AP® Physics B
2003 Scoring Guidelines

These materials were produced by Educational Testing Service® (ETS®), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association whose mission is to prepare, inspire, and connect students to college and opportunity. Founded in 1900, the association is composed of more than 4,300 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT®, and the Advanced Placement Program® (AP®). The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.

For further information, visit www.collegeboard.com

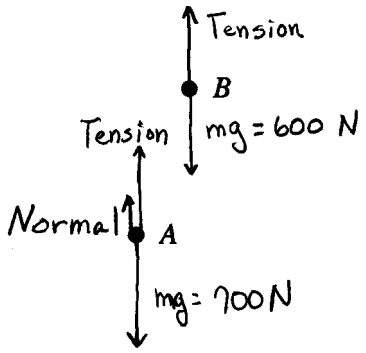
For the College Board's online home for AP professionals, visit AP Central at apcentral.collegeboard.com.

AP® PHYSICS B
2003 SCORING GUIDELINES

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 *A* (weight, normal, or tension) 1 point

For correctly including the other two forces on Student *A* 1 point

For a correct free-body diagram for Student *B* (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 *B* 1 point

$T = m_B g$

For a correct expression for the sum of the forces on Student *A* 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 $g = 10\ \text{m/s}^2$)

Question 1 (continued)

Distribution of points

(c) 3 points

For applying Newton's 2nd law to Student *B* — 1 point
$\Sigma F_B = m_B a$

For a correct expression for the sum of the forces on Student *B* — 1 point
$\Sigma F_B = T - m_B g$

Solving for *T* 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 — 1 point
$T = 603 \text{ N}$ (or 615 N using $g = 10 \text{ m/s}^2$)

(d) 2 points

For a correct response of "No" — 1 point
For a reasonable explanation — 1 point
Example: To lift student *A* off the floor, the tension must be greater than the students' weight of (70 kg)*g*

An answer of "Yes" was acceptable IF the answer to (c) was greater than the weight of Student *A* AND the justification was consistent.

(e) 3 points

For applying Newton's 2nd Law to Student *B* — 1 point
$\Sigma F_B = m_B a$

For a correct expression for the sum of the forces on Student *B* — 1 point
$\Sigma F_B = T - m_B g$

Solving for *a*
$a = \dfrac{T}{m_b} - g$

The minimum tension required to lift Student *A* is the student's weight
Substituting:
$a = \dfrac{686 \text{ N}}{60 \text{ kg}} - 9.8 \text{ m/s}^2$

For the correct answer — 1 point
$a = 1.63 \text{ m/s}^2$ (or 1.67 m/s^2 using $g = 10 \text{ m/s}^2$)

For indicating correct units in parts (b), (c) and (e) — 1 point

AP® PHYSICS B
2003 SCORING GUIDELINES

Question 2

15 points total **Distribution of points**

(a) 3 points

For the correct formula for total capacitance in series 1 point

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$ OR $C_T = \frac{C_1 C_2}{C_1 + C_2}$

For correct substitution 1 point

$\frac{1}{C_T} = \frac{1}{12\,\mu\text{F}} + \frac{1}{6\,\mu\text{F}}$ OR $C_T = \frac{(12\,\mu\text{F})(6\,\mu\text{F})}{12\,\mu\text{F} + 6\,\mu\text{F}}$

For the correct numerical answer 1 point

$C_T = 4\,\mu\text{F}$

(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 1 point

$R_T = R_1 + R_2 = 10\,\Omega + 20\,\Omega = 30\,\Omega$

For use of correct form of Ohm's law 1 point

$I = \frac{V}{R} = \frac{6\text{ V}}{30\,\Omega}$

For the correct answer 1 point

$I = 0.2$ A

(c) 3 points

Potential difference between A and B is the voltage across the 20 Ω resistor

For a correct form of Ohm's law 1 point

$V = IR$

For correct substitutions for I from part (b) and for R 1 point

$V = (0.2\text{ A})(20\,\Omega)$

For the correct answer 1 point

$V = 4$ V

Note: 1 point was subtracted for indicating a wrong unit.

Alternately, full credit could be obtained for finding the voltage across the 10 Ω resistor and subtracting it from 6 V *or* for recognizing that the voltages across the 20 Ω and 10 Ω resistors would add to 6 V and be in a 2/1 ratio, and using this to obtain the correct answer.

Question 2 (continued)

Distribution of points

(d) 4 points

For using the correct formula to determine the charge — 1 point
$Q = CV$

For correct substitution of value of C from part (a) — 1 point

For correct substitution of value of V from part (c) — 1 point
$Q = \left(4 \times 10^{-6}\ \text{F}\right)\left(4\ \text{V}\right)$

For the correct answer — 1 point
$Q = 16 \times 10^{-6}\ \text{C} = 16\ \mu\text{C}$

Alternately, full credit could be obtained by first determining the voltage across the 6 μF 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 μF 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 20 Ω resistor).

AP® PHYSICS B
2003 SCORING GUIDELINES

Question 3

15 points total **Distribution of points**

(a) 3 points

For using the correct kinematic equation 1 point

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

For using Newton's second law to determine the acceleration 1 point

$F = ma$, so $a = F/m$

Both x_0 and v_0 equal zero.

For the correct answer 1 point

$x = Ft^2/2M$ (or $IDBt^2/2M$ using $F = IDB$)

(b) 3 points

For an appropriate kinematic or momentum equation 1 point

$v^2 = v_0^2 + 2a(x - x_0)$ (or other kinematic equations) OR $M\,\Delta v = Ft$

If an equation containing *t* was used, the expression from part (a) can be used to find *t*

For indicating the correct distance 1 point

$x - x_0 = L$

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 1 point

$v = \sqrt{2FL/M}$ (or $\sqrt{2IDBL/M}$ using $F = IDB$)

Alternately, 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 1 point

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

For substituting the value of v determined in part (b) 1 point

$E = \frac{1}{2}m\left(\sqrt{2FL/M}\right)^2$

For the correct answer 1 point

$E = FL$ (or $IDBL$ using $F = IDB$)

Full credit could also be earned for using the work-energy theorem and indicating that the work equals *FL*

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 — 1 point
For example, referencing the right-hand rule or giving a verbal explanation of how it applies to the situation

(e) 4 points

For using the expression for v determined in part (b) — 1 point
$v = \sqrt{2FL/M}$ OR $\sqrt{2IDBL/M}$

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 — 1 point
$v = \sqrt{2(200\text{ A})(0.1\text{ m})(5\text{ T})(10\text{ m})/(0.5\text{ kg})} = 63\text{ m/s}$
(or 60 m/s with the correct number of significant figures)

AP® PHYSICS B
2003 SCORING GUIDELINES

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 2 points
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."

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

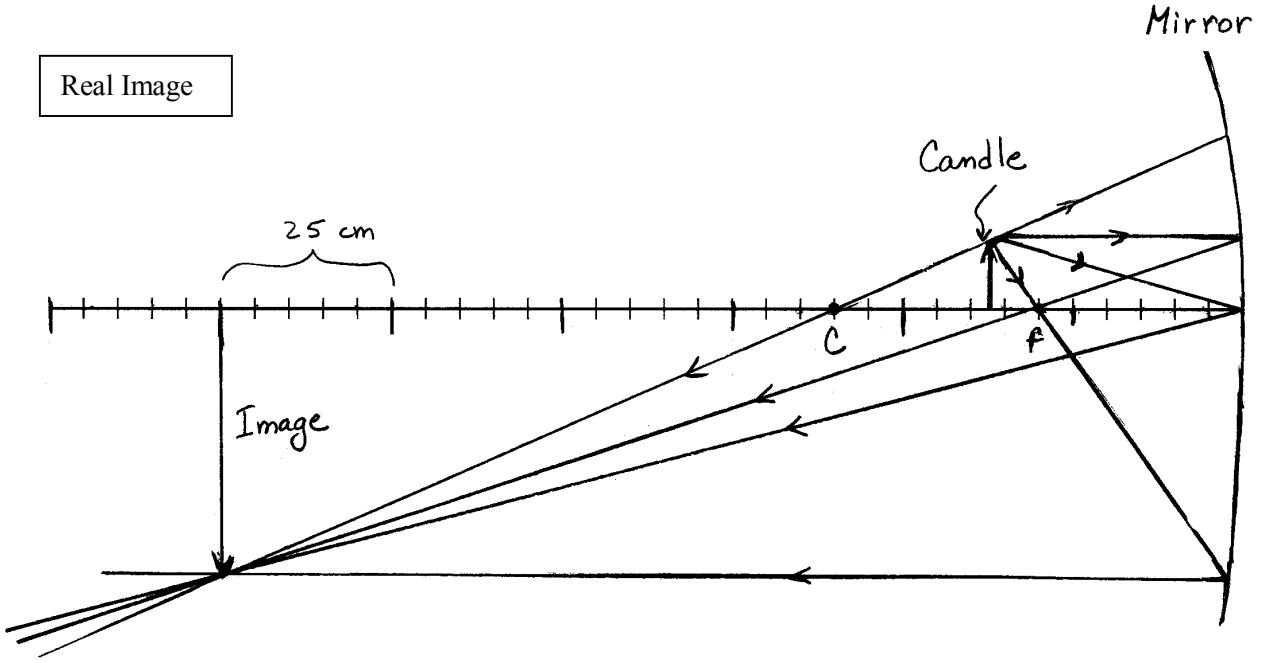
If part (a) is blank or earned no points, then part (b) earned no points.
If part (a) only earned 1 point, then part (b) could not earn more than 1 point.
If everything or nothing is checked, then part (b) earned no points.

(c) 6 points

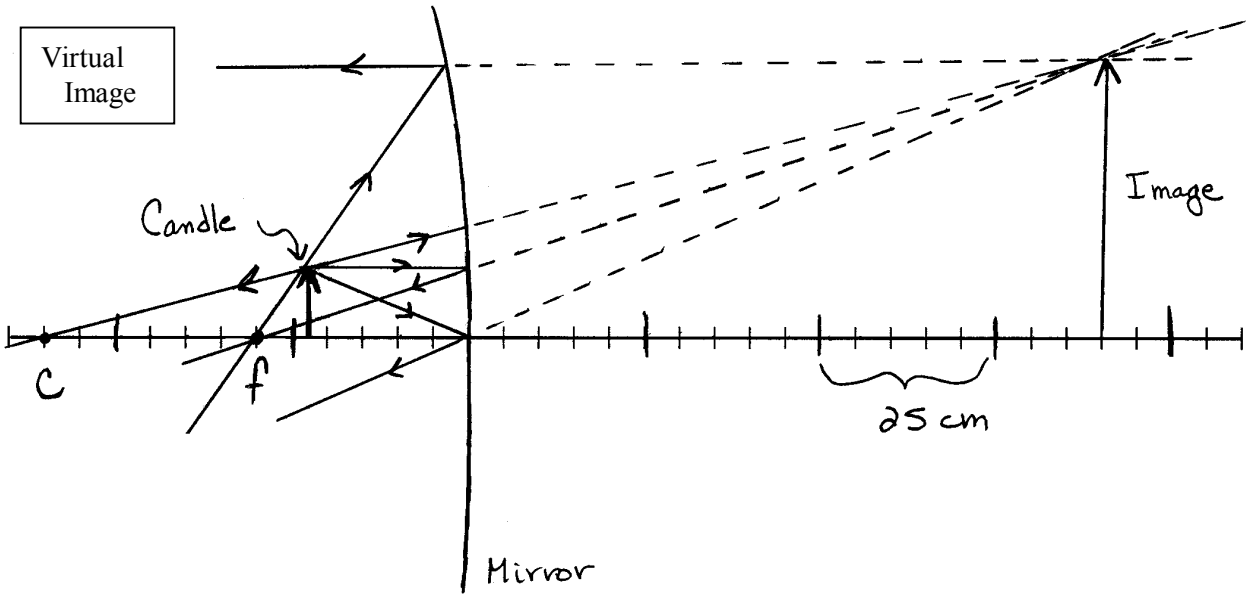
Note: Diagrams are drawn with curvature of mirror not to scale, in order to clearly illustrate the situation.

Question 4 (continued)

Distribution of points



(c) (continued)



For showing the concave mirror 1 point

Question 4 (continued)

	Distribution of points
At least one ray from the candle is shown reflecting from the mirror	1 point
One point each for up to two correctly drawn principal rays	2 points
For showing the intersection of principal rays at a location such that the image distance is larger than the object distance (This point was only awarded if the correct mirror and rays were present.)	1 point
For a correctly oriented image drawn at the intersection of the principal rays (This point was only awarded if the fifth point was earned.)	1 point

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.

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 of 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.

AP® PHYSICS B
2003 SCORING GUIDELINES

Question 5

10 points total **Distribution of points**

(a) 1 point

For a correct calculation of the change in internal energy 1 point

$U_a - U_c = \Delta U_{c\to a} = Q_{c\to a} + W_{c\to a}$

$\Delta U_{c\to a} = 685\text{ J} - 120\text{ J}$

$\Delta U_{c\to a} = 565\text{ J}$

(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 1 point

$\Delta U_{a\to b\to c} = -\Delta U_{c\to a} = -565\text{ J}$

Calculating the heat:

$Q_{c\to d\to a} = \Delta U_{c\to d\to a} - W_{c\to d\to a}$

$Q_{c\to d\to a} = -565\text{ J} - 75\text{ J}$

For the correct answer 1 point

$Q_{c\to d\to a} = -640\text{ J}$

(c) 3 points

The total work done is the sum of the work for the two sections of the path

$W_{c\to d\to a} = W_{c\to d} + W_{d\to a}$

For some indication that the work done along path $c \to d$ is zero 1 point

The work done along path $d \to a$ is the area under the curve

$W_{c\to d\to a} = 0 - P\,\Delta V$

For correct substitution 1 point

$W_{c\to d\to a} = -(6.0\times10^5\text{ Pa})(1.0\times10^{-3}\text{ m}^3 - 0.75\times10^{-3}\text{ m}^3)$

For the correct answer 1 point

$W_{c\to d\to a} = -150\text{ J}$

(d) 3 points

For correct choice of heat added to the gas 1 point

For a complete explanation that references the first law 2 points

Example: Since $\Delta U_{c\to d\to a}$ 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.

AP® PHYSICS B
2003 SCORING GUIDELINES

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) 1 point

$P - P_0 = \rho g h$

Gauge pressure is equal to the pressure difference from the surface to the given depth

$P_{\text{gauge}} = \left(1.025\times10^3 \ \frac{\text{kg}}{\text{m}^3}\right)\left(9.8 \ \frac{\text{m}}{\text{s}^2}\right)(35 \text{ m})$

For the correct answer 1 point

$P_{gauge} = 3.5\times10^5$ Pa.

(b) 1 point

For any indication, in words or with a calculation, that absolute pressure is the gauge pressure calculated above plus atmospheric pressure 1 point

$P_{\text{abs}} = P_{\text{gauge}} + P_{\text{atm}} = 3.5\times10^5 \text{ Pa} + 1.0\times10^5 \text{ Pa} = 4.5\times10^5 \text{ Pa}$

(c) 5 points

For any indication that the plate is in equilibrium 1 point

$T + F_{buoy} - mg = 0$ (other statements such as $a = 0$ or $\Sigma F = 0$ also acceptable)

For substituting correct values into the relations for the mass or weight of the plate 1 point

$m = \rho V = \left(2.7\times10^3 \ \frac{\text{kg}}{\text{m}^3}\right)\left(1.0\times2.0\times0.03 \text{ m}^3\right) = 1.6\times10^2 \text{ kg}$ OR $mg = \rho V g = 1.6\times10^3 \text{ N}$

For indicating the existence of an upward 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 fluid into the appropriate relation for the mass of the displaced fluid or the buoyant force 1 point

$F_{bouy} = \rho_{\text{fluid}} V g = \left(1.025\times10^3 \ \frac{\text{kg}}{\text{m}^3}\right)\left(0.06 \text{ m}^3\right)\left(9.8 \ \frac{\text{m}}{\text{s}^2}\right) = (61.5 \text{ kg})\left(9.8 \ \frac{\text{m}}{\text{s}^2}\right) = 6.0\times10^2 \text{ N}$

Solving for the tension and substituting:

$T = mg - F_{bouy} = 1.6\times10^3 \text{ N} - 6.0\times10^2 \text{ N}$

For the correct answer 1 point

$T = 1.0\times10^3$ N (or 9.9×10^2 N using $g = 10 \text{ m/s}^2$)

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.

Question 6 (continued)

Distribution of points

(d) 2 points

For checking "increase" 1 point
For a valid explanation 1 point
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.

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.

Alternate interpretation
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" and gave an explanation stating that a constant acceleration implies a constant force, they were awarded 2 points.

AP® PHYSICS B
2003 SCORING GUIDELINES

Question 7

10 points total **Distribution of points**

(a) 2 points

For any indication of conservation of energy 1 point

$\frac{1}{2}m_{\text{He}}v_0^{\,2} = \frac{1}{2}m_{\text{He}}v_1^{\,2} + \frac{1}{2}m_{\text{Ne}}v_2^{\,2} + \left(E_2' - E_2\right)$, 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:

a. $v_1 = 0$ and $v_2 = 0$

b. $v_1 = 0$, $v_2 \neq 0$

c. $v_1 \neq 0$, $v_2 \neq 0$, and $v_1 \neq v_2$

d. $v_1 = v_2 \neq 0$

For any indication of conservation of momentum 1 point

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

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

e. $v_1 = 0$, $v_2 \neq 0$

f. $v_1 \neq 0$, $v_2 \neq 0$, and $v_1 \neq v_2$

g. $v_1 = v_2 \neq 0$

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) 1 point

For correctly substituting m_{He}, including correct units 1 point

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.

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 — 1 point

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

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 — 1 point

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

For the correct answer, including units — 1 point

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

Alternate solution — *Alternate points*

For using the equation relating momentum and energy of a photon, including the correct difference in neon energy levels — *1 point*

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

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

For using the equation relating wavelength and momentum, and substituting the value of momentum obtained above — *1 point*

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

For the correct answer, including units — *1 point*

$\lambda = 634$ nm (or 633 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 — 1 point

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

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

$$N = E/\left(E_2' - E_1'\right)$$

For correctly substituting the values of E_1' and E_2' into the equation above — 1 point

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

For the correct answer — 1 point

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