



AP[®] Physics B 2003 Scoring Guidelines

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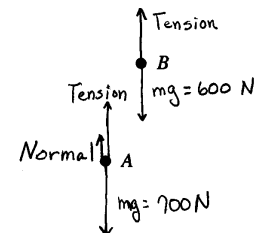
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Question 1

15 points total

Distribution
of points

(a) 3 points



- | | |
|--|---------|
| For a free body diagram that includes any one of the three forces on Student <i>A</i> (weight, normal, or tension) | 1 point |
| For correctly including the other two forces on Student <i>A</i> | 1 point |
| For a correct free-body diagram for Student <i>B</i> (including both weight and tension) | 1 point |
| One point was deducted for each extraneous vector, up to a maximum of the number of point already earned | |

(b) 3 points

- | | |
|--|---------|
| For equating the tension in the rope to the weight of Student <i>B</i> | 1 point |
| $T = m_B g$ | |
| For a correct expression for the sum of the forces on Student <i>A</i> | 1 point |
| $\Sigma F_A = T + N - m_A g = 0$ | |
| Eliminating T and solving for N | |
| $N = m_A g - m_B g$ | |
| $N = (70 \text{ kg} - 60 \text{ kg})(9.8 \text{ m/s}^2) = 686 \text{ N} - 588 \text{ N}$ | |
| For the correct answer | 1 point |
| $N = 98 \text{ N}$ (or 100 N using $g = 10 \text{ m/s}^2$) | |

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Question 1 (continued)

	Distribution of points
(c) 3 points	
For applying Newton's 2 nd law to Student <i>B</i> $\Sigma F_B = m_B a$	1 point
For a correct expression for the sum of the forces on Student <i>B</i> $\Sigma F_B = T - m_B g$	1 point
Solving for <i>T</i> and substituting: $T = m_B g + m_B a = 588 \text{ N} + (60 \text{ kg})(0.25 \text{ m/s}^2)$	
For the correct answer $T = 603 \text{ N}$ (or 615 N using $g = 10 \text{ m/s}^2$)	1 point
(d) 2 points	
For a correct response of "No"	1 point
For a reasonable explanation Example: To lift student <i>A</i> off the floor, the tension must be greater than the students' weight of $(70 \text{ kg})g$	1 point
An answer of "Yes" was acceptable IF the answer to (c) was greater than the weight of Student <i>A</i> AND the justification was consistent.	
(e) 3 points	
For applying Newton's 2 nd Law to Student <i>B</i> $\Sigma F_B = m_B a$	1 point
For a correct expression for the sum of the forces on Student <i>B</i> $\Sigma F_B = T - m_B g$	1 point
Solving for <i>a</i> $a = \frac{T}{m_b} - g$	
The minimum tension required to lift Student <i>A</i> is the student's weight Substituting: $a = \frac{686 \text{ N}}{60 \text{ kg}} - 9.8 \text{ m/s}^2$	
For the correct answer $a = 1.63 \text{ m/s}^2$ (or 1.67 m/s^2 using $g = 10 \text{ m/s}^2$)	1 point
For indicating correct units in parts (b), (c) and (e)	1 point

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Question 2

15 points total	Distribution of points
(a) 3 points	
For the correct formula for total capacitance in series $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$ OR $C_T = \frac{C_1 C_2}{C_1 + C_2}$	1 point
For correct substitution $\frac{1}{C_T} = \frac{1}{12 \mu\text{F}} + \frac{1}{6 \mu\text{F}}$ OR $C_T = \frac{(12 \mu\text{F})(6 \mu\text{F})}{12 \mu\text{F} + 6 \mu\text{F}}$	1 point
For the correct numerical answer $C_T = 4 \mu\text{F}$	1 point
(b) 3 points	
The capacitors are fully charged so current flows through the resistors but not the capacitors.	
For calculating the total resistance in series $R_T = R_1 + R_2 = 10 \Omega + 20 \Omega = 30 \Omega$	1 point
For use of correct form of Ohm's law $I = \frac{V}{R} = \frac{6 \text{ V}}{30 \Omega}$	1 point
For the correct answer $I = 0.2 \text{ A}$	1 point
(c) 3 points	
Potential difference between <i>A</i> and <i>B</i> is the voltage across the 20Ω resistor	
For a correct form of Ohm's law $V = IR$	1 point
For correct substitutions for <i>I</i> from part (b) and for <i>R</i> $V = (0.2 \text{ A})(20 \Omega)$	1 point
For the correct answer $V = 4 \text{ V}$	1 point
<u>Note:</u> 1 point was subtracted for indicating a wrong unit.	
<i>Alternately</i> , full credit could be obtained for finding the voltage across the 10Ω resistor and subtracting it from 6 V <u>or</u> for recognizing that the voltages across the 20Ω and 10Ω resistors would add to 6 V and be in a 2/1 ratio, and using this to obtain the correct answer.	

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Question 2 (continued)

	Distribution of points
(d) 4 points	
For using the correct formula to determine the charge $Q = CV$	1 point
For correct substitution of value of C from part (a)	1 point
For correct substitution of value of V from part (c) $Q = (4 \times 10^{-6} \text{ F})(4 \text{ V})$	1 point
For the correct answer $Q = 16 \times 10^{-6} \text{ C} = 16 \mu\text{C}$	1 point
 <i>Alternately</i> , full credit could be obtained by first determining the voltage across the $6 \mu\text{F}$ capacitor (which can be done one way by recognizing that the voltages across the two capacitors are in a 2/1 ratio and sum to 4 V) and substituting this value for V and the value for C of $6 \mu\text{F}$ into the equation $Q = CV$.	
(e) 2 points	
For checking the box “remains the same”	1 point
For a reasonable justification	1 point
Example: No current is flowing from A to P to B . Therefore breaking the circuit at point P does not affect the current in the outer loop, and therefore will not affect the potential difference between A and B (or across the 20Ω resistor).	

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Question 3

15 points total	Distribution of points
(a) 3 points	
For using the correct kinematic equation $x - x_0 = v_0 t + \frac{1}{2} a t^2$	1 point
For using Newton’s second law to determine the acceleration $F = ma$, so $a = F/m$	1 point
Both x_0 and v_0 equal zero. For the correct answer $x = Ft^2/2M$ (or $IDBt^2/2M$ using $F = IDB$)	1 point
(b) 3 points	
For an appropriate kinematic or momentum equation $v^2 = v_0^2 + 2a(x - x_0)$ (or other kinematic equations) OR $M \Delta v = Ft$	1 point
If an equation containing t was used, the expression from part (a) can be used to find t For indicating the correct distance $x - x_0 = L$	1 point
Substituting $v^2 = 0 + 2(F/M)L$ OR $Mv = F\sqrt{2(x - x_0)/a} = F\sqrt{2LM/F}$	
For the correct answer $v = \sqrt{2FL/M}$ (or $\sqrt{2IDBL/M}$ using $F = IDB$)	1 point
 <i>Alternately</i> , full credit was also awarded for using conservation of energy and directly relating the change in kinetic energy to the work done, i.e. $\frac{1}{2}mv^2 = FL$.	
(c) 3 points	
For indicating that the energy supplied equals the final kinetic energy $E = \frac{1}{2}mv^2$	1 point
For substituting the value of v determined in part (b) $E = \frac{1}{2}m\left(\sqrt{2FL/M}\right)^2$	1 point
For the correct answer $E = FL$ (or $IDBL$ using $F = IDB$)	1 point
 Full credit could also be earned for using the work-energy theorem and indicating that the work equals FL .	

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Question 3 (continued)

	Distribution of points
(d) 2 points	
For indicating that the magnetic field points out of the plane of the page, or in the +z-direction	1 point
For a correct explanation For example, referencing the right-hand rule or giving a verbal explanation of how it applies to the situation	1 point
(e) 4 points	
For using the expression for v determined in part (b) $v = \sqrt{2FL/M}$ OR $\sqrt{2IDBL/M}$	1 point
For an indication that $F = I\ell B$	1 point
For an indication that $\ell = D$	1 point
For correctly substituting the values of D and L , and obtaining the correct answer, with units $v = \sqrt{2(200 \text{ A})(0.1 \text{ m})(5 \text{ T})(10 \text{ m})/(0.5 \text{ kg})} = 63 \text{ m/s}$ (or 60 m/s with the correct number of significant figures)	1 point

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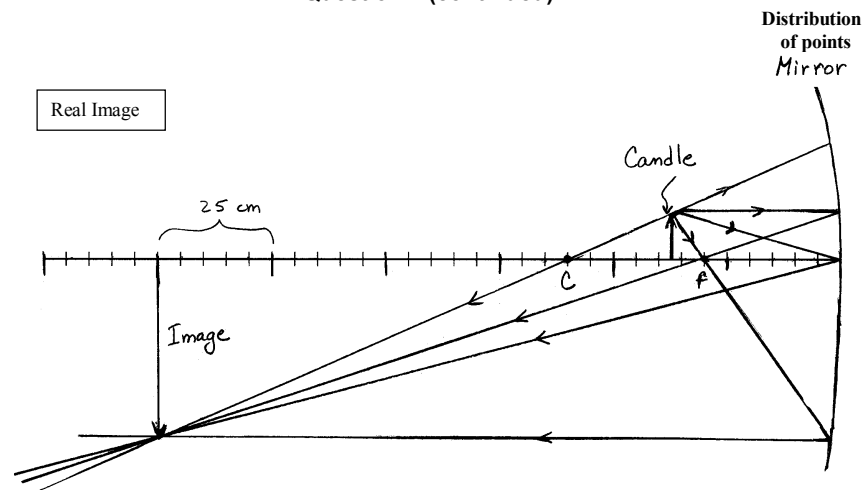
Question 4

15 points total		Distribution of points
Two possible situations fit the requirements: one forms a real image and the other a virtual image.		
(a) 3 points		
For placing the concave mirror on the optical bench		1 point
For a very good description of a procedure for locating the image For example: "Place the mirror at one end of the bench and the candle more than 30 cm from the mirror. Place the screen out beyond the candle and reposition it to get an image. Measure the height of the image. Reposition candle and screen until image height is four times object height."		2 points
No points were awarded if there was no reference to use of a mirror Only one point could be earned if student used a convex mirror instead of a concave mirror An imperfect or incomplete description of a useful procedure received 1 point		
(b) 2 points		
For checking a meter stick and/or ruler, plus everything else that they used in part (a)		1 point
For having no checks on items that they did not use in part (a)		1 point
If part (a) is blank or earned no points, then part (b) earned no points. If part (a) only earned 1 point, then part (b) could not earn more than 1 point. If everything or nothing is checked, then part (b) earned no points.		
(c) 6 points		

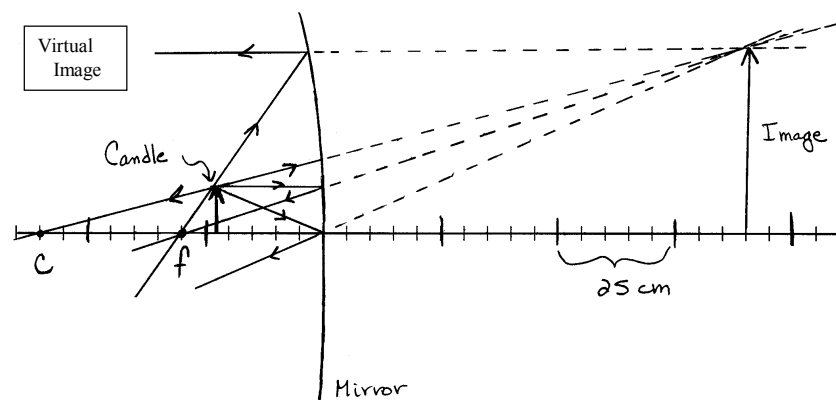
Note: Diagrams are drawn with curvature of mirror not to scale, in order to clearly illustrate the situation.

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Question 4 (continued)



(c) (continued)



For showing the concave mirror

1 point

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Question 4 (continued)

Distribution
of points

At least one ray from the candle is shown reflecting from the mirror
One point each for up to two correctly drawn principal rays
For showing the intersection of principal rays at a location such that the image distance is larger than the object distance

1 point
2 points
1 point

(This point was only awarded if the correct mirror and rays were present.)

For a correctly oriented image drawn at the intersection of the principal rays

1 point

(This point was only awarded if the fifth point was earned.)

No points were awarded if there was no curved mirror used in the diagram. The curved mirror could be indicated by drawing it curved, or labeling it, or showing rays consistent with a curved mirror.

Only one point was awarded for using a convex mirror instead of a concave mirror.

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Question 4 (continued)

	Distribution of points
(d) 3 points	
If the student drew at least one ray AND an image in part (c) that made it possible to interpret the drawing, then part (d) was graded on the basis of a literal interpretation of the drawing. All answers had to be consistent with the drawing.	
For correct indication of the image as real or virtual	1 point
For correct indication of the image as upright or inverted (the orientation must be clearly indicated by the image drawn)	1 point
For correct indication of the image as larger or smaller	1 point
If part (c) was blank or didn't have both an image and at least one ray, then part (d) was graded on the basis of the two possible CORRECT answers. The first two points above could be earned by indicating one of the correct pairs of answers: real & inverted OR virtual & upright. The last point could be earned only by indicating that the image is larger.	
(e) 1 point	
For an answer that said another type of image could be formed (e.g., virtual versus real and/or upright versus inverted) or some other answer (e.g., adding a lens to the concave-mirror system) that went beyond simply restating the premise.	1 point
If student gave the correct explanation and one or more wrong explanations, zero points were awarded.	

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Question 5

10 points total	Distribution of points
(a) 1 point	
For a correct calculation of the change in internal energy $U_a - U_c = \Delta U_{c \rightarrow a} = Q_{c \rightarrow a} + W_{c \rightarrow a}$ $\Delta U_{c \rightarrow a} = 685 \text{ J} - 120 \text{ J}$ $\Delta U_{c \rightarrow a} = 565 \text{ J}$	1 point
(b) 3 points	
i. (1 point) For correct choice of heat removed from the gas	1 point
ii. (2 points) For recognition that the change in internal energy is opposite in sign from part (a) answer $\Delta U_{a \rightarrow b \rightarrow c} = -\Delta U_{c \rightarrow a} = -565 \text{ J}$ Calculating the heat: $Q_{c \rightarrow d \rightarrow a} = \Delta U_{c \rightarrow d \rightarrow a} - W_{c \rightarrow d \rightarrow a}$ $Q_{c \rightarrow d \rightarrow a} = -565 \text{ J} - 75 \text{ J}$ For the correct answer $Q_{c \rightarrow d \rightarrow a} = -640 \text{ J}$	1 point
(c) 3 points	
The total work done is the sum of the work for the two sections of the path $W_{c \rightarrow d \rightarrow a} = W_{c \rightarrow d} + W_{d \rightarrow a}$ For some indication that the work done along path $c \rightarrow d$ is zero The work done along path $d \rightarrow a$ is the area under the curve $W_{c \rightarrow d \rightarrow a} = 0 - P \Delta V$ For correct substitution $W_{c \rightarrow d \rightarrow a} = -(6.0 \times 10^5 \text{ Pa})(1.0 \times 10^{-3} \text{ m}^3 - 0.75 \times 10^{-3} \text{ m}^3)$ For the correct answer $W_{c \rightarrow d \rightarrow a} = -150 \text{ J}$	1 point
(d) 3 points	
For correct choice of heat added to the gas For a complete explanation that references the first law Example: Since $\Delta U_{c \rightarrow d \rightarrow a}$ is positive (i.e. 565 J) and work is done (i.e. -150 J), Q must be positive. An incomplete argument with correct relevant assertions and no mistakes earned 1 point. An incomplete argument with irrelevant or incorrect assertions earned no points.	1 point 2 points

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Question 6

10 points total	Distribution of points
(a) 2 points	
For any correct indication of the relation between pressure difference and depth in either part (a) or part (b) $P - P_0 = \rho gh$ Gauge pressure is equal to the pressure difference from the surface to the given depth $P_{\text{gauge}} = \left(1.025 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right) \left(9.8 \frac{\text{m}}{\text{s}^2}\right) (35 \text{ m})$ For the correct answer $P_{\text{gauge}} = 3.5 \times 10^5 \text{ Pa}.$	1 point 1 point
(b) 1 point	
For any indication, in words or with a calculation, that absolute pressure is the gauge pressure calculated above plus atmospheric pressure $P_{\text{abs}} = P_{\text{gauge}} + P_{\text{atm}} = 3.5 \times 10^5 \text{ Pa} + 1.0 \times 10^5 \text{ Pa} = 4.5 \times 10^5 \text{ Pa}$	1 point
(c) 5 points	
For any indication that the plate is in equilibrium $T + F_{\text{buoy}} - mg = 0$ (other statements such as $a = 0$ or $\Sigma F = 0$ also acceptable)	1 point
For substituting correct values into the relations for the mass or weight of the plate $m = \rho V = \left(2.7 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right) (1.0 \times 2.0 \times 0.03 \text{ m}^3) = 1.6 \times 10^2 \text{ kg}$ OR $mg = \rho Vg = 1.6 \times 10^3 \text{ N}$	1 point
For indicating the existence of an <u>upward</u> buoyant force, using a diagram, an arrow, or an equation in which the buoyant force has the opposite sign of the plate's weight	1 point
For substituting the density of the <u>fluid</u> into the appropriate relation for the mass of the displaced fluid or the buoyant force $F_{\text{buoy}} = \rho_{\text{fluid}} Vg = \left(1.025 \times 10^3 \frac{\text{kg}}{\text{m}^3}\right) (0.06 \text{ m}^3) \left(9.8 \frac{\text{m}}{\text{s}^2}\right) = (61.5 \text{ kg}) \left(9.8 \frac{\text{m}}{\text{s}^2}\right) = 6.0 \times 10^2 \text{ N}$ Solving for the tension and substituting: $T = mg - F_{\text{buoy}} = 1.6 \times 10^3 \text{ N} - 6.0 \times 10^2 \text{ N}$ For the correct answer $T = 1.0 \times 10^3 \text{ N}$ (or $9.9 \times 10^2 \text{ N}$ using $g = 10 \text{ m/s}^2$)	 1 point
Notes: Full credit was awarded for a correct answer with relevant work that did not explicitly show all of the steps above. One point was deducted for one incorrect numerical calculation with all other work correct.	

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Question 6 (continued)

	Distribution of points
(d) 2 points	
For checking "increase" For a valid explanation Example: In (c) the net force is zero, but to accelerate there must be a non-zero net force. Since the weight and the buoyant force are fixed, the tension must be greater to have a non-zero net force upward.	 1 point 1 point
Note: A valid explanation is not one that merely restates the conclusion that the tension increases when the plate accelerates. It must go further by referring to Newton's second law and the fact that the net force must be upward when the plate accelerates upward.	
<i>Alternate interpretation</i> Some students clearly interpreted the question to be referring to a change in the tension over time, rather than a change with respect to the situation in part (c). If the student checked "remains the same" <u>and</u> gave an explanation stating that a constant acceleration implies a constant force, they were awarded 2 points.	

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Question 7

10 points total

(a) 2 points

For any indication of conservation of energy

$\frac{1}{2}m_{\text{He}}v_0^2 = \frac{1}{2}m_{\text{He}}v_1^2 + \frac{1}{2}m_{\text{Ne}}v_2^2 + (E_2' - E_2)$, where v_0 is the minimum speed of the helium atom before the collision, and v_1 and v_2 are the speeds of the helium and neon atoms after the collision, respectively

The point is awarded for any of the following assumptions for v_1 and v_2 :

- $v_1 = 0$ and $v_2 = 0$
- $v_1 = 0$, $v_2 \neq 0$
- $v_1 \neq 0$, $v_2 \neq 0$, and $v_1 \neq v_2$
- $v_1 = v_2 \neq 0$

For any indication of conservation of momentum

$$m_{\text{He}}v_0 = \pm m_{\text{He}}v_1 + m_{\text{Ne}}v_2$$

The point is awarded for recognizing conservation of momentum, with any of the following assumptions for v_1 and v_2 :

- $v_1 = 0$, $v_2 \neq 0$
- $v_1 \neq 0$, $v_2 \neq 0$, and $v_1 \neq v_2$
- $v_1 = v_2 \neq 0$

To earn both points, assumptions for the two equations must be the same. The value of the final answer depends on the assumption used.

(b) 2 points

Using the expression for the DeBroglie wavelength

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

For correctly substituting the answer obtained for v_0 from part (a)

For correctly substituting m_{He} , including correct units

Students did not have to show conversions of units that would be needed to complete the calculation correctly.

Both points were awarded if a value for momentum calculated in part (a) was substituted directly.

**Distribution
of points**

1 point

1 point

1 point

1 point

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Question 7 (continued)

**Distribution
of points**

(c) 3 points

Using the equation relating energy and frequency for a photon:

$$f = E/h$$

For substituting the correct difference in neon energy levels for the energy of the photon

$$f = \frac{20.66 \text{ eV} - 18.70 \text{ eV}}{4.14 \times 10^{-15} \text{ eV} \cdot \text{s}} = 4.73 \times 10^{14} \text{ Hz}$$

Using the equation relating wavelength and frequency

$$\lambda = c/f$$

For substituting the calculated value of f and the correct value for the speed of light into the above equation

$$\lambda = (3 \times 10^8 \text{ m/s}) / (4.73 \times 10^{14} \text{ Hz})$$

For the correct answer, including units

$$\lambda = 634 \text{ nm (or } 633 \text{ nm if values are substituted directly into the equation } \lambda = hc/E, \text{ using the value of } hc \text{ in eV} \cdot \text{nm from the Table of Information)}$$

Alternate solution

For using the equation relating momentum and energy of a photon, including the correct difference in neon energy levels

$$p = E/c = (E_2' - E_1')/c$$

$$p = (20.66 \text{ eV} - 18.70 \text{ eV}) / (3 \times 10^8 \text{ m/s}) = 6.53 \times 10^{-9} \text{ eV} \cdot \text{s/m}$$

For using the equation relating wavelength and momentum, and substituting the value of momentum obtained above

$$\lambda = h/p = (4.14 \times 10^{-15} \text{ eV} \cdot \text{s}) / (6.53 \times 10^{-9} \text{ eV} \cdot \text{s/m})$$

For the correct answer, including units

$$\lambda = 634 \text{ nm (or } 633 \text{ nm as explained above)}$$

(d) 3 points

The total energy per pulse equals the power times the duration of the pulse

$$E = P \Delta t$$

For substituting the values into the equation above

$$E = (0.50 \text{ W})(20 \times 10^{-3} \text{ s}) = 1 \times 10^{-2} \text{ J} = 6.25 \times 10^{16} \text{ eV}$$

The number of photons equals the total energy per pulse divided by the energy per photon

$$N = E / (E_2' - E_1')$$

For correctly substituting the values of E_2' and E_1' into the equation above

$$N = 6.25 \times 10^{16} \text{ eV} / (20.66 \text{ eV} - 18.70 \text{ eV})$$

For the correct answer

$$N = 3.19 \times 10^{16}$$

1 point

1 point

1 point

*Alternate points
1 point*

1 point

1 point

1 point

1 point