AP® PHYSICS B
2002 SCORING GUIDELINES

Question 6

10 points total	**Distribution of points**
(a) 3 points	
For a correct verbal description of the method used to determine the spring constant (One point could be awarded for an incomplete description)	2 points
For an appropriate equation for k, or a verbal representation of the equation	1 point

Example 1: Measure the unstretched length of the spring. Hang it with the object at rest and measure the stretched length. Call the difference in these lengths ℓ. Equating the weight of the object and the force exerted by the extended spring gives $mg = k\ell$ from which k can be determined.

Example 2: Set the hanging mass into oscillation. Determine the period T by timing n oscillations and dividing that time by n. The equation $T = 2\pi\sqrt{m/k}$ can then be used to find k.

Example 3: Hold the object at the position where the spring is unstretched and then release it. Measure the maximum distance h it falls. Equating maximum potential and kinetic energies, $mgh = \frac{1}{2}kh^2$, allows determination of k.

(b) 2 points	
For a correct observation that includes an indication of whether the change is an increase or decrease	1 point
For a correct explanation of the change	1 point

Example 1: The spring is stretched less when the object is at rest in the fluid. The fluid exerts an upward buoyant force on the object. Since the net force on the object is still zero, the spring does not need to exert as much force as before, and thus stretches less.

Example 2: If the spring oscillates in the fluid, its period will be greater. The fluid exerts a drag force on the object in the direction opposite to its motion, and thus slows it down.

Question 6 (cont'd.)

15 points total **Distribution of points**

(c & d) 5 points

These parts were scored together. The following describe the criteria for receiving each of the possible scores.

5 points A complete and accurate explanation of a correct experimental method, with correct equations and definitions of symbols

4 points A mostly complete response, with only one or two errors in the explanation or equations
This was the maximum possible score if the student incorrectly used the volume of displaced fluid.

3 points Partially complete response with one or two major errors
OR A complete description of the method (part (c)) with no mathematical treatment (part (d))
OR A complete mathematical treatment with symbol definitions (part (d)) with no description of the method (part (c))

2 points An incomplete explanation and presentation, but one that shows some understanding of the principles involved

1 point An explanation and presentation that shows very little understanding of the principles involved

The following is one example of a correct method.

1) Measure the length of the spring when the object is immersed in the liquid, and subtract the unstretched length to determine the amount the spring is stretched. This will allow calculation of the force exerted by the spring on the object.
2) The volume of fluid displaced is equal to the volume of the object, which can be determined from the given mass and density of the object.
3) The buoyant force on the object is equal to the difference of the object's weight and the force exerted by the spring.
4) The buoyant force also equals the weight of the displaced fluid, which equals the product of the fluid density, displaced volume, and g.

Question 6 (cont'd.)

15 points total **Distribution of points**

(c & d) continued

Symbol	Physical quantity
m	Mass of object
g	Acceleration due to gravity
k	Spring constant
ℓ	Amount of spring stretch when <u>not</u> immersed
ℓ_w	Amount of spring stretch when immersed
V	Volume (of both object and displaced fluid)
D	Density of object
ρ	Density of fluid
$F_{bouyant}$	Buoyant force on object
F_{spring}	Spring force on object
w_{fluid}	Weight of fluid displaced
m_{fluid}	Mass of fluid displaced

Equation to determine the spring constant

$mg = k\ell$

Equations corresponding to points 1 through 4 in the method described on the previous page:

$F_{spring} = k\ell_w$

$V = m/D$

$F_{bouyant} = mg - F_{spring} = mg - k\ell_w$

$F_{bouyant} = w_{fluid} = m_{fluid}g = \rho Vg$

Solving for ρ (which was not required):

$\rho Vg = mg - k\ell_w$

$\rho Vg = mg - \frac{mg}{\ell}\ell_w = mg\left(1 - \frac{\ell_w}{\ell}\right)$

$\rho = \frac{m}{V}\left(1 - \frac{\ell_w}{\ell}\right) = \frac{m}{m/D}\left(1 - \frac{\ell_w}{\ell}\right)$

$\rho = D\left(1 - \frac{\ell_w}{\ell}\right)$

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

$P_{\text{gauge}} = \left(1.025\times 10^3\ \dfrac{\text{kg}}{\text{m}^3}\right)\left(9.8\ \dfrac{\text{m}}{\text{s}^2}\right)(35\ \text{m})$

For the correct answer — 1 point

$P_{gauge} = 3.5\times 10^5\ \text{Pa.}$

(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

$P_{\text{abs}} = P_{\text{gauge}} + P_{\text{atm}} = 3.5\times 10^5\ \text{Pa} + 1.0\times 10^5\ \text{Pa} = 4.5\times 10^5\ \text{Pa}$

(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

$m = \rho V = \left(2.7\times 10^3\ \dfrac{\text{kg}}{\text{m}^3}\right)\left(1.0\times 2.0\times 0.03\ \text{m}^3\right) = 1.6\times 10^2\ \text{kg}$ OR $mg = \rho V g = 1.6\times 10^3\ \text{N}$

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 — 1 point

$F_{bouy} = \rho_{\text{fluid}} V g = \left(1.025\times 10^3\ \dfrac{\text{kg}}{\text{m}^3}\right)\left(0.06\ \text{m}^3\right)\left(9.8\ \dfrac{\text{m}}{\text{s}^2}\right) = (61.5\ \text{kg})\left(9.8\ \dfrac{\text{m}}{\text{s}^2}\right) = 6.0\times 10^2\ \text{N}$

Solving for the tension and substituting:

$T = mg - F_{bouy} = 1.6\times 10^3\ \text{N} - 6.0\times 10^2\ \text{N}$

For the correct answer — 1 point

$T = 1.0\times 10^3\ \text{N}$ (or $9.9\times 10^2\ \text{N}$ 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" <u>and</u> gave an explanation stating that a constant acceleration implies a constant force, they were awarded 2 points.

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

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

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

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

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

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

$\upsilon_1 A_1 = \upsilon_2 A_2$

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

Substituting the given values:

$(0.50 \text{ m/s})\pi\left(\dfrac{0.03 \text{ m}}{2}\right)^2 = \upsilon_2 \pi\left(\dfrac{0.0125 \text{ m}}{2}\right)^2$

For the correct answer — 1 point

$\upsilon_2 = 2.88$ 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: $p_1 + \rho g h_1 + \frac{1}{2}\rho \upsilon_1^2 = p_2 + \rho g h_2 + \frac{1}{2}\rho \upsilon_2^2$

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.

Question 2

15 points total | **Distribution of points**

(a) 2 points

For work showing $p_{absolute} - p_{atm}$ in an appropriate equation or calculation — 1 point

$p_g = p_{absolute} - p_{atm}$

$p_g = 413 \text{ atm} - 1 \text{ atm}$

For the correct answer — 1 point

$p_g = 412 \text{ atm}$

Note: An answer with no work shown only received 1 point total

(b) 3 points

For showing $p = \rho gh$ in any of the following equations or during calculation — 1 point

$p = p_0 + \rho gh$ OR $p_g = \Delta p = \rho gh$ OR $p = \rho gh$

For correct substitutions in any of these equations — 1 point

For example, $D = \dfrac{p_g}{\rho g} = \dfrac{(412 \text{ atm})\left(1 \times 10^5 \text{ N}/\left(\text{m}^2 \bullet \text{atm}\right)\right)}{\left(1025 \text{ kg/m}^3\right)\left(9.8 \text{ m/s}^2\right)}$

For answer consistent with (a), with a reasonable number of significant figures (1 to 4) — 1 point

$D = 4100$ m (or 4020 m using $g = 10 \text{ m/s}^2$). Any negative sign was ignored.

Note: A range of answers was possible depending on the value used for g (9.8 or 10 m/s^2) and on the conversion factor used to convert atmospheres to N/m^2 (the approximate value in the equation sheet or the more precise value found in some calculators).

(c) 2 points

For correct substitution of numerical values into a correct relationship — 1 point

$F = p_g A = (412 \text{ atm})\left(1 \times 10^5 \text{ N}/\left(\text{m}^2 \bullet \text{atm}\right)\right)\left(0.0100 \text{ m}^2\right)$

Note: Since “force due to the water” might have been interpreted as due to the total pressure instead of the gauge pressure, 413 atm was also accepted for the pressure.

For the correct answer with units consistent with calculation using 412 atm, 413 atm, or answer to (a) — 1 point

$F = 4.12 \times 10^5$ N

Note: In the absence of explicit indication of numerical substitution, a correct answer with a correct equation could earn 2 points.

Also accepted was $F = \rho Vg$, where $\rho = 1025 \text{ kg/m}^3$ and $V = \left(0.0100 \text{ m}^3\right)$(answer to (b))

Question 2 (continued)

Distribution of points

(d) 2 points

For substitution in the correct equation OR for the correct numerical answer Negative sign was ignored.	1 point
For a correct numerical answer with correct units	1 point

$a = \Delta v/t = (10.0\text{ m/s} - 0\text{ m/s})/(30.0\text{ s})$

$a = 0.333\ \text{m/s}^2$

(e) 2 points

For correct substitution into a correct equation	1 point
For correct answer (using acceleration from (d) in the first two of the following solutions)	1 point

$v^2 = v_0^{\ 2} + 2a\,\Delta x$

$d = v_f^{\ 2}/2a = (10.0\text{ m/s})^2/2(0.333\text{ m/s}) = 150\text{ m}$

OR

$d = \frac{1}{2}at^2$

$d = \frac{1}{2}\left(0.333\ \text{m/s}^2\right)(30.0\text{ s})^2 = 150\text{ m}$

OR

$v_{\text{avg}} = \Delta x/t$

$d = v_{avg}t = (30\text{ s})(10.0\text{ m/s} + 0\text{ m/s})/2 = 150\text{ m}$

Note: In the absence of explicit indication of numerical substitution, a correct answer with a correct equation could earn 2 points. Negative sign was ignored.

(f) 4 points

For computing the distance Δy that the ship falls at constant velocity using D from part (b) and d from part (e)	1 point

$\Delta y = D - d = 4100\text{ m} - 150\text{ m}$

$\Delta y = 3950\text{ m}$

For consistent substitution in a correct equation to find t_2, the time the ship falls at constant velocity	1 point

$\Delta y = v_f t_2$

$t_2 = \Delta y/v_f = (3950\text{ m})/(10\ \text{m/s}) = 395\text{ s}$

For finding the total time by adding t_2 to the given time t_1 to reach terminal velocity	1 point

$t_{\text{tot}} = t_2 + t_1 = 395\text{ s} + 30\text{ s}$

For the correct total time	1 point

$t = 425\text{ s}$ (or answer consistent with previous answers)

Question 5

10 points total | **Distribution of points**

(a) 3 points

For an equation that uses the ratio of densities ρ_r/ρ_w to find the fraction of the total volume (or height) submerged — 1 point

The weight of the raft equals the weight of the displaced water.

$W_r = W_w$

$m_r g = m_w g$

$\rho_r V_r g = \rho_w V_w g$

Solving for the volume of displaced water, which equals the submerged volume of the raft

$$V_w = \frac{\rho_r}{\rho_w} V_r$$

For recognizing that the submerged volume (or height) must be subtracted from the total volume (or height) — 1 point

$V_{submerged} = Ah = V_r - V_w$

$$Ah = V_r - \frac{\rho_r}{\rho_w} V_r = V_r \left(1 - \frac{\rho_r}{\rho_w}\right)$$

$$h = \frac{V_r}{A}\left(1 - \frac{\rho_r}{\rho_w}\right)$$

$$h = \frac{1.8\ \text{m}^3}{8.2\ \text{m}^2}\left(1 - \frac{650\ \text{kg/m}^3}{1000\ \text{kg/m}^3}\right)$$

For the correct answer — 1 point

$h = 0.077\ \text{m}$

Some students misinterpreted the statement about the volume of the raft, taking it to mean the volume of the part above the water instead of the total volume. If the solution to part (b) showed work that demonstrated understanding of the concepts needed for part (a), appropriate credit for this part was awarded.

Question 5 (continued)

	Distribution of points
(b) 4 points	
For indicating that the buoyant force is equal to the weight of the raft	1 point
$F_{buoy} = W_r$	
For correct substitutions for calculating the buoyant force, either by directly calculating the raft's weight or calculating the weight of the displaced water	1 point
$F_{buoy} = \rho_r V_r g = (650\ \text{kg/m}^3)(1.80\ \text{m}^3)(9.8\ \text{m/s}^2)$	
OR $F_{buoy} = \rho_w V_w g = (1000\ \text{kg/m}^3)(1.17\ \text{m}^3)(9.8\ \text{m/s}^2)$	
For the correct answer with units	1 point
$F_{buoy} = 1.15 \times 10^4\ \text{N}$ (or $1.17 \times 10^4\ \text{N}$ using $g = 10\ \text{m/s}^2$)	
For indicating that the direction of the buoyant force is up	1 point

(c) 3 points

The additional weight that can be carried is equal to the weight of water displaced by the part of the raft now above water.

For indicating a correct equation for the net force — 1 point

$W_{addl} = W_{extra\ water}$ OR $W_{addl} = F_{buoyNEW} - W_{raft}$

The first equation above yields $W_{addl} = \rho_w V_{top} g = \rho_w A h g$

Substituting the algebraic expression for h from part (a) and simplifying yields $W_{addl} = \rho_w V_r g - \rho_r V_r g = V_r g(\rho_w - \rho_r)$, which is equivalent to substitution into the second equation above.

For correct numerical substitutions to get the weight (or mass) of the top of the raft — 1 point

$W_{addl} = (1.80\ \text{m}^3)(9.8\ \text{m/s}^2)(1000\ \text{kg/m}^3 - 650\ \text{kg/m}^3)$

$W_{addl} = 6200\ \text{N}$ (variation due to rounding earlier on was accepted)

For dividing the total weight (or mass) by the weight (or mass) of a person and indicating the correct number of people that the raft can carry. (The final answer must indicate a *whole* number of people.) — 1 point

$$n = \frac{W_{addl}}{m_p g} = \frac{6200\ \text{N}}{(75\ \text{kg})(9.8\ \text{m/s}^2)} = 8.4$$

A maximum of 8 people can be on the raft.

Question 4

10 points total | **Distribution of points**

(a) 2 points

For any indication that the volume rate of flow is defined as volume/time — 1 point

Define the symbol $\mathcal{V}$ for the volume flow rate

$\mathcal{V} = 7.2 \times 10^{-4}\ \text{m}^3 / [(2.0\ \text{min})(60\ \text{s/min})]$

For the correct answer, including units — 1 point

$\mathcal{V} = 6.0 \times 10^{-6}\ \text{m}^3/\text{s}$

(b) 2 points

For a correct relationship between volume flow rate, speed, and area — 1 point

$\mathcal{V} = vA$

$v = \mathcal{V}/A$

$v = \left(6.0 \times 10^{-6}\ \text{m}^3/\text{s}\right) / \left(2.5 \times 10^{-6}\ \text{m}^2\right)$

For the correct answer, including units — 1 point

$v = 2.4\ \text{m/s}$

<u>Note</u>*: An attempt to use kinematics with the distance x and height d could earn a maximum of 1 point.*

(c) 3 points

For applying Bernoulli's Equation, either to points at the top of the liquid and the hole or to points just inside and outside of the hole, and recognizing the specific conditions for one of the three variables (pressure, speed, or height) — 1 point

For recognizing the conditions for the remaining two variables — 1 point

<u>Top and hole</u>	<u>Inside and outside</u>
$P_t + \rho g y_t + \frac{1}{2}\rho v_t^2 = P_h + \rho g y_h + \frac{1}{2}\rho v_h^2$	$P_{\text{in}} + \rho g y_{\text{in}} + \frac{1}{2}\rho v_{\text{in}}^2 = P_{\text{out}} + \rho g y_{\text{out}} + \frac{1}{2}\rho v_{\text{out}}^2$
$P_t = P_h = P_{atm}$	$P_{\text{in}} = P_{atm} + \rho g h$, $P_{\text{out}} = P_{atm}$
$v_t = 0$	$v_{\text{in}} = 0$
$y_t = h$, $y_h = 0$	$y_{\text{in}} = y_{\text{out}} = 0$

Both cases simplify to the same equation, where v_e is the exit speed

$\rho g h = \rho v_e^2 / 2$

$h = v_e^2 / 2g = (2.4\ \text{m/s})^2 / 2\left(9.8\ \text{m/s}^2\right)$

For the correct answer, including units — 1 point

$h = 0.29\ \text{m}$

<u>Notes:</u> *Solutions that begin with the equation $\rho g h = \rho v^2/2$ could earn 2 of the 3 points.*

Solutions that begin with the equation $mgh = mv^2/2$ could earn 1 of the 3 points.

Question 4 (continued)

Distribution of points

(c) (continued)

Alternate solution 1 — *Alternate points*

For explicitly stating by name that Torricelli's theorem applies — *1 point*

For writing the correct expression for the theorem — *1 point*

$\upsilon = \sqrt{2gh}$

$h = \dfrac{\upsilon^2}{2g} = \dfrac{(2.4\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)}$

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

$h = 0.29\ \text{m}$

Alternate solution 2 — *Alternate points*

For relating the pressure difference across the hole to the acceleration of the liquid through the hole — *1 point*

$F = ma = \Delta P\, A$

$\Delta P = \rho g h$

$a = \rho g h A/m = ghA/V$, *where V is the volume of the hole*

For applying an appropriate kinematics equation and substituting the expression for acceleration — *1 point*

$\upsilon^2 = \upsilon_0^2 + 2a\ell$, *where* $\upsilon_0 = 0$ *and* ℓ *is the thickness of the container wall*

$\upsilon^2 = 2(ghA/V)\ell = 2gh$

$h = \dfrac{\upsilon^2}{2g} = \dfrac{(2.4\ \text{m/s})^2}{2\left(9.8\ \text{m/s}^2\right)}$

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

$h = 0.29\ \text{m}$

(d) 3 points

For correctly indicating that the liquid will hit to the left of the beaker — 1 point

For an explanation that relates the decrease in water height to a decrease in the pressure at the hole and a decrease in velocity exiting the hole — 2 points

Other explanations, such as relating force and acceleration at the hole, describing changes in potential and kinetic energy, or using a relationship from part (c), could earn full credit.

Note: In the exam booklets, the container was erroneously referred to as the beaker in this part. Answers indicating that the liquid would hit to the right of the beaker received full credit if there was an explanation indicating that the student was now using the container as the reference object.

Question 4

10 points total | **Distribution of points**

(a) 3 points

For a correct application of kinematics to the vertical motion — 1 point

$v_{yf}^2 = v_{y0}^2 - 2gh = 0$

$v_{y0}^2 = 2gh$

For correctly expressing the vertical component of the initial velocity — 1 point

$v_{y0} = v_0 \sin 50°$

For a correct solution — 1 point

$v_0 \sin 50° = \sqrt{2gh}$

$$v_0 = \frac{\sqrt{2gh}}{\sin 50°} = \frac{\sqrt{2\left(9.8 \text{ m/s}^2\right)(0.150 \text{ m})}}{\sin 50°}$$

$v_0 = 2.24 \text{ m/s}$ (or 2.26 m/s using $g = 10 \text{ m/s}^2$)

(b) 2 points

For a correct expression for the volume flow rate, using an area of πr_0^2 — 1 point

Volume flow rate $= A_0 v_0 = \pi r_0^2 v_0$

For a correct solution with correct units, consistent with v_0 found in part (a) — 1 point

Volume flow rate $= \pi\left(4.00 \times 10^{-3} \text{ m}\right)^2 (2.24 \text{ m/s})$

Volume flow rate $= 1.13 \times 10^{-4} \text{ m}^3/\text{s}$ (or $1.14 \times 10^{-4} \text{ m}^3/\text{s}$ using $g = 10 \text{ m/s}^2$)

Question 4 (continued)

Distribution of points

(c) 5 points

For a correct expression for the water velocity in the feeder pipe with substitutions consistent with previous work — 1 point

$$A_0 \upsilon_0 = A_p \upsilon_p$$

$$\upsilon_p = \frac{A_0}{A_p}\upsilon_0 = \left(\frac{r_0}{r_p}\right)^2 \upsilon_0 = \left(\frac{4.00 \times 10^{-3}\ \text{m}}{7.00 \times 10^{-3}\ \text{m}}\right)^2 2.24\ \text{m/s}$$

For a correctly calculated answer consistent with previous work — 1 point

$\upsilon_p = 0.731\ \text{m/s}$ (or $\upsilon_p = 0.738\ \text{m/s}$ using $g = 10\ \text{m/s}^2$)

For a correct expression of Bernoulli's equation — 1 point

$$P_0 + \rho g h_0 + \frac{1}{2}\rho \upsilon_0^2 = P_p + \rho g h_p + \frac{1}{2}\rho \upsilon_p^2$$

$$P_p - P_0 = \rho g \left(h_0 - h_p\right) + \frac{1}{2}\rho\left(\upsilon_0^2 - \upsilon_p^2\right)$$

For consistent/correct substitutions of heights and velocities — 1 point

$$P_p - P_0 = \left(1.0 \times 10^3\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)(3.00\ \text{m}) + \frac{1}{2}\left(1.0 \times 10^3\ \text{kg/m}^3\right)\left[(2.24\ \text{m/s})^2 - (0.731\ \text{m/s})^2\right]$$

For correctly accounting for atmospheric pressure (with no obvious algebraic errors) leading to an answer — 1 point

P_0 is atmospheric pressure, and $P_p = P_0 + P_{gauge}$

$P_{gauge} = P_p - P_0 = 3.16 \times 10^4\ \text{Pa}$ (or $3.23 \times 10^4\ \text{Pa}$ using $g = 10\ \text{m/s}^2$)

Question 4

10 points total | **Distribution of points**

(a) 3 points

For a correct expression for the volume flow rate I_V — 1 point

$I_V = Av$

For a correct substitution for area (only if the first point was awarded) — 1 point

$A = \pi r^2$

$I_V = \pi r^2 v = (3.14)(0.015\ \text{m})^2(6.0\ \text{m/s})$

For the correct answer — 1 point

$I_V = 4.2 \times 10^{-3}\ \text{m}^3/\text{s}$

(b) 3 points

For a correct application of Bernoulli's equation to point 1 in the feeder pipe below ground and point 2 at the surface where the water emerges — 1 point

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

$P_1 = P_{abs}$ and $P_2 = P_{atm}$

$P_{abs} = P_{atm} + \rho g(y_2 - y_1) + \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$

For the correct use of the equation of continuity to find v_1 — 1 point

$A_1 v_1 = A_2 v_2$

$v_1 = \frac{v_2 A_2}{A_1} = \frac{v_2 \pi r_2^2}{\pi r_1^2} = \frac{(6.0\ \text{m/s})(0.015\ \text{m})^2}{(0.025\ \text{m})^2} = 2.2\ \text{m/s}$

$v_2^2 - v_1^2 = (6.0\ \text{m/s})^2 - (2.2\ \text{m/s})^2 = 31\ \text{m}^2/\text{s}^2$

$P_{abs} = 1.0 \times 10^5\ \text{Pa} + \left(10^3\ \text{kg/m}^3\right)\left(9.8\ \text{m/s}^2\right)(2.5\ \text{m}) + \frac{1}{2}\left(10^3\ \text{kg/m}^3\right)\left(31\ \text{m}^2/\text{s}^2\right)$

For the correct answer with units — 1 point

$P_{abs} = 1.4 \times 10^5\ \text{Pa}$

Question 4 (continued)

	Distribution of points
(c) 4 points	
For correct use of kinematics or conservation of energy or Torricelli's theorem to find the exit speed, with correct substitution of values	1 point
$\upsilon_2^{\;2} = 2gh$	
$\upsilon_2 = \sqrt{2gh} = \sqrt{2\left(9.8\ \text{m/s}^2\right)(4.0\ \text{m})}$	
For the correct answer for the exit speed	1 point
$\upsilon_2 = 8.9\ \text{m/s}$	
For correct use of the equation of continuity to find r_{new}, with correct substitution of values	1 point
$A\upsilon = A_{\text{new}}\upsilon_{\text{new}}$	
$\pi r^2\upsilon = \pi r_{\text{new}}^2\upsilon_{\text{new}}$	
$r_{\text{new}}^2 = r^2\dfrac{\upsilon}{\upsilon_{\text{new}}} = (0.015\ \text{m})^2\dfrac{(6.0\ \text{m/s})}{(8.9\ \text{m/s})}$	
For the correct answer with units, consistent with the new exit speed found above	1 point
$r_2 = 1.2 \times 10^{-2}\ \text{m}$	

*2009 is not available at this time