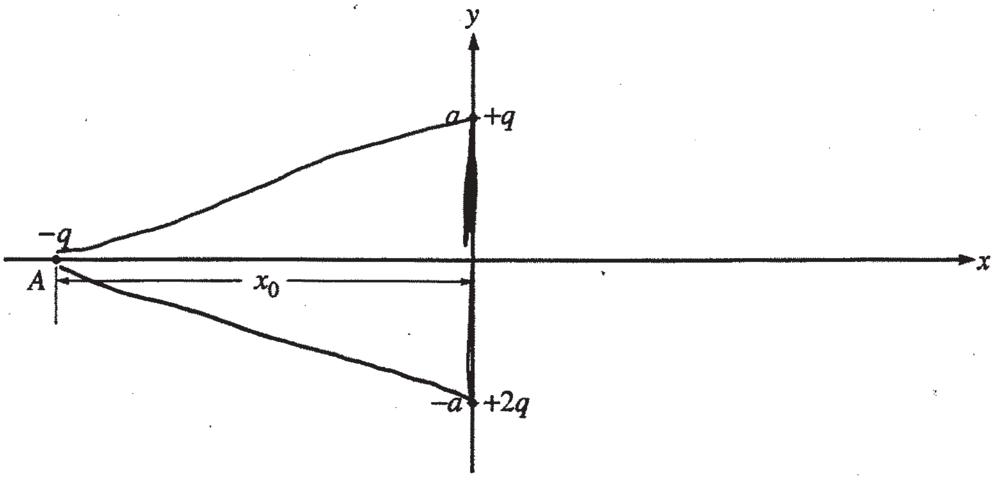
3B

A third charge of $-q$ is first placed at an arbitrary point A ($x = -x_0$) on the x-axis as shown in the figure below.



(c) Write expressions in terms of q, a, x_0, and fundamental constants for the magnitudes of the forces on the $-q$ charge at point A caused by each of the following.

i. The $+q$ charge

$F = \frac{k q_1 q_2}{r}$

$F = \frac{k(-q)(q)}{\sqrt{(x_0)^2 + (a)^2}}$

$a^2 + b^2 = c^2$

$(x_0)^2 + a^2 = c^2$

$\sqrt{x_0^2 + a^2} = c$

ii. The $+2q$ charge

$F = \frac{k q_1 q_2}{r}$

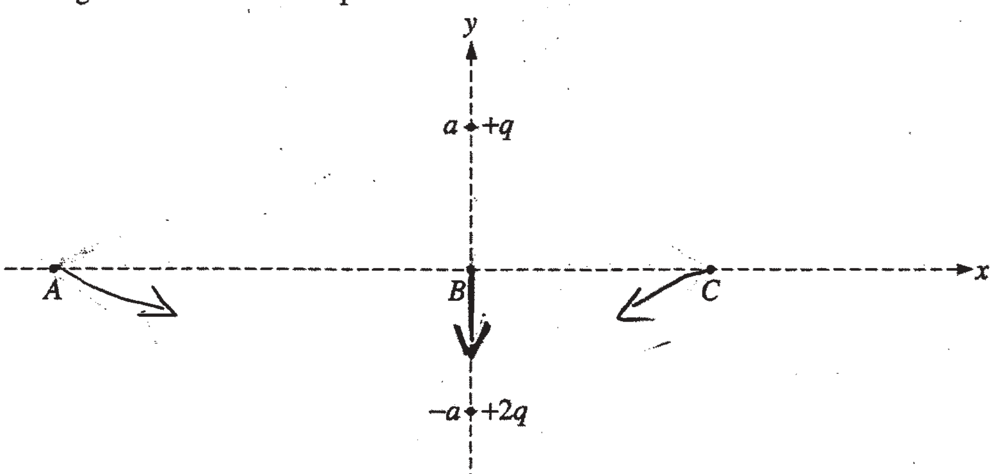
$F = \frac{k(-q)(2q)}{\sqrt{(x_0)^2 + (a)^2}}$

$a^2 + b^2 = c^2$

$(x_0)^2 + (-a)^2 = c^2$

$c = \sqrt{(x_0)^2 + (a)^2}$

(d) The $-q$ charge can also be placed at other points on the x-axis. At each of the labeled points (A, B, and C) in the following diagram, draw a vector to represent the direction of the net force on the $-q$ charge due to the other two charges when it is at those points.



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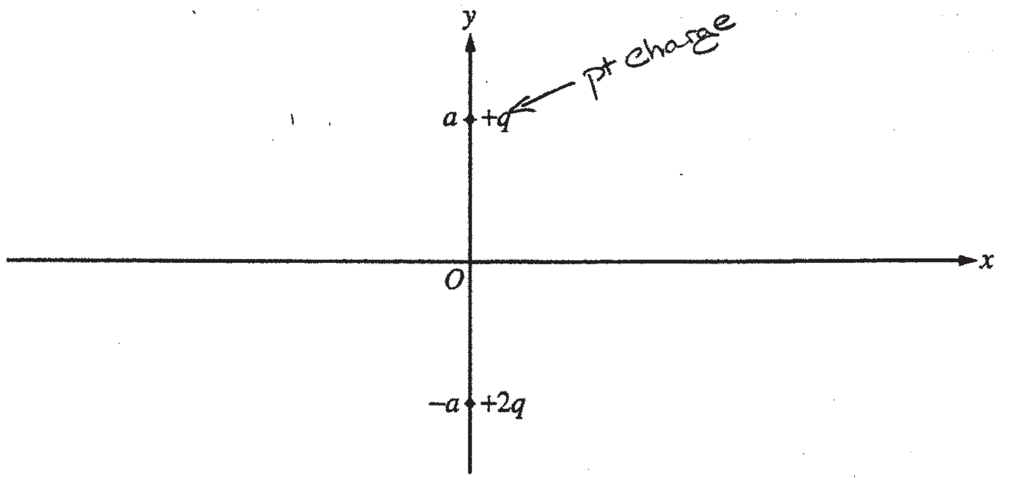
3C



3. (15 points)

Two point charges are fixed on the y-axis at the locations shown in the figure above. A charge of $+q$ is located at $y = +a$ and a charge of $+2q$ is located at $y = -a$. Express your answers to parts (a) and (b) in terms of q, a, and fundamental constants.

(a) Determine the magnitude and direction of the electric field at the origin.

$$E_{Field} = \frac{KQ}{r^2} = \frac{9.\times10^9(2q)}{-a^2} = \boxed{\frac{9\times10^9(2q)}{a^2}}$$

$$K = 9\times10^9$$

(b) Determine the electric potential at the origin.

$$PE_{electric} = k\frac{qq}{r}$$

$$\frac{9\times10^9(q)(2q)}{a}$$

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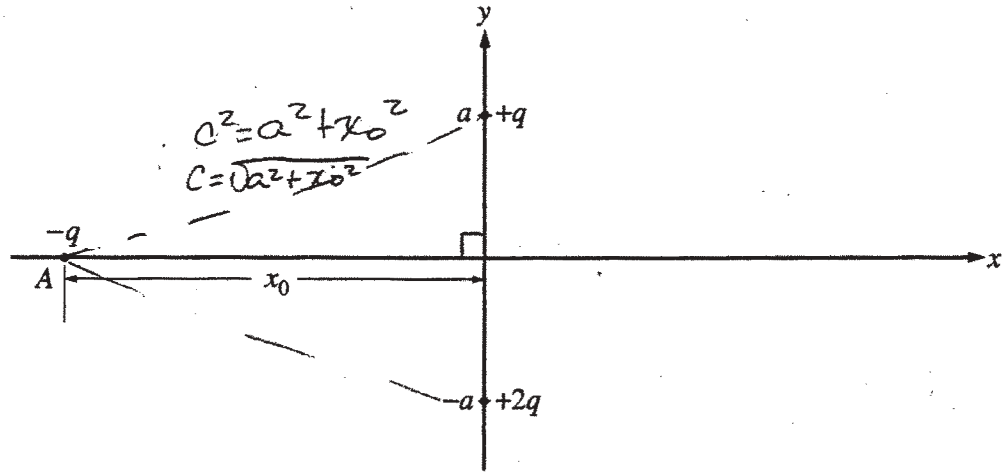
A third charge of $-q$ is first placed at an arbitrary point A ($x = -x_0$) on the x-axis as shown in the figure below.

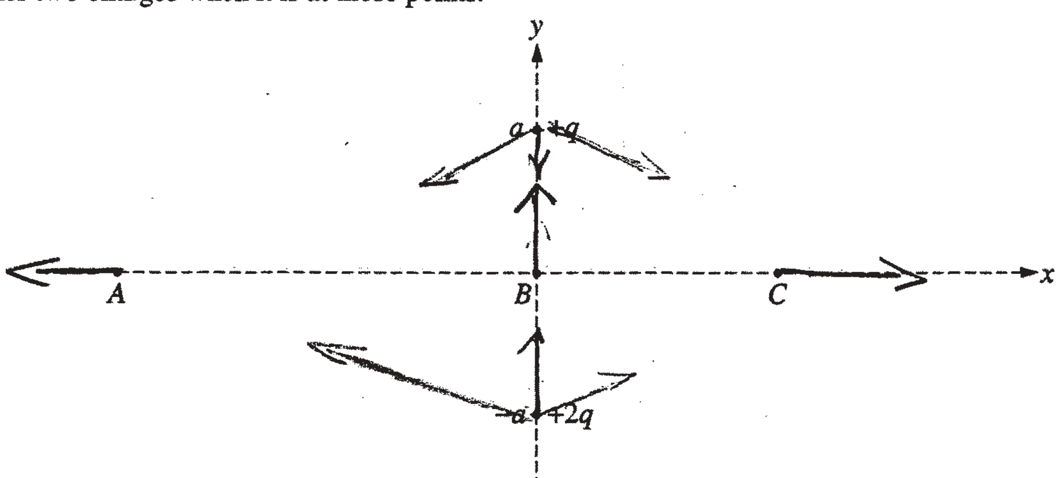


(c) Write expressions in terms of q, a, x_0, and fundamental constants for the magnitudes of the forces on the $-q$ charge at point A caused by each of the following.

i. The $+q$ charge $F = \dfrac{9\times10^9 (q)(q)}{a^2 + x_0^2}$

ii. The $+2q$ charge $F = \dfrac{9\times10^9 (2q)(q)}{a^2 + x_0^2}$

(d) The $-q$ charge can also be placed at other points on the x-axis. At each of the labeled points (A, B, and C) in the following diagram, draw a vector to represent the direction of the net force on the $-q$ charge due to the other two charges when it is at those points.



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4A

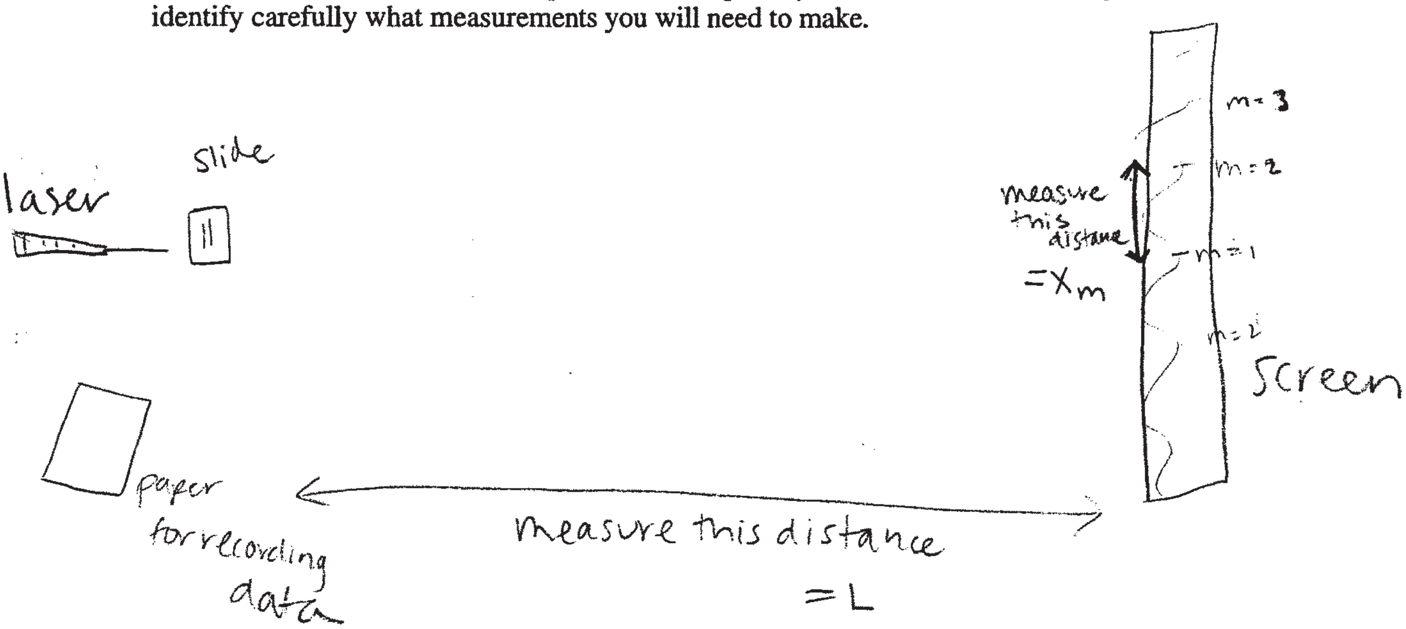
4. (15 points)

Your teacher gives you a slide with two closely spaced slits on it. She also gives you a laser with a wavelength $\lambda = 632$ nm. The laboratory task that you are assigned asks you to determine the spacing between the slits. These slits are so close together that you cannot measure their spacing with a typical measuring device.

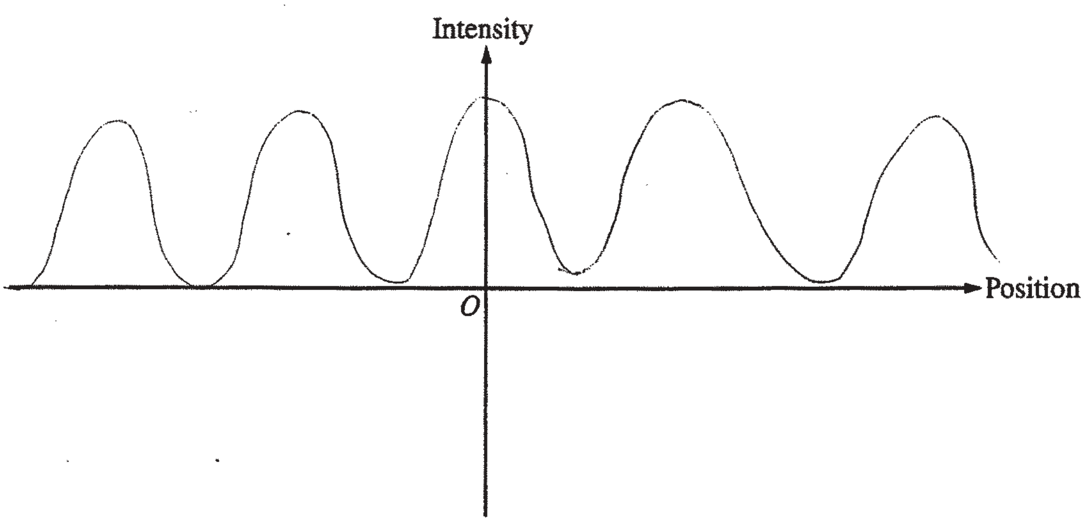
(a) From the list below, select the additional equipment you will need to do your experiment by checking the line next to each item.

___ Meterstick	___ Ruler	✓ Tape measure	___ Light-intensity meter
✓ Large screen	✓ Paper	✓ Slide holder	___ Stopwatch

(b) Draw a labeled diagram of the experimental setup that you would use. On the diagram, use symbols to identify carefully what measurements you will need to make.



(c) On the axes below, sketch a graph of intensity versus position that would be produced by your setup, assuming that the slits are very narrow compared to their separation.



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(d) Outline the procedure that you would use to make the needed measurements, including how you would use each piece of the additional equipment you checked in (a).

first I would set up the screen and the slide a distance L apart. I would then shine the laser through the slide from behind until a diffraction patter was visible on the screen. Then I would measure the distance between the dark spots on the screen, (X_m) I would use the slide holder when positioning the slide, the tape measure to measure the distances L + X_m and the paper to record data.

(e) Using equations, show explicitly how you would use your measurements to calculate the slit spacing.

using the equation $X_m \approx \frac{m \lambda L}{d}$, I would substitute my measurements for X_m and L, the given wavelength of light, and 1 for m. Then I would solve for d, the separation of the slits.

GO ON TO THE NEXT PAGE.

4B

4. (15 points)

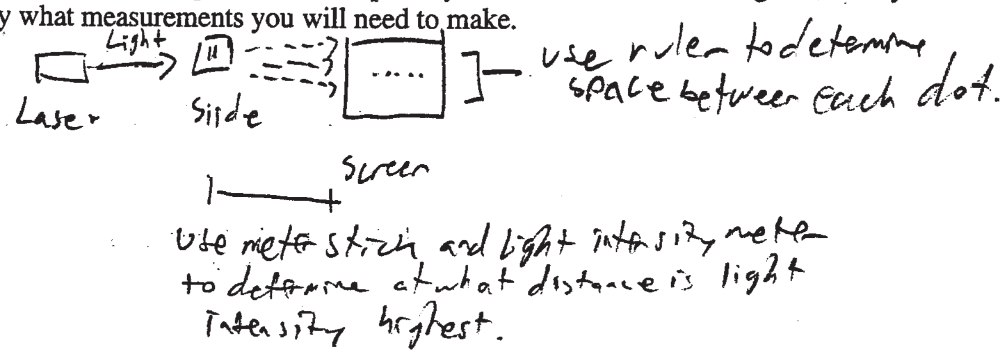
Your teacher gives you a slide with two closely spaced slits on it. She also gives you a laser with a wavelength $\lambda = 632$ nm. The laboratory task that you are assigned asks you to determine the spacing between the slits. These slits are so close together that you cannot measure their spacing with a typical measuring device.

(a) From the list below, select the additional equipment you will need to do your experiment by checking the line next to each item.

X Meterstick   X Ruler   ___ Tape measure   X Light-intensity meter

X Large screen   ___ Paper   X Slide holder   ___ Stopwatch

(b) Draw a labeled diagram of the experimental setup that you would use. On the diagram, use symbols to identify carefully what measurements you will need to make.



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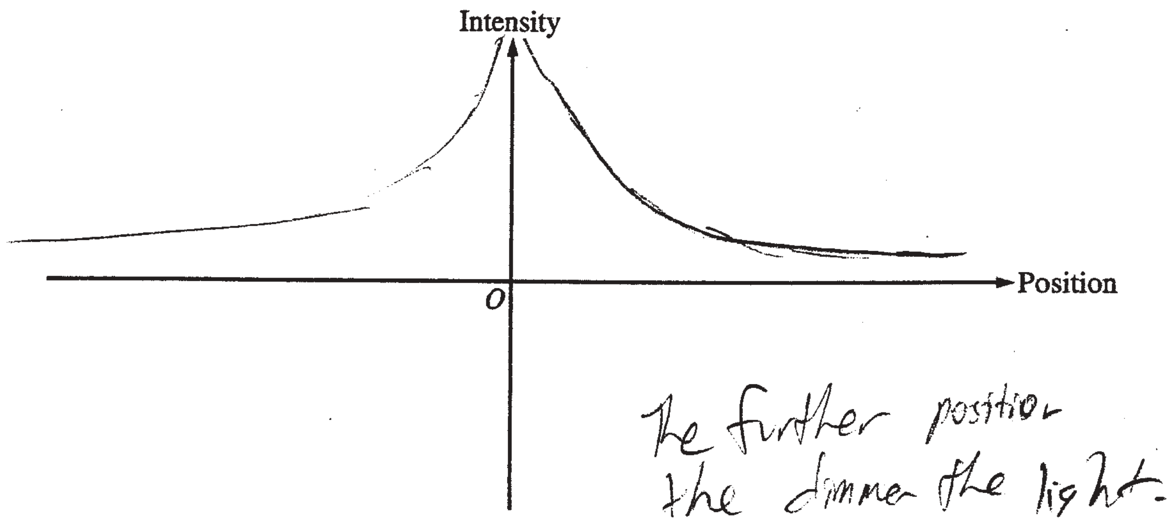

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4B

(d) Outline the procedure that you would use to make the needed measurements, including how you would use each piece of the additional equipment you checked in (a).

set up the laser, screen, and slide in a manner that the laser will pass through the slide and display on the screen. Measure the distance from the slide to the screen and document this as "L". Use the ruler then to measure distance between each pair of bright spots (order number). Calculate distance from order "0".

Use the intensity meter to record the optimum distance for brightness.

(e) Using equations, show explicitly how you would use your measurements to calculate the slit spacing.

using $x_m \approx \frac{m \lambda L}{d}$

solve for d (separation)

x is the distance between bright spots and

L is the distance from the slide to the screen

λ is the given wavelength

GO ON TO THE NEXT PAGE.

4c

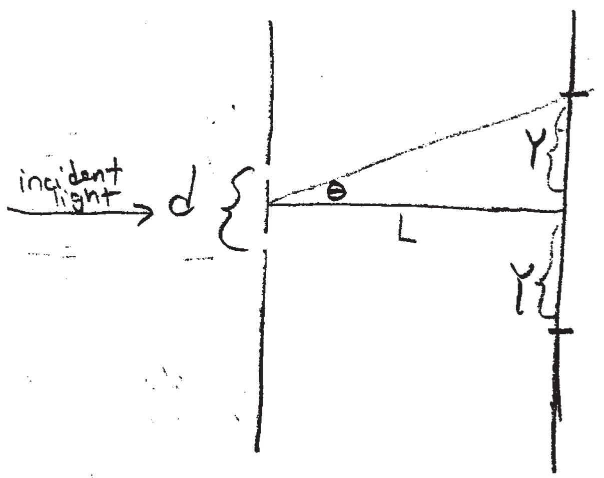
4. (15 points)

Your teacher gives you a slide with two closely spaced slits on it. She also gives you a laser with a wavelength $\lambda = 632$ nm. The laboratory task that you are assigned asks you to determine the spacing between the slits. These slits are so close together that you cannot measure their spacing with a typical measuring device.

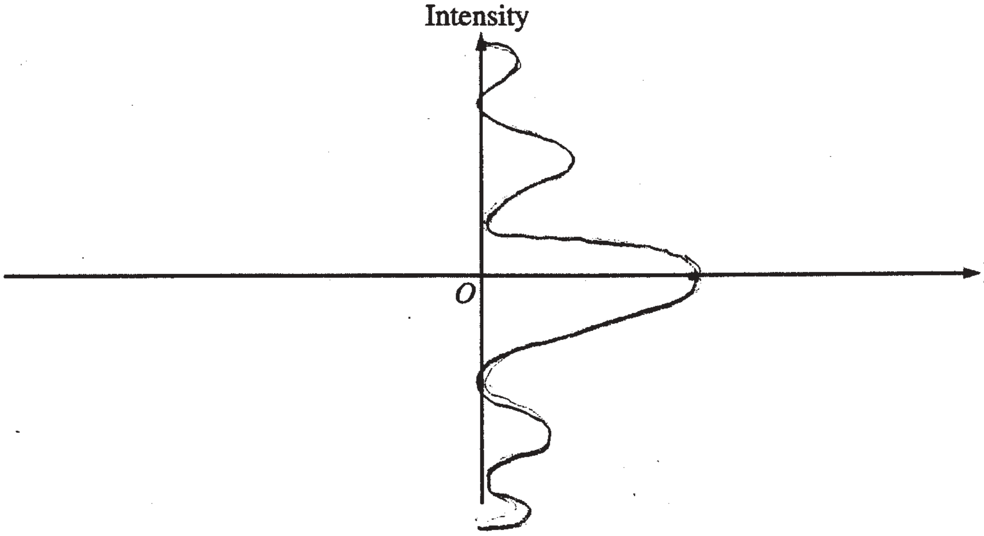
(a) From the list below, select the additional equipment you will need to do your experiment by checking the line next to each item.

✓ Meterstick	___ Ruler	___ Tape measure	___ Light-intensity meter
✓ Large screen	___ Paper	✓ Slide holder	___ Stopwatch

(b) Draw a labeled diagram of the experimental setup that you would use. On the diagram, use symbols to identify carefully what measurements you will need to make.



(c) On the axes below, sketch a graph of intensity versus position that would be produced by your setup, assuming that the slits are very narrow compared to their separation.



GO ON TO THE NEXT PAGE.

(d) Outline the procedure that you would use to make the needed measurements, including how you would use each piece of the additional equipment you checked in (a).

1. Insert slide in slide holder.
2. Shine laser through slide.
3. Using the large screen, locate the laser light on the screen. This distance betwen slide and screen is L.
4. Locate the three bright dots on the screen and, using the meterstick, measure the distance between them. This is Y.
5. Using this information, it is possible to find d, the distance between the slits.

(e) Using equations, show explicitly how you would use your measurements to calculate the slit spacing.

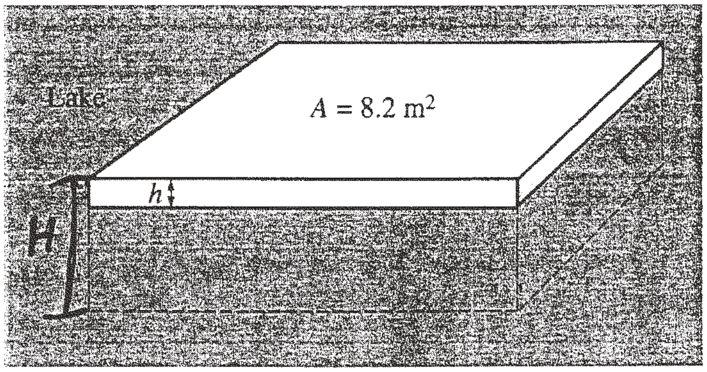
$\cos\theta = \frac{Y}{L}$ use this to find θ

$d\sin\theta = \frac{m}{\lambda}$

$d\sin\theta = \frac{1}{632\text{nm}}$ plug θ in to find d.

GO ON TO THE NEXT PAGE.

5A



Note: Figure not drawn to scale.

5. (10 points)

A large rectangular raft (density 650 kg/m³) is floating on a lake. The surface area of the top of the raft is 8.2 m² and its volume is 1.80 m³. The density of the lake water is 1000 kg/m³.

(a) Calculate the height h of the portion of the raft that is above the surrounding water.

$H = \frac{1.8}{8.2} = .2195\,m$

$F_{buoy} = \rho V g$

$M = \rho V$

$m = 1170$

$F_g = ma$

$F_g = 11477.7$

$F_{buoy} = 11477.7N$

$11477.7 = (1000)(V)(9.81)$

$V_{under\ water} = 1.17m^3$

$V_{above} = V_{TOT} - V_{under}$

$V = .63$

$h = \frac{.63}{8.2}$ $h = .07683m$

(b) Calculate the magnitude of the buoyant force on the raft and state its direction.

$F_{buoy} = 11477.7N$ against the raft

$F_{buoy} = \rho V g$

$(1000)(1.17)(9.81)$

5A

(c) If the average mass of a person is 75 kg, calculate the maximum number of people that can be on the raft without the top of the raft sinking below the surface of the water. (Assume that the people are evenly distributed on the raft.)

$F = ma$

$75 \cdot 9.81 = 735.75 N$

$V_{above} = .63 m^3$

$F_{buoy} = (1000)(.63)(9.81)$

$= 6180.3 N$

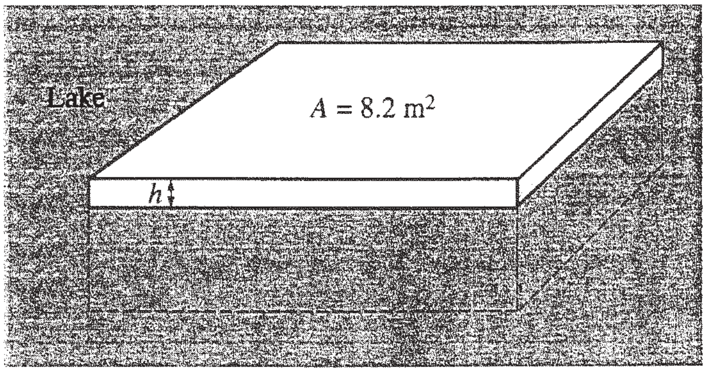
$\frac{6180.3}{735.75} = x$ numbers of people

$x = 8.4$

8 people can stand on the raft before it sinks

GO ON TO THE NEXT PAGE.

5B



Note: Figure not drawn to scale.

5. (10 points)

A large rectangular raft (density 650 kg/m^3) is floating on a lake. The surface area of the top of the raft is 8.2 m^2 and its volume is 1.80 m^3. The density of the lake water is 1000 kg/m^3.

(a) Calculate the height h of the portion of the raft that is above the surrounding water.

$V = A \cdot h$

$1.80 m^3 = 8.2 m^2 \cdot H$

$H = 0.22 m$

$h = H - \frac{650}{1000} H$

$\boxed{h = 0.077 m}$

(b) Calculate the magnitude of the buoyant force on the raft and state its direction.

$B = \rho_{fluid} V_{object}\, g_{gravity} = (1000)(1.8)(9.8) = \boxed{17{,}640 N}$

↑ magnitude of buoyant force

$F_{weight} = mag$

$m = \rho_{object} \times V_{object}$

$m = 650 \times 1.8 = 1170 kg$

$\Sigma F = B - F_{weight} = (1000)(1.8)(9.8) - (1170)(9.8)$

$\Sigma F = 17{,}640 - 11{,}466 = 6{,}174 N$

the direction is up!

GO ON TO THE NEXT PAGE.

(c) If the average mass of a person is 75 kg, calculate the maximum number of people that can be on the raft without the top of the raft sinking below the surface of the water. (Assume that the people are evenly distributed on the raft.)

$\Sigma F = 0 = B - F_{weight}$

$F_{weight} = B = 17{,}640$

$(75n + 1170)\,g = 17{,}640$

$75n + 1170 = 1800$

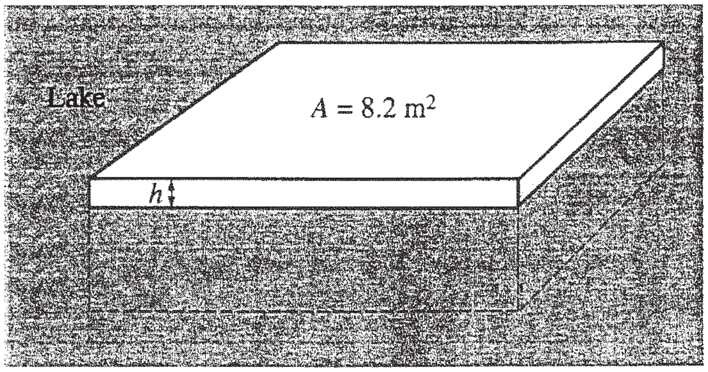
$75n = 630$

$n = 8.4$

the maximum is 8 people

GO ON TO THE NEXT PAGE.

5c



Note: Figure not drawn to scale.

5. (10 points)

A large rectangular raft (density 650 kg/m^3) is floating on a lake. The surface area of the top of the raft is 8.2 m^2 and its volume is 1.80 m^3. The density of the lake water is 1000 kg/m^3.

(a) Calculate the height h of the portion of the raft that is above the surrounding water.

$1.8 m^3 = 8.2 m^2 h$

$.22 m = h$

(b) Calculate the magnitude of the buoyant force on the raft and state its direction.

$F = \rho V g$

$650 \cdot 1.8 \cdot 9.8$

$= 11466 N$

GO ON TO THE NEXT PAGE.

5c

(c) If the average mass of a person is 75 kg, calculate the maximum number of people that can be on the raft without the top of the raft sinking below the surface of the water. (Assume that the people are evenly distributed on the raft.)

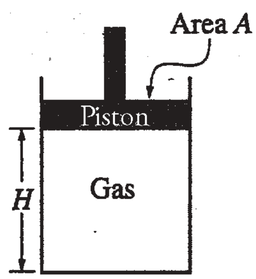
$11466 \geq n \cdot 75 \cdot 9.8$

$n = 15.6$

$\boxed{n = 15}$

GO ON TO THE NEXT PAGE.

6A



6. (10 points)

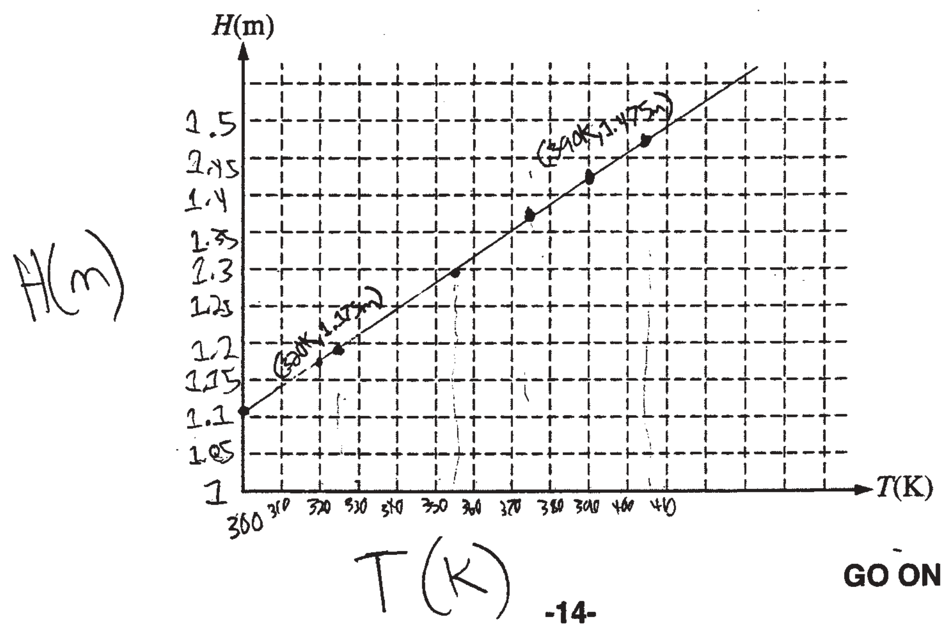
An experiment is performed to determine the number n of moles of an ideal gas in the cylinder shown above. The cylinder is fitted with a movable, frictionless piston of area A. The piston is in equilibrium and is supported by the pressure of the gas. The gas is heated while its pressure P remains constant. Measurements are made of the temperature T of the gas and the height H of the bottom of the piston above the base of the cylinder and are recorded in the table below. Assume that the thermal expansion of the apparatus can be ignored.

T (K)	H (m)
300	1.11
325	1.19
355	1.29
375	1.37
405	1.47

(a) Write a relationship between the quantities T and H, in terms of the given quantities and fundamental constants, that will allow you to determine n.

$$PV = nRT$$
$$PAH = nRT$$
$$n = \frac{P \cdot A \cdot H}{R \cdot T}$$

(b) Plot the data on the axes below so that you will be able to determine n from the relationship in part (a). Label the axes with appropriate numbers to show the scale.



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6A

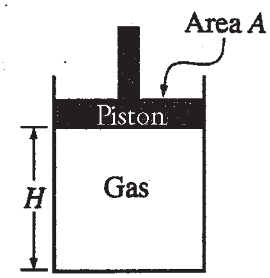
(c) Using your graph and the values $A = 0.027\ \text{m}^2$ and $P = 1.0$ atmosphere, determine the experimental value of n.

$$n = \frac{1.0\times10^5\ \text{N/m}^2 \cdot .027\ \text{m}^2}{8.31\ \text{Nm/mol}\cdot\text{K}} \cdot \frac{1.425\text{m} - 1.175\text{m}}{390\text{K} - 320\text{K}}$$

$$n = 1.160\ \text{mol}$$

GO ON TO THE NEXT PAGE.

6B



6. (10 points)

An experiment is performed to determine the number n of moles of an ideal gas in the cylinder shown above. The cylinder is fitted with a movable, frictionless piston of area A. The piston is in equilibrium and is supported by the pressure of the gas. The gas is heated while its pressure P remains constant. Measurements are made of the temperature T of the gas and the height H of the bottom of the piston above the base of the cylinder and are recorded in the table below. Assume that the thermal expansion of the apparatus can be ignored.

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300	1.11
325	1.19
355	1.29
375	1.37
405	1.47

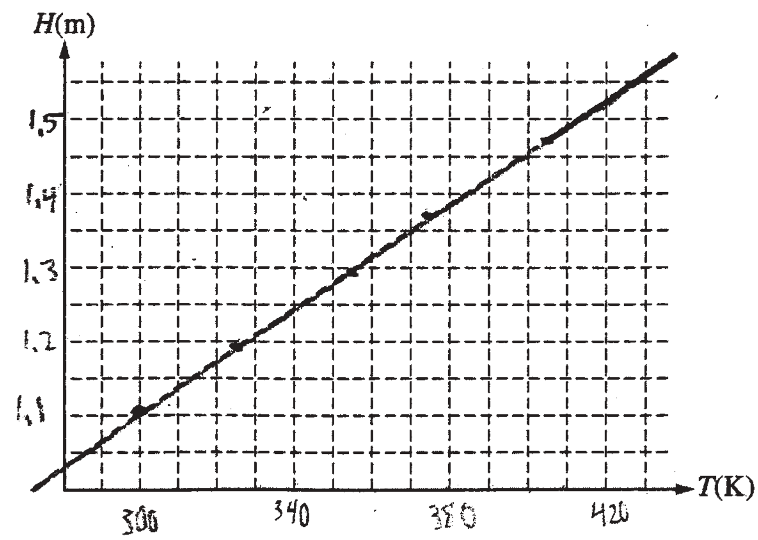
(a) Write a relationship between the quantities T and H, in terms of the given quantities and fundamental constants, that will allow you to determine n.

$PV = nRT$

$PHA = nRT$

$n = \frac{H}{T}\left(\frac{PA}{R}\right)$

(b) Plot the data on the axes below so that you will be able to determine n from the relationship in part (a). Label the axes with appropriate numbers to show the scale.



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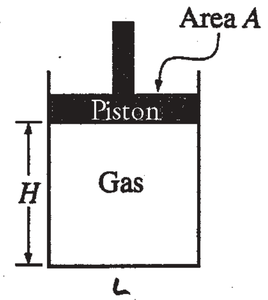
(c) Using your graph and the values $A = 0.027\ \text{m}^2$ and $P = 1.0$ atmosphere, determine the experimental value of n.

$$\frac{H}{T} = .0037\ \frac{m}{K}$$

$$n = .0037\ \frac{m}{K} \times \frac{1\ \text{atm} \times .027\ m^2}{8.31\ \frac{J}{mol\ K}}$$

$$n = 1.20 \times 10^{-5}\ \text{mol}$$

6C



6. (10 points)

An experiment is performed to determine the number n of moles of an ideal gas in the cylinder shown above. The cylinder is fitted with a movable, frictionless piston of area A. The piston is in equilibrium and is supported by the pressure of the gas. The gas is heated while its pressure P remains constant. Measurements are made of the temperature T of the gas and the height H of the bottom of the piston above the base of the cylinder and are recorded in the table below. Assume that the thermal expansion of the apparatus can be ignored.

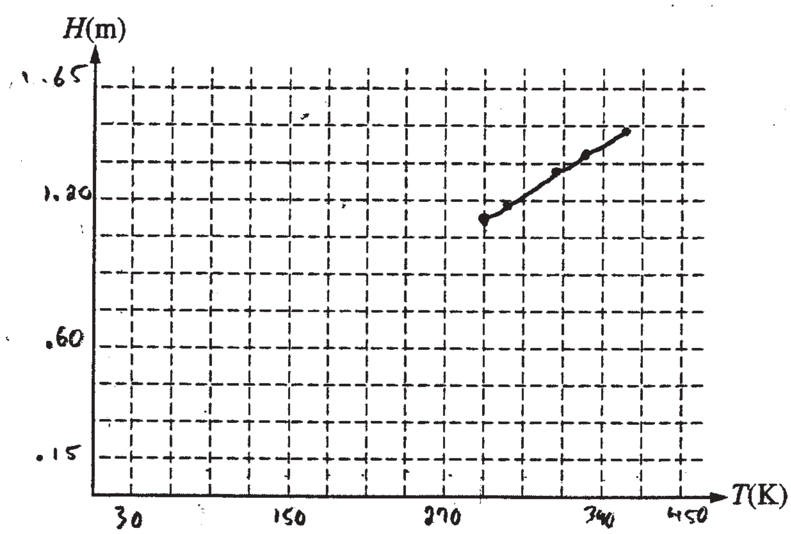
T (K)	H (m)
300	1.11
325	1.19
355	1.29
375	1.37
405	1.47

(a) Write a relationship between the quantities T and H, in terms of the given quantities and fundamental constants, that will allow you to determine n.

$PV = nRT$

$n = \frac{PV}{RT} = \frac{P(H \cdot L)}{RT}$

(b) Plot the data on the axes below so that you will be able to determine n from the relationship in part (a). Label the axes with appropriate numbers to show the scale.

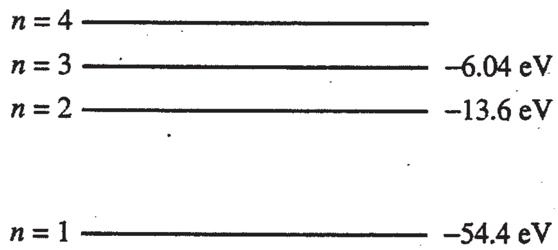


GO ON TO THE NEXT PAGE.

(c) Using your graph and the values $A = 0.027\ m^2$ and $P = 1.0$ atmosphere, determine the experimental value of n.

$$n = \frac{1.0\ (1.11}{(8.31)(300)} =$$

GO ON TO THE NEXT PAGE.



Note: Energy levels not drawn to scale.

7. (10 points)

The diagram above shows the lowest four discrete energy levels of an atom. An electron in the $n = 4$ state makes a transition to the $n = 2$ state, emitting a photon of wavelength 121.9 nm.

(a) Calculate the energy level of the $n = 4$ state.

$$E_{photon} = \frac{hc}{\lambda}$$

$$E_{photon} = \frac{(4.14\times10^{-15})(3\times10^{8})}{121.9\times10^{-9}} = 10.19\text{ eV}$$

$$E_4 = -13.6\text{ eV} + 10.19\text{ eV}$$

$$\boxed{E = -3.41\text{ eV}}$$

(b) Calculate the momentum of the photon.

$$p_{photon} = \frac{h}{\lambda}$$

$$p = \frac{(6.63\times10^{-34})}{121.9\times10^{-9}}$$

$$\boxed{p = 5.44\times10^{-27}\ \text{J}\cdot\text{s/m}}$$

GO ON TO THE NEXT PAGE.

The photon is then incident on a silver surface in a photoelectric experiment, and the surface emits an electron with maximum possible kinetic energy. The work function of silver is 4.7 eV.

(c) Calculate the kinetic energy, in eV, of the emitted electron.

$KE_{max} = E_{photon} - \phi$

$KE_{max} = 10.19 - 4.7$

$KE_{max} = 5.49\ eV$

(d) Determine the stopping potential for the emitted electron.

$E = eV_s$

$5.49\ eV = eV_s$

$5.49\ V = V_s$

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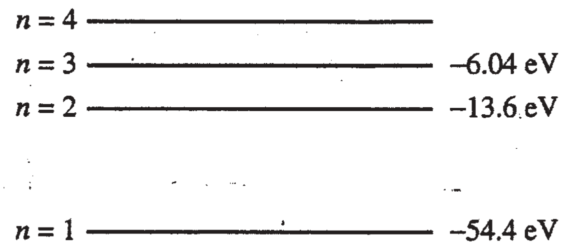
7B



Note: Energy levels not drawn to scale.

7. (10 points)

The diagram above shows the lowest four discrete energy levels of an atom. An electron in the $n = 4$ state makes a transition to the $n = 2$ state, emitting a photon of wavelength 121.9 nm.

(a) Calculate the energy level of the $n = 4$ state.

$$E = \frac{-54.4\text{ eV}}{n^2} = \frac{-54.4\text{ eV}}{(4^2)} = \boxed{-3.40\text{ eV}}$$

(b) Calculate the momentum of the photon.

$p = mv \qquad \lambda = \frac{h}{p} \qquad p = \frac{h}{\lambda} \qquad \lambda = 121.9\text{ nm}$

$$p = \frac{6.63\times10^{-34}\ \text{J}\cdot\text{s}}{121.9\times10^{-9}\ \text{m}} = \boxed{5.44\times10^{-27}\ \text{kg}\cdot\text{m/s}}$$

($\text{J}\cdot\text{s} = \text{kg}\,\frac{\text{m}^2}{\text{s}^2}\,\text{s}$)

GO ON TO THE NEXT PAGE.

The photon is then incident on a silver surface in a photoelectric experiment, and the surface emits an electron with maximum possible kinetic energy. The work function of silver is 4.7 eV.

(c) Calculate the kinetic energy, in eV, of the emitted electron.

$K_{max} = hf - \phi$ $\quad c = \lambda f \quad f = \frac{c}{\lambda} = \frac{3.0\times10^{8}\ m/s}{121.9\times10^{-9}\ m} = 2.46\times10^{15}\ \frac{1}{s}$

$K_{max} = (6.63\times10^{-34}\ J/s)(2.46\times10^{15}\ \frac{1}{s}) - 7.52\times10^{-19}\ J \quad 4.7\ eV \times \frac{1.60\times10^{-19}\ J}{1\ eV} = 7.52\times10^{-19}\ J$

$K_{max} = 8.79\times10^{-19}\ J \times \frac{1\ eV}{1.60\times10^{-19}\ J} = \boxed{5.49\ eV}$

(d) Determine the stopping potential for the emitted electron.

$K_{max} = 0$

$hf - \phi = 0$

$f = \frac{\phi}{h} \quad f = \frac{\phi}{h} = \frac{4.7\ eV}{4.14\times10^{-15}\ eV\cdot s}$

$f = 1.13\times10^{15}\ \frac{1}{s} = \boxed{1.13\times10^{15}\ Hz}$

GO ON TO THE NEXT PAGE.

7C

$n = 4$ ————————
$n = 3$ ———————— -6.04 eV
$n = 2$ ———————— -13.6 eV

$n = 1$ ———————— -54.4 eV

Note: Energy levels not drawn to scale.

7. (10 points)

The diagram above shows the lowest four discrete energy levels of an atom. An electron in the $n = 4$ state makes a transition to the $n = 2$ state, emitting a photon of wavelength 121.9 nm.

(a) Calculate the energy level of the $n = 4$ state.

$c = \lambda f$

$\lambda = 121.9\,nm$

$3.0\times10^{8}\,m/s = (1.219\times10^{-7}\,m)(f)$

$f = 2.46\times10^{15}\,1/s$

$E = hf$

$= (4.14\times10^{-15}\,eV\cdot s)(2.46\times10^{15}\,1/s)$

$E = -10.18\,eV$

(b) Calculate the momentum of the photon.

$\lambda = \frac{h}{p}$

$121.9\,nm = \frac{6.63\times10^{-34}\,J\cdot s}{p}$

$p = 5.44\times10^{-36}\,J\cdot s/nm$

GO ON TO THE NEXT PAGE.

The photon is then incident on a silver surface in a photoelectric experiment, and the surface emits an electron with <u>maximum</u> possible kinetic energy. The work function of silver is 4.7 eV.

(c) Calculate the kinetic energy, in eV, of the emitted electron.

$K_{max} = hf - \phi$

$= (4.14 \times 10^{-15}\ eV \cdot s)(2.46 \times 10^{15}\ 1/s) - 4.7\ eV$

$K_{max} = 5.48\ eV$

(d) Determine the stopping potential for the emitted electron.

$K_{max} = hf - \phi$

$0 = (4.14 \times 10^{-15}\ eV \cdot s)(f) - 4.7\ eV$

$(4.14 \times 10^{-15}\ eV \cdot s)(f) = 4.7\ eV$

$f = 1.135 \times 10^{15}\ 1/s$

GO ON TO THE NEXT PAGE.