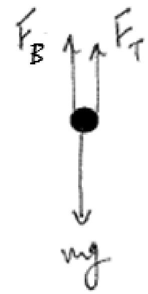
AP® Physics B
2013 Scoring Guidelines

Question 1

10 points total | **Distribution of points**

(a) 3 points



For showing the buoyant force in the correct direction and labeling it — 1 point
For showing the tension in the correct direction and labeling it — 1 point
For showing the gravitational force in the correct direction and labeling it — 1 point
One earned point was deducted for any extraneous forces.

(b) 2 points

For use of the correct expression for the buoyant force — 1 point

$F_B = \rho V g$

Substitute correct values

$F_B = \left(1000\ \mathrm{kg/m^3}\right)\left(6.25 \times 10^{-3}\ \mathrm{m^3}\right)\left(9.8\ \mathrm{m/s^2}\right)$

For a correct answer, with units — 1 point

$F_B = 61.3\ \mathrm{N}$ (62.5 N if using $g = 10\ \mathrm{m/s^2}$)

(c) 3 points

For a correct expression of Newton's second law when the anchor is at equilibrium — 1 point

$F_T + F_B = mg$

For substituting a value consistent with the buoyant force from part (b) — 1 point

For substituting correct values for calculation of the gravitational force — 1 point

$F_T = (50\ \mathrm{kg})\left(9.8\ \mathrm{m/s^2}\right) - (61.3\ \mathrm{N})$

$F_T = 429\ \mathrm{N}$ (438 N if using $g = 10\ \mathrm{m/s^2}$)

Question 1 (continued)

Distribution of points

(d) 2 points

For selecting $d' > d$	1 point
For a correct justification	1 point

Example
When the anchor is lifted onto the boat, the buoyant force on the boat must now support the weight of both the boat and the anchor. This will increase the buoyant force, which requires a greater volume of water, which means the boat will reach a greater depth into the water.

Question 2

15 points total — **Distribution of points**

(a)

i. 2 points

For selecting "Negative"	1 point
For a correct justification	1 point

Examples

- The spring pushes on the box in a direction opposite to the box's motion, therefore the work done is negative.
- The box slows down, so its kinetic energy decreases. Therefore the work done is negative.

ii. 3 points

For a correct expression relating work to change in kinetic energy — 1 point

$W = \Delta K$

$W = \frac{1}{2}m\left(v_2^2 - v_1^2\right) = -\frac{1}{2}mv_1^2$

For substituting the correct values — 1 point

$W = -\left(\frac{1}{2}\right)(20\text{ kg})(4.0\text{ m/s})^2$

For a correct answer — 1 point

$W = 160\text{ J}$ (either positive or negative value acceptable)

(b) 2 points

For a correct expression of conservation of energy — 1 point

$K_1 = U_2$

$\frac{1}{2}mv_1^2 = \frac{1}{2}kx_2^2$

For correct substitution of values consistent with the answer from part (a) ii — 1 point

$(160\text{ J}) = \left(\frac{1}{2}\right)k(0.50\text{ m})^2$

$k = 1280\text{ N/m}$

(c) 2 points

For a correct expression of the maximum acceleration — 1 point

$a = F_{max}/m = kx_{max}/m$

For correct substitution consistent with the answer from part (b) — 1 point

$a = (1280\text{ N/m})(0.50\text{ m})/(20\text{ kg})$

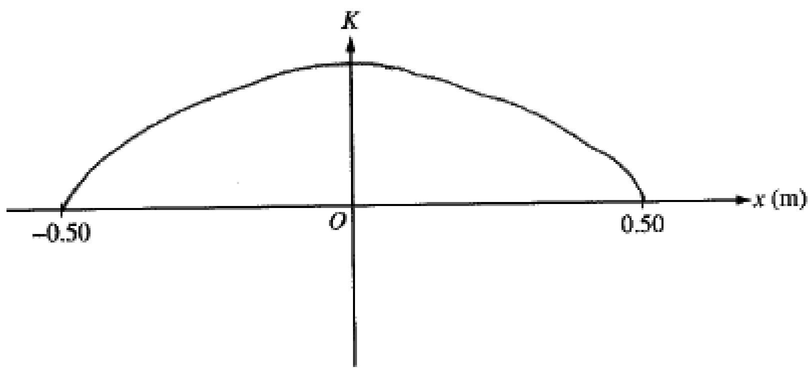
$a = 32\text{ m/s}^2$

Question 2 (continued)

	Distribution of points
(d) 2 points	
For a correct expression of the frequency	1 point
$f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$	
For correct substitution consistent with the answer from part (b)	1 point
$f = \left(\frac{1}{2\pi}\right)\sqrt{\frac{(1280\ \mathrm{N/m})}{(20\ \mathrm{kg})}}$	
$f = 1.27\ \mathrm{Hz}$	

(e)

i. 2 points



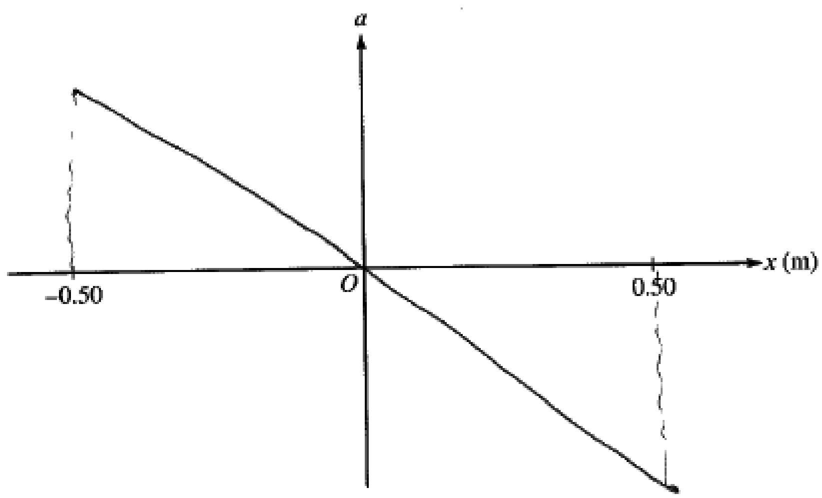
For a graph that shows positive kinetic energy values and zero kinetic energy at −0.50 m and +0.50 m	1 point
For a smooth curve that is concave down	1 point

Question 2 (continued)

Distribution of points

(e) (continued)

ii. 1 point



For a straight line with negative slope that begins at −0.50 m, ends at +0.50 m, and passes through the origin — 1 point

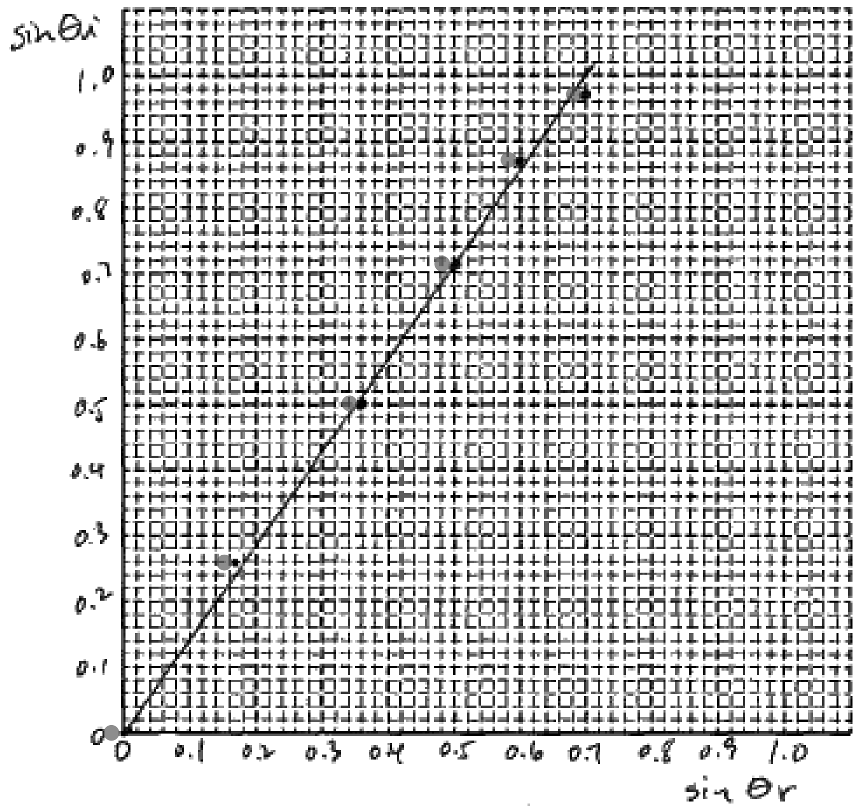
Units 1 point

For correct units on three out of four calculated answers — 1 point

Question 3

10 points total **Distribution of points**

(a) 3 points



For labeling both axes with variables that will yield a straight-line graph	1 point
For correctly scaling both axes	1 point
For correctly plotting the points	1 point

(b) 4 points

For a straight line that best represents the data	1 point
For relating the slope to the index of refraction using Snell's law	1 point

$n =$ slope (or $1/\text{slope}$ if plotting $\sin\theta_r$ as a function of $\sin\theta_i$)

For substituting two points on the line	1 point

For the example graph shown, $n = \dfrac{(1.00 - 0.20)}{(0.70 - 0.14)}$

For a calculated index of refraction in the range 1.2 - 1.6	1 point

$n = 1.43$

Question 3 (continued)

		Distribution of points
(c)	3 points	
	For a new experimental method in which the student aims the laser at the curved side of the block	1 point
	For stating that the critical angle is the minimum angle at which no light is refracted or total internal reflection is reached	1 point
	For relating the index of refraction to the critical angle and stating that $n_2 = 1$ (the second medium is air)	1 point

Example

Aim the laser through the curved side of the block at normal incidence, so that it emerges from the center of the flat side. Pivot the block about the center of the flat side so that the emerging beam just grazes the flat side (or the beam begins to disappear).

Measure the angle between the incident beam and the normal to the flat side. This is the critical angle θ_c .The index of refraction is given by $n = 1/\sin\theta_c$.

Question 4

10 points total **Distribution of points**

(a) 3 points

For using a correct expression for the vertical motion to determine time t — 1 point

$$\Delta y = \upsilon_{yi} t + \frac{1}{2} a t^2$$

$$\upsilon_{yi} = 0 \text{, so } t = \sqrt{\frac{2(\Delta y)}{a}}$$

For substituting the correct height and acceleration into the vertical equation — 1 point

$$t = \sqrt{\frac{(2)(2.4\ \text{m})}{(9.8\ \text{m/s}^2)}} = 0.70\ \text{s}$$

For substituting the correct values into the constant horizontal velocity equation — 1 point

$$\upsilon_x = \frac{\Delta x}{t}$$

$$\upsilon_x = \frac{(1.8\ \text{m})}{(0.70\ \text{s})} = 2.6\ \text{m/s}$$

(b) 2 points

For using a correct expression to determine the acceleration of the block — 1 point

$$\upsilon_x^2 = \upsilon_0^2 + 2ad$$

$$a = \frac{\upsilon_x^2}{2d}$$

For correct substitutions consistent with part (a) — 1 point

$$a = \frac{(2.6\ \text{m/s})^2}{(2)(0.95\ \text{m})} = 3.5\ \text{m/s}^2$$

Question 4 (continued)

Distribution of points

(c) 3 points

For using Newton's second law

$\sum F = ma$

$m_{obj}g = \left(m_{obj} + M + m_{ball}\right)a$

For a correct value for the total force on the system — 1 point

$m_{obj}g = (2.5 \text{ kg})\left(9.8 \text{ m/s}^2\right) = 25 \text{ N}$

For correct values in the expression for the total mass being accelerated — 1 point

$\left(m_{obj} + M + m_{ball}\right)a = (2.5 \text{ kg} + 0.3 \text{ kg} + M)a = (2.8 \text{ kg} + M)a$

For the correct substitution of the acceleration of the block from part (b) — 1 point

$25 \text{ N} = (2.8 \text{ kg} + M)\left(3.5 \text{ m/s}^2\right)$

$M = 4.24 \text{ kg}$

(d) 2 points

For stating that with the same force, the horizontal acceleration of the ball will be less as a result of the increased mass of the system — 1 point

For stating the launch velocity will be lower — 1 point

<u>Example</u>

A larger combined mass of the system will result in a smaller acceleration, so the ball has a smaller speed upon launch. However, the time to hit the floor will be the same since it's falling the same vertical distance with the same vertical acceleration in freefall. So the horizontal distance $\left(\upsilon_{launch} \times t_{fall}\right)$ will be less.

One earned point was deducted for any incorrect statement in the reasoning not included in the points shown.

Question 5

10 points total | **Distribution of points**

(a) 1 point

Use the equation for the change in internal energy (first law of thermodynamics)

$\Delta U = Q + W$

$\Delta U = (3200\ \text{J}) + (2100\ \text{J})$

For the correct answer, including units — 1 point

$\Delta U = 5300\ \text{J}$

(b)

i. 2 points

For selecting "Decreases" — 1 point

For a correct justification — 1 point

Examples

Because work is done on the gas, W is positive. $W = -P\Delta V$, so ΔV must be negative and the volume decreases.

Because work is done on the gas, W is positive and the gas is compressed. If the gas is compressed, the volume decreases.

ii. 2 points

For selecting "Increases" — 1 point

For a correct justification — 1 point

Example

The internal energy increases (as shown in part (a)) and the temperature of an ideal gas increases as the internal energy increases.

iii. 2 points

For selecting "Increases" — 1 point

For a correct justification — 1 point

Example

From the ideal gas law, PV/T is constant. So if V decreases and T increases, P must increase.

Question 5 (continued)

		Distribution of points
(c)	1 point	
	For stating the internal energy does not change $\Delta U = 0$	1 point
(d)	2 points	
	For selecting "Energy is transferred out of the gas"	1 point
	For a correct justification	1 point

<u>Example</u>

$\Delta U = Q + W$ is zero for an ideal gas at constant temperature and W is positive since work is done on the gas. Therefore Q is negative, meaning energy is transferred out of the gas by heating.

Question 6

15 points total | **Distribution of points**

(a) 2 points

For the correct substitution of the values of μ_0, I, and r into the correct expression for the magnetic field around a wire — 1 point

$$B = \frac{\mu_0 I}{2\pi r} = \frac{\left(4\pi \times 10^{-7}\ \text{T}\bullet\text{m/A}\right)(65\ \text{A})}{(2\pi)(0.025\ \text{m})}$$

For the correct answer — 1 point

$$B = 5.2 \times 10^{-4}\ \text{T}$$

(b)

i. 4 points

For an expression of equilibrium between the magnetic and gravitational forces on the wire — 1 point

$$W = F_B$$

For correct expressions for the magnetic and gravitational forces — 1 point

$$mg = BIL$$

For a correct expression for the current in terms of the linear density — 1 point

$$I = \left(\frac{m}{L}\right)\frac{g}{B}$$

For correctly substituting the answer from part (a) into the above equation to solve for the current — 1 point

$$I = \left(5.6 \times 10^{-3}\ \text{kg/m}\right)\frac{\left(9.8\ \text{m/s}^2\right)}{\left(5.2 \times 10^{-4}\ \text{T}\right)}$$

$I = 106\ \text{A}$ (or 108 A using $g = 10\ \text{m/s}^2$)

ii. 1 point

For selecting "To the right" — 1 point

(c) 2 points

For stating that the wire would move upward — 1 point

For stating that the wire would accelerate with a correct justification — 1 point

Example

As wire Y is moved closer to X, the magnetic field from X will increase. This will create an upward net force on Y that will accelerate Y upward toward wire X.

(d) 1 point

Question 6 (continued)

	Distribution of points
For stating that the direction of the current in one of the wires must change	1 point

<u>Examples</u>

- The current must be reversed in one wire, but not in the other.
- Reverse the current in wire X.
- Change the direction of the current in wire Y.

(e)

i. 3 points

For a correct statement of either Faraday's law, or the motional emf formula	1 point

$\mathcal{E} = B\upsilon L$ OR $\mathcal{E} = -\dfrac{\Delta\phi}{\Delta t}$ (since $\mathcal{E} = -B\dfrac{\Delta A}{\Delta t} = -B\upsilon L$, with the minus sign irrelevant since the question asks for a magnitude)

For a correct expression for, or determination of, the value of the magnetic field	1 point

Method 1) Taking half the value determined in part (a), because the wires are now twice as far apart

$$B = \frac{1}{2}\left(5.2 \times 10^{-4}\ \text{T}\right) = 2.6 \times 10^{-4}\ \text{T}$$

Method 2) Using the formula for the magnetic field around a wire

$$B = \frac{\mu_0 I}{2\pi r} = \frac{\left(4\pi \times 10^{-7}\ \text{T•m/A}\right)(65\ \text{A})}{(2\pi)(0.050\ \text{m})} = 2.6 \times 10^{-4}\ \text{T}$$

For substituting *correct* values of L and υ and *any* value of B into a correct expression	1 point

$$\mathcal{E} = (2.6 \times 10^{-4}\ \text{T})(3.0\ \text{m/s})(1.2\ \text{m}) = 9.4 \times 10^{-4}\ \text{V}$$

ii. 2 points

For selecting "The right end"	1 point
For a correct justification	1 point

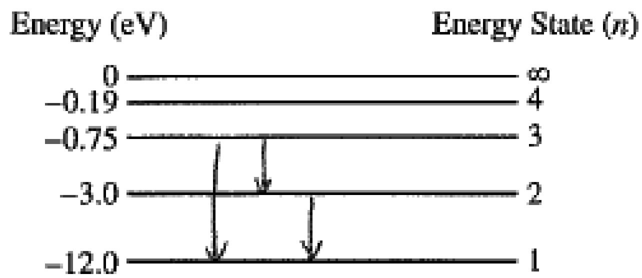
<u>Example</u>

Using the right-hand rule, positive charges moving upward in the magnetic field, which is out of the page, would experience a magnetic force to the right. Thus, the right end of wire Y develops a positive charge and the left end develops a negative charge.

Question 7

10 points total | **Distribution of points**

(a) 3 points



For an arrow from the $n = 3$ to the $n = 2$ energy state — 1 point
For an arrow from the $n = 3$ to the $n = 1$ energy state — 1 point
For an arrow from the $n = 2$ to the $n = 1$ energy state — 1 point
One earned point was deducted if there were any incorrect or extra lines on the diagram.

(b) 2 points

Use an expression relating energy to wavelength
$E = hf = hc/\lambda$
For substitution using the correct 3 to 2 transition energy — 1 point
$\lambda = hc/E = (1240\ \text{eV}\bullet\text{nm})/((3.0 - 0.75)\ \text{eV})$
For an answer consistent with whichever transition was chosen — 1 point
$\lambda = 551\ \text{nm}$ or $5.51 \times 10^{-7}\ \text{m}$
(138 nm for the 2 to 1 transition, and 110 nm for the 3 to 1 transition)

(c) 1 point

For the correct, positive value for the ionization energy — 1 point
$E = 12\ \text{eV}$ or $1.9 \times 10^{-18}\ \text{J}$

(d) 2 points

For correctly stating that an 11.0 eV photon has no effect — 1 point
For a correct explanation — 1 point

Example
Since there is no energy level at −1.0 eV, an 11.0 eV photon will have no effect on electrons in the −12.0 eV (n = 1) energy state.

Question 7 (continued)

	Distribution of points
(e) 2 points	
For correctly stating that a 14.0 eV photon will remove the electron from (or ionize) the atom	1 point
For a correct explanation	1 point

Example

A 14.0 eV photon has sufficient energy to ionize the atom, since only 12.0 eV is required for ionization.