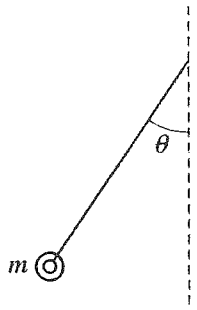
2003 AP® PHYSICS B FREE-RESPONSE QUESTIONS (Form B)

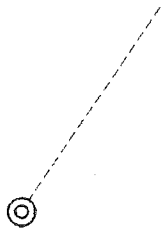
PHYSICS B
SECTION II
Time—90 minutes
7 Questions

Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested time is about 15 minutes for answering each of questions 1-4, and about 10 minutes for answering each of questions 5-7. The parts within a question may not have equal weight. Show all your work in the goldenrod booklet in the spaces provided after each part, NOT in this lavender insert.



1. (15 points)
An airplane accelerates uniformly from rest. A physicist passenger holds up a thin string of negligible mass to which she has tied her ring, which has a mass m. She notices that as the plane accelerates down the runway, the string makes an angle θ with the vertical as shown above.

(a) In the space below, draw a free-body diagram of the ring, showing and labeling all the forces present.



The plane reaches a takeoff speed of 65 m/s after accelerating for a total of 30 s.

(b) Determine the minimum length of the runway needed.

(c) Determine the angle θ that the string makes with the vertical during the acceleration of the plane before it leaves the ground.

(d) What additional information would be needed in order to estimate the mechanical energy of the airplane at the instant of takeoff? Explain your answer.

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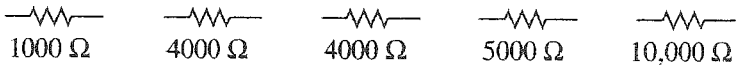
2. (15 points)
A student is asked to design a circuit to supply an electric motor with 1.0 mA of current at 3.0 V potential difference.

(a) Determine the power to be supplied to the motor.

(b) Determine the electrical energy to be supplied to the motor in 60 s.

(c) Operating as designed above, the motor can lift a 0.012 kg mass a distance of 1.0 m in 60 s at constant velocity. Determine the efficiency of the motor.

To operate the motor, the student has available only a 9.0 V battery to use as the power source and the following five resistors.



(d) In the space below, complete a schematic diagram of a circuit that shows how one or more of these resistors can be connected to the battery and motor so that 1.0 mA of current and 3.0 V of potential difference are supplied to the motor. Be sure to label each resistor in the circuit with the correct value of its resistance.

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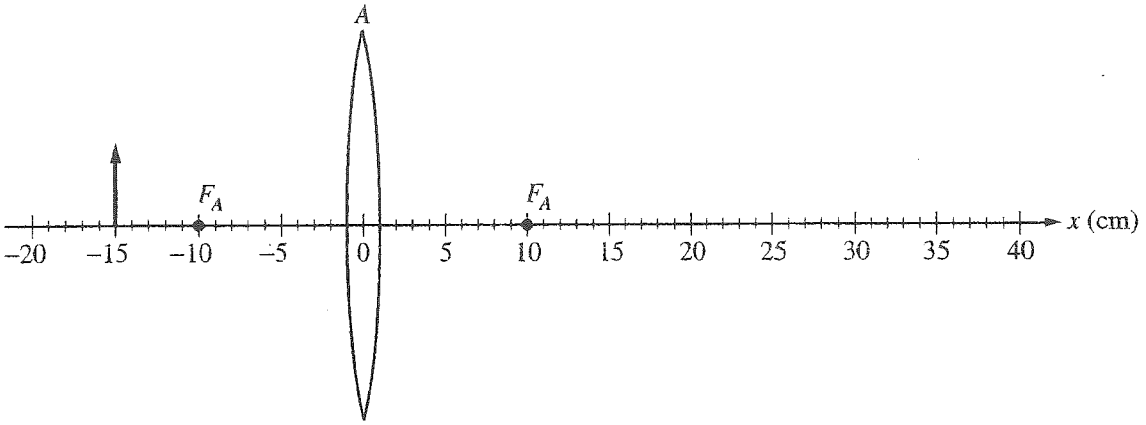
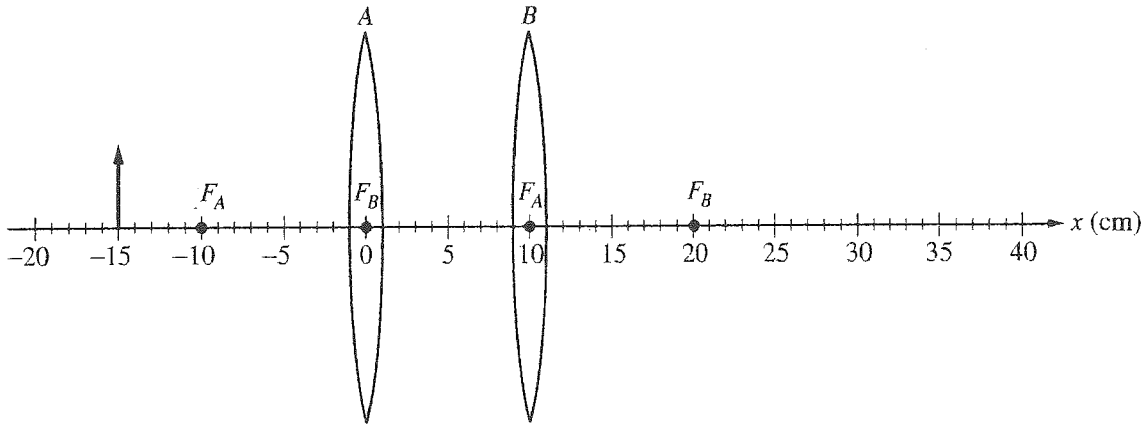


3. (15 points)
A thin convex lens A of focal length $f_A = 10$ cm is positioned on an x-axis as shown above. An object of height 5 cm, represented by the arrow, is positioned 15 cm to the left of lens A.

(a) On the figure above, draw necessary rays and sketch the image produced by lens A.

(b) Calculate the location of the image produced by lens A.

(c) Calculate the height of the image produced by lens A.



A second thin convex lens B of focal length $f_B = 10$ cm is now positioned 10 cm to the right of lens A, as shown above.

(d) Determine the location on the x-axis given above of the final image produced by the combination of lenses.

(e) Check the appropriate spaces below to indicate the characteristics of the final image produced by the combination of lenses.

____ inverted ____ larger than the original object

____ upright ____ smaller than the original object

Explain your answers.

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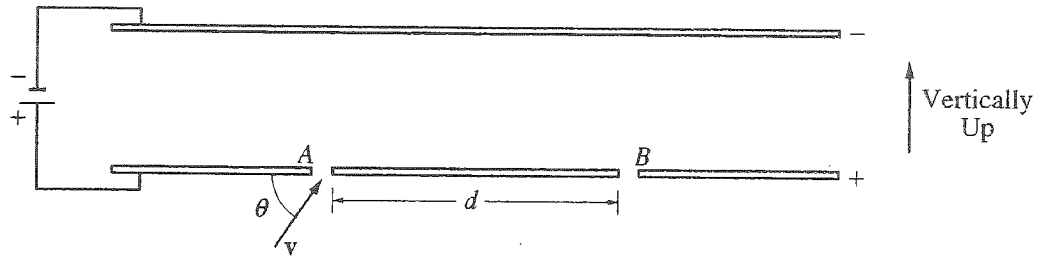

4. (15 points)

An electric field **E** exists in the region between the two electrically charged parallel plates shown above. A beam of electrons of mass m, charge q, and velocity **v** enters the region through a small hole at position A. The electrons exit the region between the plates through a small hole at position B. Express your answers to the following questions in terms of the quantities m, q, **E**, θ, and **v**. Ignore the effects of gravity.

(a) i. On the diagram of the parallel plates above, draw and label a vector to show the direction of the electric field **E** between the plates.

ii. On the following diagram, show the direction of the force(s) acting on an electron after it enters the region between the plates.

iii. On the diagram of the parallel plates above, show the trajectory of an electron that will exit through the small hole at position B.

(b) Determine the magnitude of the acceleration of an electron after it has entered the region between the parallel plates.

(c) Determine the total time that it takes the electrons to go from position A to position B.

(d) Determine the distance d between positions A and B.

(e) Now assume that the effects of gravity cannot be ignored in this problem. How would the distance d change for an electron entering the region at A and leaving at B? Explain your reasoning.

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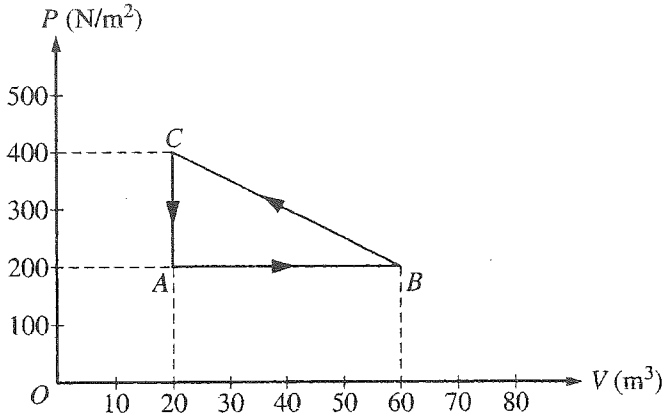

5. (10 points)
One mole of an ideal gas is taken around the cycle $A \rightarrow B \rightarrow C \rightarrow A$ as shown on the PV diagram above.

(a) Calculate the temperature of the gas at point A.

(b) Calculate the net work done on the gas during one complete cycle.

(c) i. Is heat added to or removed from the gas during one complete cycle?

____ added to the gas ____ removed from the gas

ii. Calculate the heat added to or removed from the gas during one complete cycle.

(d) After one complete cycle, is the internal energy of the gas greater, less, or the same as before?

____ greater ____ less ____ the same

Justify your answer.

(e) After one complete cycle, is the entropy of the gas greater, less, or the same as before?

____ greater ____ less ____ the same

Justify your answer.

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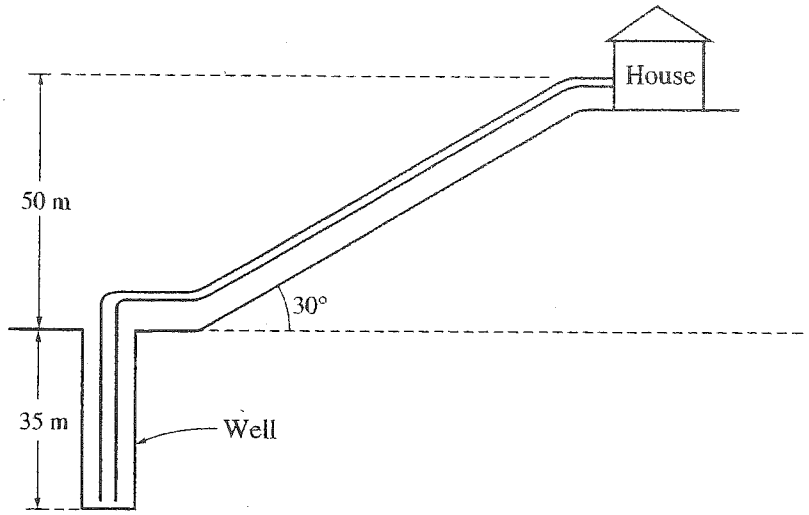

6. (10 points)

A pump, submerged at the bottom of a well that is 35 m deep, is used to pump water uphill to a house that is 50 m above the top of the well, as shown above. The density of water is 1,000 kg/m^3. All pressures are gauge pressures. Neglect the effects of friction, turbulence, and viscosity.

(a) Residents of the house use 0.35 m^3 of water per day. The day's pumping is completed in 2 hours during the day.

i. Calculate the minimum work required to pump the water used per day

ii. Calculate the minimum power rating of the pump.

(b) The average pressure the pump actually produces is 9.20×10^5 N/m^2. Within the well the water flows at 0.50 m/s and the pipe has a diameter of 3.0 cm. At the house the pipe diameter is 1.25 cm.

i. Calculate the flow velocity when a faucet in the house is open.

ii. Explain how you would calculate the minimum pressure at the faucet.

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7. (10 points)

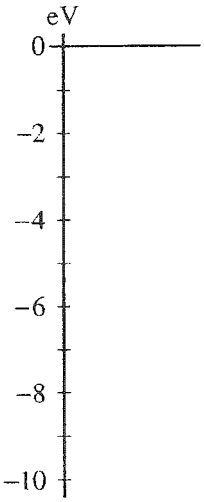
An experiment is performed on a sample of atoms known to have a ground state of −5.0 eV. The gas is illuminated with "white light" (400 - 700 nm). A spectrometer capable of analyzing radiation in this range is used to measure the radiation. The sample is observed to absorb light at only 400 nm. After the "white light" is turned off, the sample is observed to emit visible radiation of 400 nm and 600 nm.

(a) In the space below, determine the values of the energy levels and on the following scale sketch an energy-level diagram showing the energy values in eVs and the relative positions of:

i. the ground state

ii. the energy level to which the system was first excited

iii. one other energy level that the experiment suggests may exist



(b) What is the wavelength of any other radiation, if any, that might have been emitted in the experiment? Why was it not observed?

END OF EXAMINATION

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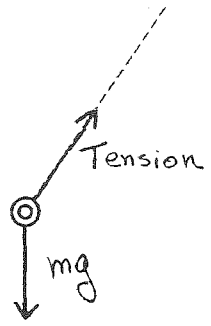
AP® PHYSICS B
2003 SCORING GUIDELINES (Form B)

Question 1

15 points total

Distribution of points

(a) 3 points



One point for each correctly drawn and appropriately labeled force — 2 points
For no incorrect forces — 1 point

(b) 5 points

For use of the correct equation relating acceleration and velocity — 1 point
$\mathbf{a} = \Delta \mathbf{v}/t$

For correctly calculating the magnitude of the acceleration — 1 point
$a = \dfrac{65 \text{ m/s} - 0}{30 \text{ s}} = \dfrac{13}{6} \text{ m/s}^2 \quad (\text{or } 2.17 \text{ m/s}^2)$

For using an equation relating distance and acceleration — 1 point
$d = d_0 + v_0 t + \dfrac{1}{2} a t^2 \quad \text{OR} \quad v^2 = v_0^2 + 2a\,\Delta d$

For substituting the calculated acceleration — 1 point
$d = \dfrac{1}{2}\left(\dfrac{13}{6} \text{ m/s}^2\right)(30 \text{ s})^2 \quad \text{OR} \quad d = (65 \text{ m/s})^2 \Big/ 2\left(\dfrac{13}{6} \text{ m/s}^2\right)$

For the correct answer — 1 point
$d = 975 \text{ m}$

Alternate solution — *Alternate points*

For use of the correct equation for average speed — *1 point*
$v_{avg} = (v_f + v_0)/2$

For correctly calculating the average speed — *1 point*
$v_{avg} = (65 \text{ m/s} + 0)/2 = 32.5 \text{ m/s}$

For using the appropriate equation relating distance to speed — *1 point*
$d = v_{avg} t$

For substituting v_{avg} into the equation — *1 point*
$d = (32.5 \text{ m/s})(30 \text{ s})$

For the correct answer — *1 point*
$d = 975 \text{ m}$

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Question 1 (continued)

Distribution of points

(c) 5 points

For using the correct x and y components of the tension
$T_x = T\sin\theta$ and $T_y = T\cos\theta$ — 1 point

For the correct equation relating the forces along the x-axis
$T\sin\theta = ma$ — 1 point

For the correct equation relating the forces along the y-axis
$T\cos\theta = mg$ — 1 point

For combining these two equations to eliminate the tension
$\tan\theta = a/g$
$\tan\theta = (2.17\ \text{m/s}^2)/(9.8\ \text{m/s}^2)$ — 1 point

For the correct answer
$\theta = 12.5°$ (or $12.2°$ using $g = 10\ \text{m/s}^2$) — 1 point

(d) 2 points

For indicating that one would need to know the mass of the airplane, with some attempt to give an explanation that relates to the mass. — 1 point

For a correct explanation — 1 point
Example: The kinetic energy is the only form of mechanical energy in this case. The velocity is known, but you need the mass to calculate the kinetic energy.

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Question 2

15 points total

Distribution of points

(a) 3 points

For correct equation for power — 1 point
$P = IV$

For the correct answer — 2 points
$P = 3$ mW (or 0.003 W)
One point was subtracted for incorrect or missing unit

(b) 3 points

For the correct equation for work or energy — 1 point
W (or energy) $= Pt$

For correct substitution of power from part (a) — 1 point
W (or energy) = (0.003 W)(60 s)

For the correct answer consistent with substitution of power from part (a), with correct units — 1 point
W (or energy) = 0.180 J

(c) 5 points

For the correct efficiency equation — 1 point
$\text{efficiency} = \dfrac{W_o}{W_i}$

For correct substitution of W_i (work done in 60 s) from part (b) — 1 point

For indicating that the work output W_o equals the change in gravitational potential energy — 1 point
$W_o = mg\Delta h$

For correct calculation of work output in 60 s — 1 point
$W_o = (0.012\text{ kg})(9.8\text{ m/s}^2)(1\text{ m}) = 0.12\text{ J}$ (or same answer using $g = 10\text{ m/s}^2$)

For correct calculation of efficiency consistent with calculation made in part (b). — 1 point
$\text{efficiency} = \dfrac{0.12\text{ J}}{0.18\text{ J}} = 66.7\%$ (or 65.3% using $g = 9.8\text{ m/s}^2$ and unrounded value for W_o)

Alternately, full credit could also be obtained by calculating efficiency using the ratio of power output to power input, in which case

$$\text{eff} = \frac{P_o}{P_i} = \frac{(0.012\text{ kg})(9.8\text{ m/s}^2)(1\text{ m})/60\text{ s}}{0.003\text{ W}} = 65.3\%$$ (or 66.7% using $g = 10\text{ m/s}^2$)

Similar point allocations were assigned using this method.

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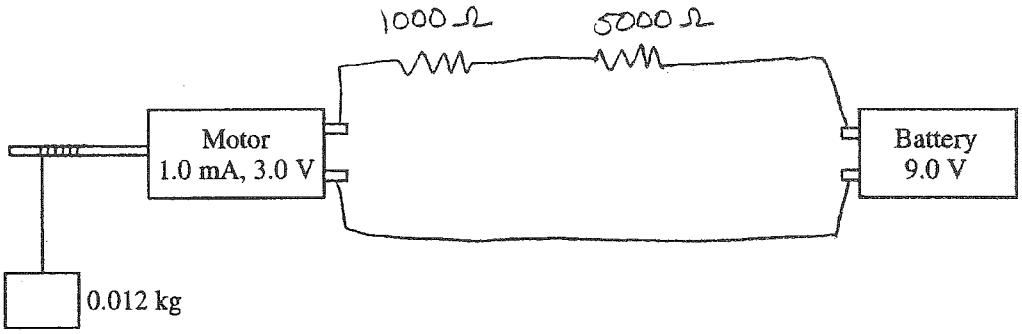
Question 2 (continued)

Distribution of points

(d) 4 points



For a calculation or notation that 6 V was the voltage drop across the resistor needed in order to reduce the voltage across the motor from 9 V to 3 V. 1 point

Series resistance needed to produce this voltage drop $= \frac{6.0\text{ V}}{1.0\text{ mA}} = 6000\ \Omega$

For the selection of a 1000 Ω and a 5000 Ω resistor 1 point

For the placement of the 1000 Ω and 5000 Ω resistor in series 1 point

For an appropriate sketch of the system with appropriate symbols and labels for resistors 1 point

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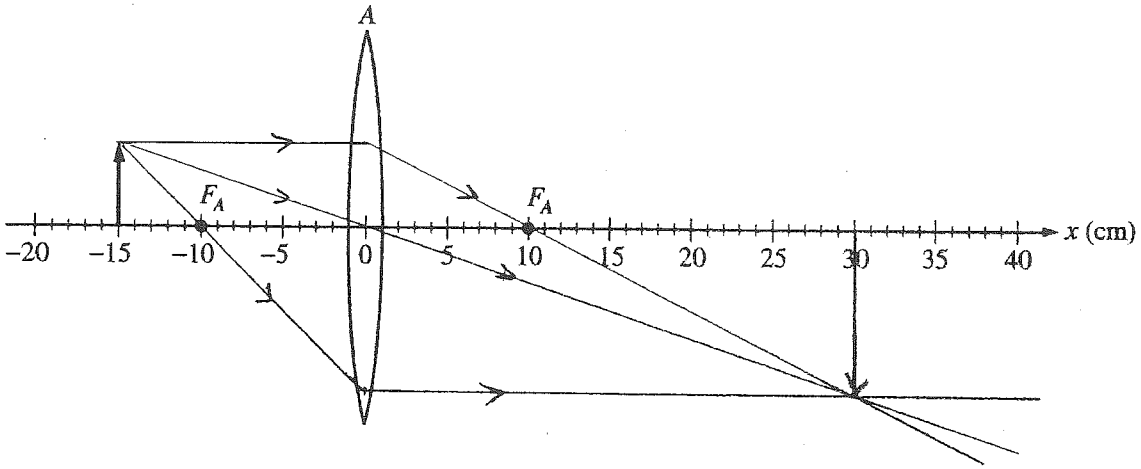
Question 3

15 points total

Distribution of points

(a) 4 points



One point for each correctly drawn ray passing through the lens (maximum of 2 points)	2 points
For the intersection of the rays occurring at 30 cm ± 5 cm	1 point
For correctly drawing the image	1 point

(b) 3 points

For using the lens equation — 1 point

$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$

For correct substitutions — 1 point

$$\frac{1}{15\text{ cm}}+\frac{1}{s_i}=\frac{1}{10\text{ cm}}$$

For answer consistent with substitutions — 1 point

$s_i = 30$ cm

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Question 3 (continued)

Distribution of points

(c) 3 points

For correct equation relating ratio of image to object heights to ratio of image to object distances — 1 point

$\frac{h_i}{h_o} = -\frac{s_i}{s_o}$ OR $\frac{|h_i|}{|h_o|} = \frac{|s_i|}{|s_o|}$

For consistent substitution — 1 point

$\frac{h_i}{5\text{ cm}} = -\frac{30\text{ cm}}{15\text{ cm}}$ OR $\frac{|h_i|}{5\text{ cm}} = \frac{30\text{ cm}}{15\text{ cm}}$

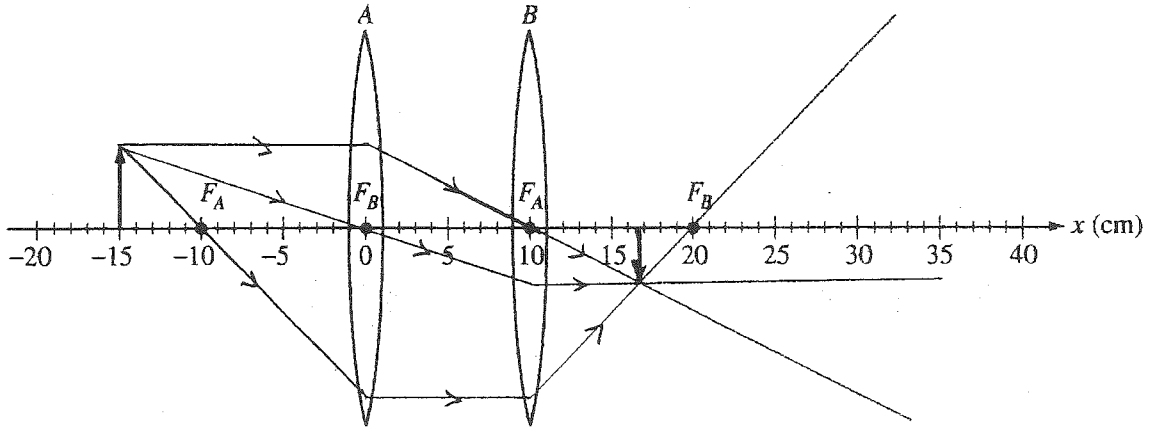
For answer consistent with substitutions — 1 point

$h_i = -10\text{ cm}$ OR $|h_i| = 10\text{ cm}$

Note: Since the minus sign in the first answer just indicates the image is inverted, it was not necessary for full credit, since the question could be interpreted as asking only for the actual size of the image.

(d) 3 points

Method 1: Ray diagram



One point for each correctly drawn ray passing through both lenses (maximum of 2 points) — 2 points

For the image location at 16.6 cm ± 3 cm — 1 point

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Question 3 (continued)

Distribution of points

Method 2: Mathematical approach using the lens equation

The image produced by the first lens becomes the virtual object for the second lens.
For the correct object distance to substitute into the lens equation for the second lens — 1 point

$s_o' = -(30\text{ cm} - 10\text{ cm}) = -20\text{ cm}$ (The minus indicates that the object is virtual.)

$$\frac{1}{s_o'} + \frac{1}{s_i'} = \frac{1}{f}$$

$$\frac{1}{-20\text{ cm}} + \frac{1}{s_i'} = \frac{1}{10\text{ cm}}$$

For the final image location with respect to the second lens — 1 point

$s_i' = 6.7\text{ cm}$

For the final image location on the scale shown — 1 point

$x_i = s_i' + 10\text{ cm} = 16.7\text{ cm}$

(e) 2 points

For checking spaces consistent with answer to part (d) and a correct explanation — 2 points
Explanation had to either refer to ray diagram, or, if a mathematical approach was used in part (d), had to be consistent with answer to part (d).
No points were awarded for students who checked spaces without any explanations.

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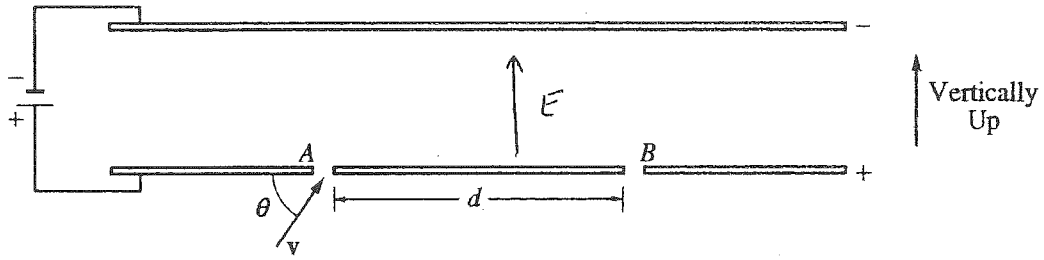
Question 4

15 points total **Distribution of points**

(a) 4 points

i. (1 point)

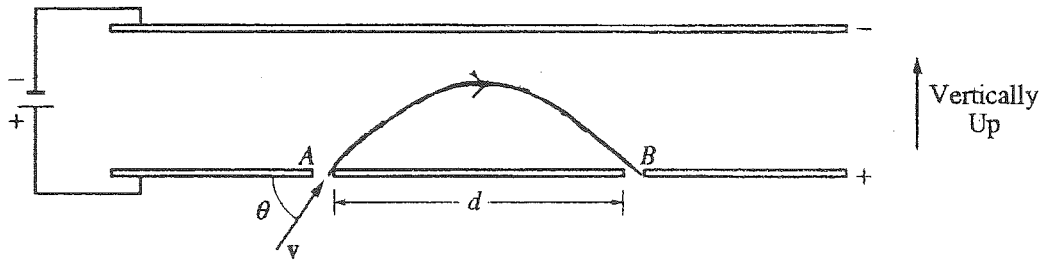


For a correctly drawn and labeled vector for E, directed vertically upward as shown in the diagram above — 1 point

ii. (1point)

For a vector directed vertically downward representing the force on an electron in the field, as shown in the diagram above — 1 point

iii. (2 points)



For a curved path from *A* to *B* — 1 point
For the path being symmetrical about the midpoint of *d* — 1 point

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Question 4 (continued)

Distribution of points

(b) 2 points

For using the equation that relates the force on a charged particle to the electric field — 1 point
$F = qE$
Equating this force to the net force in Newton's second law, $F_{net} = ma$
$qE = ma$
For the correct answer — 1 point
$a = \frac{qE}{m}$

(c) 4 points

In the electric field the electron is accelerated vertically downward.
$v_y(t) = v_{y_0} - at$, where v_{y_0} is the vertical component of the electron's velocity at point A
The time t_1 to reach maximum vertical displacement occurs when $v_y(t_1) = 0$. Solving for t_1:
$t_1 = \frac{v_{y_0}}{a}$
For using the correct component for v_{y_0} — 1 point
$v_{y_0} = v\sin\theta$
For indicating that the total time is twice t_1 — 1 point
$t_{tot} = 2t_1 = \frac{2v\sin\theta}{a}$
For correct substitution of a from part (b) — 1 point
$t_{tot} = \frac{2v\sin\theta}{\frac{qE}{m}}$
For the correct answer — 1 point
$t_{tot} = \frac{2mv\sin\theta}{qE}$

Alternately, the kinematic equations $v_y(t) = v\sin\theta - at$ OR $y(t) = y_0 + (v\sin\theta)t - \frac{1}{2}at^2$ could be used. When the electron reaches B at time t_{tot}, $v_y(t_{tot}) = -v\sin\theta$, and $y(t_{tot}) = y_0$. Substituting these values and the expression for a from part (b) into the respective equations above and solving either equation for t_{tot} gives the answer, $t_{tot} = \frac{2mv\sin\theta}{qE}$. This approach also received full credit with awarding of points similar to those above.

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Question 4 (continued)

Distribution of points

(d) 3 points

While the electron is in the field the horizontal component of its velocity is constant.

For the correct equation relating distance to time — 1 point

$d = v_x t_{tot}$

For using the correct component for v_x — 1 point

$v_x = v\cos\theta$

For correct substitutions for v_x and total time — 1 point

$$d = (v\cos\theta)\left(\frac{2mv\sin\theta}{qE}\right)$$

$$d = \frac{2mv^2\sin\theta\cos\theta}{qE}$$

(e) 2 points

For an indication that the distance d would be less — 1 point

For any reasonable explanation — 1 point

Example: The additional gravitational force downward would increase the downward acceleration thus decreasing the total time the electron would be in the field.

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Question 5

10 points total

Distribution of points

(a) 2 points

For a statement of the ideal gas law
$pV = nRT$
$(200\ \text{N/m}^2)(20\ \text{m}^3) = (1\ \text{mol})(8.32\ \text{J/(mol}\cdot\text{K)})T$ — 1 point

For the correct answer
$T = 481$ K — 1 point

(b) 2 points

For indicating that the work W done on the gas is equal to the area enclosed by the cycle or for $W = -p\Delta V$ — 1 point

W = area of triangle enclosed by cycle $= \frac{1}{2}bh = \frac{1}{2}(60\ \text{m}^3 - 20\ \text{m}^3)(400\ \text{N/m}^2 - 200\ \text{N/m}^2)$

For the correct answer
$W = 4000$ J — 1 point

(c) 2 points

i. (1 point)
For indicating that heat is removed from the gas during one complete cycle — 1 point

ii. (1 point)
Using the first law of thermodynamics
$\Delta U = Q + W$
Recognizing that $\Delta U = 0$ for a closed cycle
$Q = -W$
For the correct answer consistent with part (b) — 1 point
$Q = -4000$ J
Note: Since the question could be interpreted as asking for the magnitude of the heat added to or remove from, the minus sign was not necessary for full credit.

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AP PHYSICS B
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Question 5 (continued)

Distribution of points

(d) 2 points

For indicating that the internal energy of the gas after one cycle is the same as before — 1 point
For a reasonable justification — 1 point
Example: The internal energy of the gas is a function of the temperature and the temperature is the same at the beginning and end of each cycle.

(e) 2 points

For indicating that the entropy of the gas after one cycle is the same as before — 1 point
For a reasonable justification — 1 point
Example: The entropy is a function of the state of the gas, and after one complete cycle the gas has returned to its original state.

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Question 6

10 points total | **Distribution of points**

(a) 6 points

i. (3 points)

For correct use of the equation relating work to the distance raised — 1 point

$W = mgh$

For correct use of the equation relating mass to density and volume — 1 point

$m = \rho V$

Combining the two relationships

$W = \rho Vgh = (1000 \text{ kg/m}^3)(0.35 \text{ m}^3)(9.8 \text{ m/s}^2)(50 \text{ m} + 35 \text{ m})$

For the correct answer — 1 point

$W = 290{,}000$ J (or 300,000 J using $g = 10 \text{ m/s}^2$)

ii. (2 points)

For correct use of the equation relating power to work and time — 1 point

$$P = \frac{W}{\Delta t}$$

$$P = \frac{290{,}000 \text{ W}}{(2 \text{ hr})(60 \text{ min/hr})(60 \text{ s/min})}$$

For the correct answer — 1 point

$P = 40$ W (or 41 W using $g = 10 \text{ m/s}^2$)

(b) 4 points

i. (3 points)

For correct use of equation of continuity — 1 point

$v_1 A_1 = v_2 A_2$

For using the radius of each pipe as half the diameter — 1 point

Substituting the given values:

$$(0.50 \text{ m/s})\pi\left(\frac{0.03 \text{ m}}{2}\right)^2 = v_2\pi\left(\frac{0.0125 \text{ m}}{2}\right)^2$$

For the correct answer — 1 point

$v_2 = 2.88$ m/s

ii. (2 points)

For indicating the need to use Bernoulli's equation — 1 point

For an explanation of how to use Bernoulli's equation — 1 point

Example: $p_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = p_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

If the subscript 1 represents quantities at the pump and subscript 2 represent quantities at the house, then all the quantities are known except the pressure at the house, so the equation can be solved for this pressure.

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Question 7

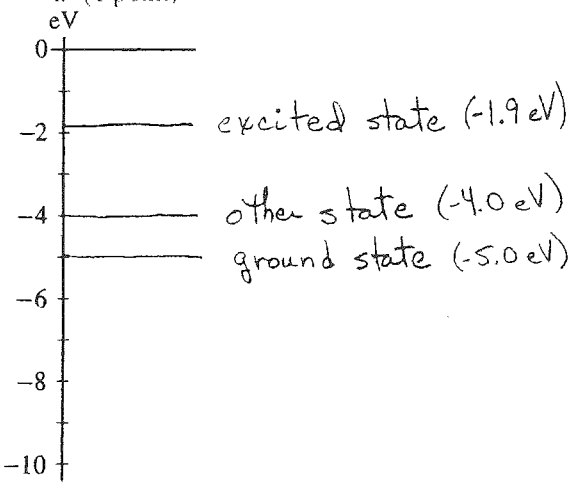
10 points total

Distribution of points

(a) 7 points

There were two possible "other" or intermediate energy levels asked for in part iii., so there were two possible correct energy level diagrams depending on which "other" energy level was used.

i. (1 point)



For drawing a horizontal line on the diagram at −5 eV — 1 point

ii. (3 points)

For correct equation(s) to calculate the energy of a 400 nm photon — 1 point

$E = hf$ and $f = c/\lambda$, so

$E = hc/\lambda$

$E = \left(1.24 \times 10^{3}\ \text{eV} \cdot \text{nm}\right)/\left(400\ \text{nm}\right)$

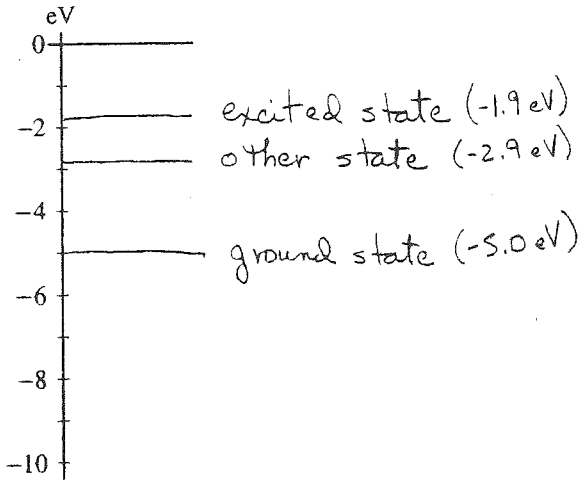
For the correct answer — 1 point

$E = 3.1$ eV

For drawing a horizontal line on the diagram at −1.9 eV to represent the first excited state, which is 3.1 eV above the ground state — 1 point

OR

iii. (3 points)



Using the same equations to calculate the energy of a 600 nm photon:

$$E = \frac{hc}{\lambda} = \frac{1.24 \times 10^{3}\ \text{eV} \cdot \text{nm}}{600\ \text{nm}}$$

For the correct answer — 1 point

$E = 2.1$ eV

This photon could represent a transition from the first excited state to an intermediate state, in which case the intermediate state is at $E = -4.0$ eV. Or the photon could represent a transition from an intermediate state to the ground state, in which case the intermediate state is at −2.9 eV. — 1 point

For drawing a horizontal line on the diagram at either −4.0 eV or −2.9 eV — 1 point

Note: Although the value of hc is given in the table of information, many students substituted h and c separately.

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Question 7 (continued)

Distribution of points

(b) 3 points

If the intermediate state is at −4.0 eV, then the transition from the intermediate state to the ground level at −5.0 eV is 1.0 eV. If the intermediate state is at −2.9 eV, then the transition from the first excited state at −1.9 eV to the intermediate state is 1.0 eV.

For calculation of 1.0 eV by subtraction of energy levels — 1 point

Since $E = \frac{hc}{\lambda}$

$$\lambda = \frac{hc}{E} = \frac{1.24 \times 10^{3}\ \text{eV} \cdot \text{nm}}{1.0\ \text{eV}}$$

For calculation of wavelength — 1 point

$\lambda = 1240$ nm

For statement that this wavelength is not seen because it is in the infrared or outside the range of wavelengths for "white light" given in the problem — 1 point

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2002 AP® PHYSICS B FREE-RESPONSE QUESTIONS

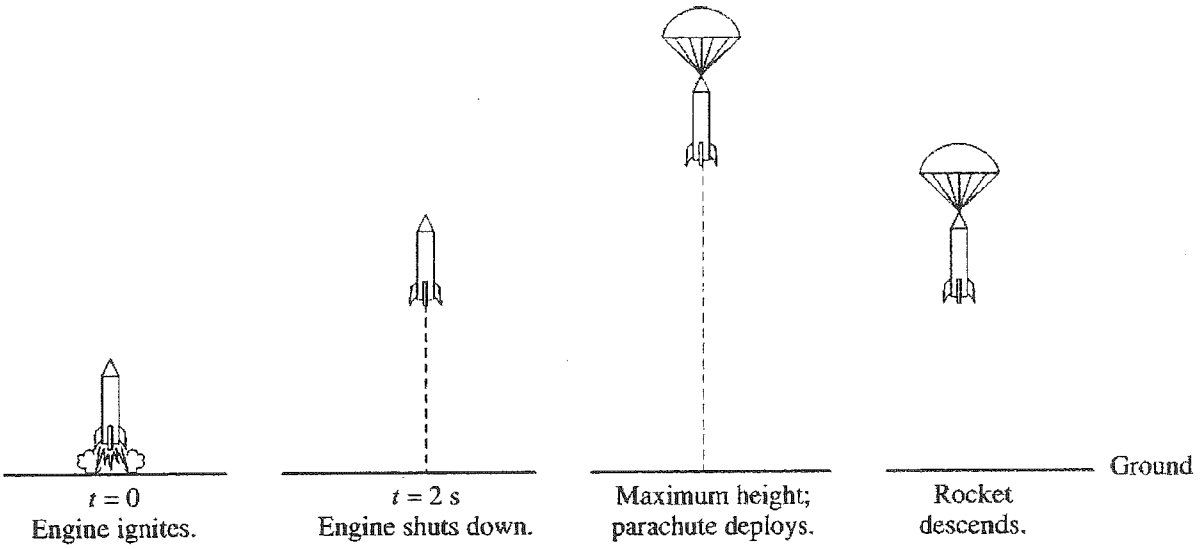
PHYSICS B

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 15 minutes for answering each of questions 1-4, and about 10 minutes for answering each of questions 5-7. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.



Note: Figures not drawn to scale.

1. (15 points)

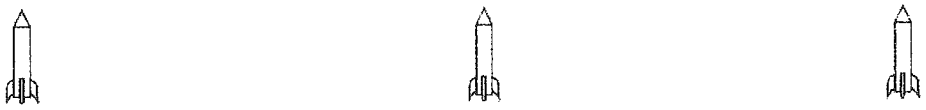
A model rocket of mass 0.250 kg is launched vertically with an engine that is ignited at time $t = 0$, as shown above. The engine provides an impulse of 20.0 N·s by firing for 2.0 s. Upon reaching its maximum height, the rocket deploys a parachute, and then descends vertically to the ground.

(a) On the figures below, draw and label a free-body diagram for the rocket during each of the following intervals.

i. While the engine is firing

ii. After the engine stops, but before the parachute is deployed

iii. After the parachute is deployed



(b) Determine the magnitude of the average acceleration of the rocket during the 2 s firing of the engine.

(c) What maximum height will the rocket reach?

(d) At what time after $t = 0$ will the maximum height be reached?

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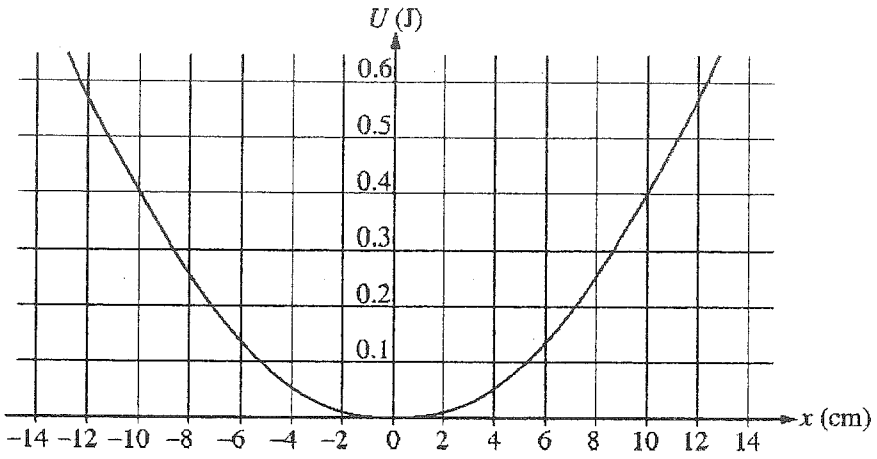


2. (15 points)

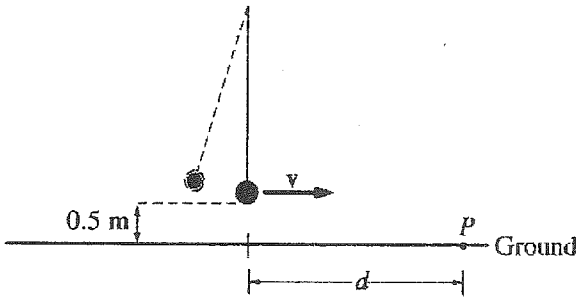
A 3.0 kg object subject to a restoring force F is undergoing simple harmonic motion with a small amplitude. The potential energy U of the object as a function of distance x from its equilibrium position is shown above. This particular object has a total energy E of 0.4 J.

(a) What is the object's potential energy when its displacement is +4 cm from its equilibrium position?

(b) What is the farthest the object moves along the x-axis in the positive direction? Explain your reasoning.

(c) Determine the object's kinetic energy when its displacement is −7 cm.

(d) What is the object's speed at $x = 0$?



Note: Figure not drawn to scale.

(e) Suppose the object undergoes this motion because it is the bob of a simple pendulum as shown above. If the object breaks loose from the string at the instant the pendulum reaches its lowest point and hits the ground at point P shown, what is the horizontal distance d that it travels?

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2002 AP® PHYSICS B FREE-RESPONSE QUESTIONS

3. (15 points)

Two lightbulbs, one rated 30 W at 120 V and another rated 40 W at 120 V, are arranged in two different circuits.

(a) The two bulbs are first connected in parallel to a 120 V source.

i. Determine the resistance of the bulb rated 30 W and the current in it when it is connected in this circuit.

ii. Determine the resistance of the bulb rated 40 W and the current in it when it is connected in this circuit.

(b) The bulbs are now connected in series with each other and a 120 V source.

i. Determine the resistance of the bulb rated 30 W and the current in it when it is connected in this circuit.

ii. Determine the resistance of the bulb rated 40 W and the current in it when it is connected in this circuit.

(c) In the spaces below, number the bulbs in each situation described, in order of their brightness. (1 = brightest, 4 = dimmest)

____30 W bulb in the parallel circuit

____40 W bulb in the parallel circuit

____30 W bulb in the series circuit

____40 W bulb in the series circuit

(d) Calculate the total power dissipated by the two bulbs in each of the following cases.

i. The parallel circuit

ii. The series circuit

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