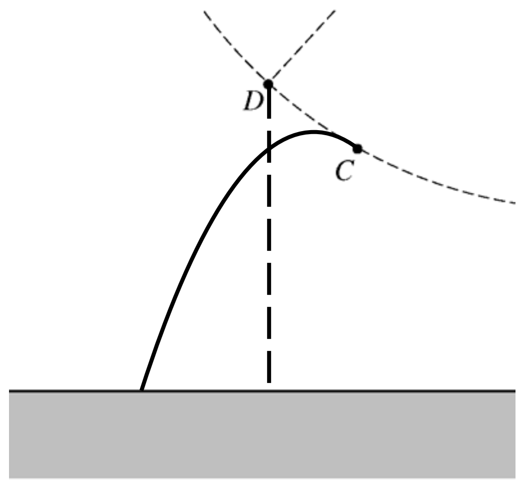
AP® Physics B
2014 Scoring Guidelines

Question 1

15 points total **Distribution of points**

(a) 3 points



For showing a parabolic path from point *C* that is tangent to the arc at *C*	1 point
For a maximum height of the parabolic path that is lower than point *D*	1 point
For showing the person traveling straight downward from point *D*	1 point

Note: the two paths may, but need not, cross each other.

(b) 2 points

For using the gravitational potential energy equation — 1 point

$\Delta U_g = mgh = (50\text{ kg})(9.8\text{ m/s}^2)(4.1\text{ m})$

For a correct answer — 1 point

$\Delta U_g = 2010\text{ J}$ (or 2050 J using $g = 10\text{ m/s}^2$)

(c) 3 points

For using an expression of conservation of energy — 1 point

$U_{g1} = U_{g2} + K_2$

$mgh_1 = mgh_2 + \frac{1}{2}mv^2$

For correctly substituting values — 1 point

$gh_1 = gh_2 + \frac{1}{2}v^2$

$v = \sqrt{2g(h_1 - h_2)}$

$v = \sqrt{2(9.8\text{ m/s}^2)(4.1\text{ m} - 2.4\text{ m})}$

For a correct answer — 1 point

$v = 5.8\text{ m/s}$

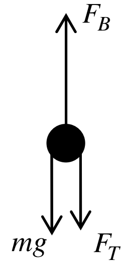
Question 1 (continued)

	Distribution of points
(d) 3 points	
For using a correct expression to solve for the time of fall	1 point
$\Delta y = v_0 t + \frac{1}{2}at^2$	
For correctly solving for the time of fall	1 point
$\Delta y = \frac{1}{2}at^2$	
$t = \sqrt{\frac{2\Delta y}{a}}$	
$t = \sqrt{\frac{2(2.4\ \text{m})}{(9.8\ \text{m/s}^2)}}$	
$t = 0.70\ \text{s}$ (or 0.69 s using $g = 10\ \text{m/s}^2$)	
In the horizontal direction, the acceleration is zero.	
$R = v_x t$	
For substituting the speed from part (c) into the constant-velocity equation for horizontal motion	1 point
$R = (5.8\ \text{m/s})(0.70\ \text{s})$	
$R = 4.1\ \text{m}$ (or 4.0 m using either unrounded speed of $5.77\ \text{m/s}$ or $g = 10\ \text{m/s}^2$)	
Units 1 point	
For correct units in the calculated answers to parts (b), (c), and (d)	1 point
(e) 3 points	
For selecting "$p_C < p_B$"	1 point
For any indication that the speed at C is less than the speed at B	1 point
For an explanation of why the speed decreases from B to C, which includes the following or equivalent statements:	1 point
by conservation of energy: U increases as the person moves from B to C, therefore K decreases, resulting in a decrease in speed	
OR	
gravitational force opposes motion as the person moves from B to C, which results in a negative acceleration and a decrease in speed	
OR	
by the impulse-momentum theorem: momentum decreases because the force of gravity provides impulse opposing the motion of the person	

Question 2

10 points total | **Distribution of points**

(a) 2 points



For showing the three force vectors for buoyancy, weight (gravity), and tension — 1 point
For showing all the forces labeled and in the correct direction — 1 point
One point is deducted if either or both of the following occur:

- Any other forces are indicated
- Any vector does not both touch and point away from the dot

(b) 3 points

For using Newton's second law to sum the forces in the vertical direction — 1 point

$F_B - F_T - F_g = 0$

$F_B = F_g + F_T$

For equating the buoyant force with the weight of displaced water, and expressing this weight in terms of density, volume, and g — 1 point

$F_B = F_g + 0.25F_g = 1.25F_g$

$\rho_W V_{\text{cube}} g = 1.25mg$

$\left(1000\ \text{kg/m}^3\right)V_{\text{cube}} = 1.25m$

For solving the equation to get a correct answer with units — 1 point

$\left(1000\ \text{kg/m}^3\right)/1.25 = m/V_{\text{cube}}$

$800\ \text{kg/m}^3 = \rho_{\text{cube}}$

Alternate solution — *Alternate Points*

Answer based on direct comparison of densities of water and the cube: since the buoyant force on the cube only depends on the density of water, and the net downward force only depends on the density of the cube, the ratio of densities can be determined.

For correctly substituting density and mass and determining the ratio of densities — *2 points*

$\rho_W V \cancel{g} = m\cancel{g} + 0.25m\cancel{g}$

$\rho_W V = 1.25m$

$\rho_W = 1.25\rho_{\text{cube}}$

Note: 2 points will be awarded for correctly writing down the ratio of the densities even without showing any work

For the correct answer — *1 point*

$\rho_{\text{cube}} = \rho_W/1.25 = \left(1000\ \text{kg/m}^3\right)/1.25 = 800\ \text{kg/m}^3$

Question 2 (continued)

Distribution of points

(c) 3 points

For any use of Newton's second law to sum the forces in the vertical direction — 1 point

$F_{net} = ma = F_B - F_g$

For correct substitution — 1 point

$ma = 1.25F_g - F_g = 0.25mg$

$a = 0.25g$

OR

$$F_B = \rho_W gV = \rho_W g\left(\frac{m}{\rho_{\text{cube}}}\right)$$

$$F_B = \left(1000\ \text{kg/m}^3\right)(g)\left(\frac{m}{800\ \text{kg/m}^3}\right)\text{, or } \rho_{\text{cube}} \text{ consistent with answer from (b)}$$

$$a = \frac{F_B - F_g}{m} = \frac{\left(1000\ \text{kg/m}^3\right)(g)\left(\dfrac{m}{800\ \text{kg/m}^3}\right) - mg}{m} = \left(\frac{1000}{800}\right)g - g$$

For calculating a correct answer, with units — 1 point

$a = 2.5\ \text{m/s}^2$

(d) 2 points

For selecting "Remains the same" — 1 point

For providing a correct explanation — 1 point

Example:

F_B relates to density, volume, and g, none of which change.

Note: If the wrong choice is selected, the explanation is not considered and no points are awarded.

Question 3

10 points total	**Distribution of points**

(a)

i. 2 points

For correctly ranking all 4 labeled points — 2 points

$\underline{1}\,A\quad \underline{2}\,B\quad \underline{4}\,C\quad \underline{3}\,D$

Note: one point is earned for a ranking that identifies A and C as having the lowest and highest temperatures, respectively, but incorrectly ranks B and D. For example:

$\underline{1}\,A\quad \underline{3}\,B\quad \underline{4}\,C\quad \underline{2}\,D$ or $\underline{1}\,A\quad \underline{2}\,B\quad \underline{3}\,C\quad \underline{2}\,D$

A and C cannot have the same ranking as other points (e.g., $\underline{1}\,A\quad \underline{1}\,B\quad \underline{2}\,C\quad \underline{2}\,D$)

ii. 1 point

For using the ideal gas law with correct substitutions for P, V, and n to get the correct answer — 1 point

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

$$T_D = \frac{P_0(4V_0)}{3R} = \frac{4P_0V_0}{3R} \text{ or } \frac{4P_0V_0}{(3\text{ mol})\bullet R}$$

Note: mole units need not be explicitly stated

(b) 2 points

For selecting "BC" only — 1 point

For providing a correct explanation — 1 point

Examples:

- For the gas to do positive work on its surroundings (or for work done on the gas to be negative), $P\Delta V$ must be positive so ΔV must be positive.
- An expanding gas exerts a force in the direction of motion, doing positive work.

(c) 2 points

"Positive" is the only box checked for which the Justify section will be read

For a correct explanation that mentions internal energy increases with the temperature increase. — 1 point

For a correct explanation that mentions the work is zero — 1 point

Example:

The volume does not change in process AB, hence the work done is zero. The temperature increase in AB means the internal energy increases. Since the work done is zero, the positive change in internal energy must be provided by heating.

Question 3 (continued)

	Distribution of points
(d) 3 points	
For a correct expression of net work done on the gas from segments BC and DA of the graph	1 point
$W_{net} = -(P\Delta V)_{BC} - (P\Delta V)_{DA}$	
For correctly substituting the values of P and ΔV into the above equation	1 point
$W_{net} = -(3P_0)(3V_0) - (P_0)(-3V_0) = -9P_0V_0 + 3P_0V_0 = -6P_0V_0$	
For having a final answer that is negative	1 point
Alternate Solution	*Alternate points*
For a correct expression or statement that the net work done on the gas is given by the area enclosed by the entire path	*1 point*
$W_{net} = -(\Delta P \bullet \Delta V)$	
For correctly substituting the values of P and ΔV into the above equation	*1 point*
$W_{net} = -(3P_0 - P_0)\bullet(4V_0 - V_0) = -2P_0 \bullet 3V_0 = -6P_0V_0$	
For having a negative answer	*1 point*

Question 4

10 points total | **Distribution of points**

(a) 2 points

For using and substituting values into the equation for the electric field magnitude due to a point charge, for both the x and y components — 1 point

$$E = \frac{kq}{r^2} \quad \text{or} \quad \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$

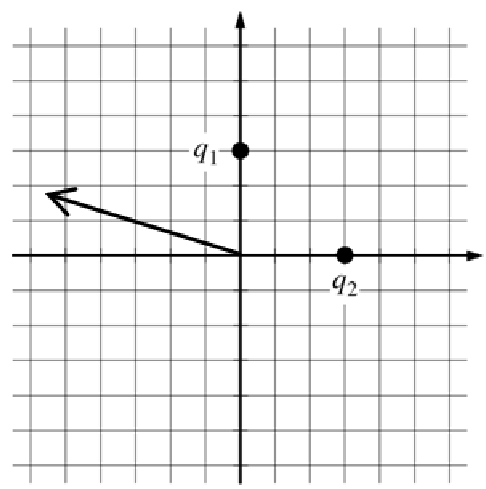
For correctly calculating the x and y component values with units — 1 point

$$\left|E_x\right| = \frac{\left(9 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2\right)\left(6 \times 10^{-9} \text{ C}\right)}{(3 \text{ m})^2} = 6.0 \text{ N/C} \quad (\text{or V/m})$$

$$\left|E_y\right| = \frac{\left(9 \times 10^9 \text{ N}\bullet\text{m}^2/\text{C}^2\right)\left(2 \times 10^{-9} \text{ C}\right)}{(3 \text{ m})^2} = 2.0 \text{ N/C} \quad (\text{or V/m})$$

Note: No points were deducted for omitting absolute-value symbols or showing incorrect signs, since direction is assessed in part (b)

(b) 2 points



For showing the direction of the net electric field in quadrant II — 1 point

For showing a direction of the net electric field consistent with the answers to part (a) — 1 point

(closer to the x-axis than to the y-axis if part (a) correctly has $\left|E_x\right| > \left|E_y\right|$,

or closer to the y-axis than to the x-axis if part (a) has $\left|E_y\right| > \left|E_x\right|$,

or at 45 degrees if part (a) has $\left|E_x\right| = \left|E_y\right|$

Note: The second point could be earned even if the vector was drawn in the wrong quadrant.

Question 4 (continued)

		Distribution of points
(c)	2 points	
	For using a correct expression for the potential at the origin as a scalar sum	1 point
	$V = \dfrac{kq_1}{r_1} + \dfrac{kq_2}{r_2}$	
	$V = \left(9 \times 10^9\ \text{N•m}^2/\text{C}^2\right)\left[\dfrac{\left(-2 \times 10^{-9}\ \text{C}\right)}{(3\ \text{m})} + \dfrac{\left(6 \times 10^{-9}\ \text{C}\right)}{(3\ \text{m})}\right]$	
	$= \left(9\ \text{N•m}^2/\text{C}^2\right)(4\ \text{C})/(3\ \text{m})$	
	For correctly calculating the potential, with units	1 point
	$\text{V} = 12\ \text{N•m/C}$ (or J/C or V)	
(d)	2 points	
	For selecting "Positive"	1 point
	For providing a correct explanation	1 point
	Example: Since $W = q\Delta V$ and both the charge and potential difference are positive, it takes positive work to move charge q_3 to the origin.	
(e)	2 points	
	For using Coulomb's law for the forces exerted on q_3 due to charges q_1 and q_2 OR For stating the relation between force and electric field components	1 point
	$F_x = \dfrac{k\lvert q_2 q_3\rvert}{r^2}$ and $F_y = \dfrac{k\lvert q_1 q_3\rvert}{r^2}$ OR $F_x = q_3 E_x$ and $F_y = q_3 E_y$	
	Calculate the components of **F**	
	$F_x = \dfrac{\left(9 \times 10^9\ \text{N•m}^2/\text{C}^2\right)\left(6 \times 10^{-9}\ \text{C}\right)\left(3 \times 10^{-9}\ \text{C}\right)}{3^2\ \text{m}^2} = 18 \times 10^{-9}\ \text{N} = 1.8 \times 10^{-8}\ \text{N}$	
	$F_y = \dfrac{\left(9 \times 10^9\ \text{N•m}^2/\text{C}^2\right)\left(2 \times 10^{-9}\ \text{C}\right)\left(3 \times 10^{-9}\ \text{C}\right)}{3^2\ \text{m}^2} = 6.0 \times 10^{-9}\ \text{N}$	
	OR	
	$F_x = q_3 E_x = (6.0\ \text{N/C})\left(3 \times 10^{-9}\ \text{C}\right) = 1.8 \times 10^{-8}\ \text{N}$	
	$F_y = q_3 E_y = (2.0\ \text{N/C})\left(3 \times 10^{-9}\ \text{C}\right) = 6.0 \times 10^{-9}\ \text{N}$	
	For substituting the calculated components into an expression for the magnitude of **F**	1 point
	$F = \sqrt{F_x^{\ 2} + F_y^{\ 2}} = \sqrt{\left(1.8 \times 10^{-8}\ \text{N}\right)^2 + \left(6.0 \times 10^{-9}\ \text{N}\right)^2}$	
	$= 1.9 \times 10^{-8}\ \text{N}$	

Question 4 (continued)

Distribution of points

(e) (continued)

Alternate Solution — *Alternate Points*

For calculating the net electric field as a vector sum of the components calculated in part (a) — *1 point*

$$E_{\text{net}} = \sqrt{E_x{}^2 + E_y{}^2} = \sqrt{(6\ \text{N/C})^2 + (2\ \text{N/C})^2} = 6.2\ \text{N/C}$$

For substituting into the relationship between force and electric field and using the value of charge q_3 — *1 point*

$$F_{net} = qE_{net} = q_3E = \left(3 \times 10^{-9}\ \text{C}\right)(6.32\ \text{N/C}) = 1.9 \times 10^{-8}\ \text{N}$$

Question 5

15 points total | **Distribution of points**

(a) 2 points

The correct choice is "Q".

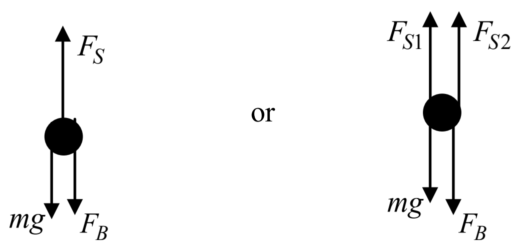
Note: Selecting "Q" earned no points, but was required in order to earn credit for a correct justification.

For recognizing that the current must be to the left in the rod (or clockwise in the circuit) — 1 point

For a complete explanation with no incorrect statements — 1 point

Example: In order to stretch the springs, the magnetic force must be downward. According to the right hand rule, this requires a current to the left in the rod. Therefore, the positive terminal of the battery must be connected to point Q.

(b) 2 points



Note: The spring force may be represented either as a single combined force or as two separate forces due to the two springs.

For the spring force (or forces) drawn upward and properly labeled (with no additional upward forces) — 1 point

For the magnetic and gravitational forces drawn downward and properly labeled (with no additional downward forces) — 1 point

One earned point is deducted for any of the following:

- Any horizontal forces
- Any vector that is not distinct and/or does not both touch and point away from the dot
- The vectors are not reasonably straight and reasonably vertical

(c) 4 points

For using a correct expression for Newton's second law — 1 point

Using a single spring force: $F_S - mg - F_B = 0$ or $F_S = mg + F_B$

Using two spring forces : $F_{S1} + F_{S2} - mg - F_B = 0$ or $F_{S1} + F_{S2} = mg + F_B$

For any recognition, implicit or explicit, that mg is balanced by the original stretch in the springs and ultimately not part of this calculation — 1 point

The spring force is $2k\Delta y$. It is not necessary to explicitly show how the original spring force is canceled by mg.

$2k\Delta y = F_B$

For correctly substituting BIL for the magnetic force — 1 point

$2k\Delta y = BIL$

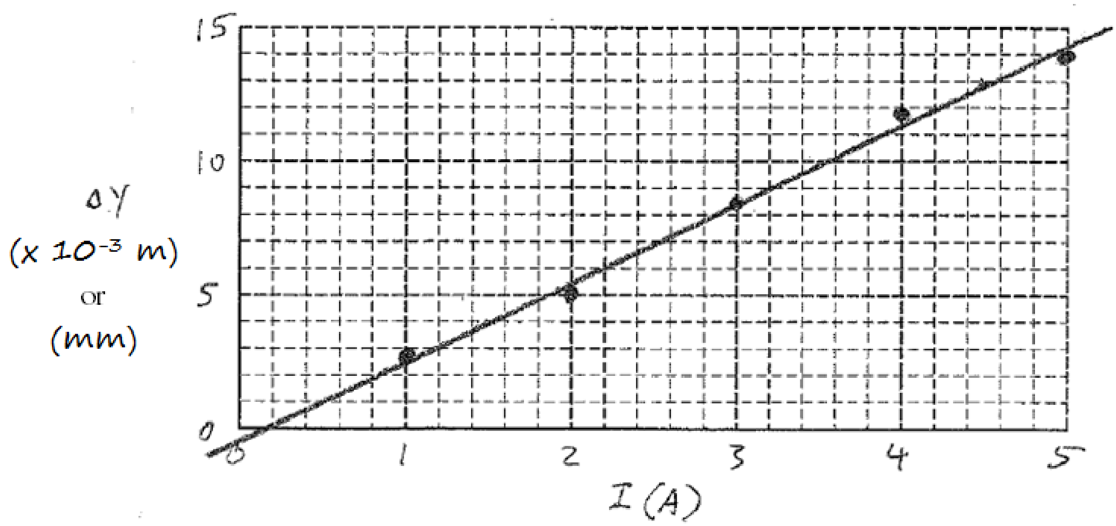
For solving for Δy to get a correct answer — 1 point

$\Delta y = BIL/2k$

Question 5 (continued)

Distribution of points

(d) 4 points



For correctly labeling both axes with variables and units — 1 point

Note: This point is not earned if axes are labeled with I as a function of Δy.

For using an appropriate linear scale on both axes — 1 point

For correctly plotting the points — 1 point

For drawing a reasonable and straight best fit line for the data — 1 point

Note: The point (0, 0) may be included in the plot without penalty since it is also a data point, though unmeasured and unrecorded.

(e) 3 points

For obtaining a relationship between the slope and the magnetic field B consistent with part (c). — 1 point

From part (c): $\Delta y = \dfrac{BIL}{2k} = \dfrac{BL}{2k} I$

$$\text{slope} = \frac{BL}{2k} \quad \text{so} \quad B = \frac{2k\bullet\text{slope}}{L}$$

For calculating a slope using *two* points on the line drawn in part (d), including data points *only* if they are on that line — 1 point

Example: Using the two points (5.0 A, 14.2 mm) and (1.2 A, 3.0 mm) that are on the line in the graph above.

$$\text{slope} = \left(\frac{14.2 - 3.0}{5.0 - 1.2}\right)\bullet\frac{10^{-3}\ \text{m}}{\text{A}} = \frac{11.2}{3.8} \times 10^{-3}\ \frac{\text{m}}{\text{A}} = 2.95 \times 10^{-3}\ \frac{\text{m}}{\text{A}}$$

For a substitution of values into the expression for the magnetic field B consistent with part (c) and the calculated slope — 1 point

$$B = \frac{2\bullet(25\ \text{N/m})\bullet(2.95 \times 10^{-3}\ \text{m/A})}{0.35\ \text{m}} = 0.42\ \text{N/A}\bullet\text{m} \text{ or } 0.42\ \text{T}$$

Question 6

10 points total | **Distribution of points**

(a) 1 point

For correctly calculating the wavelength, with units — 1 point

$c = \lambda f$

$$\lambda = \frac{c}{f} = \frac{\left(3.00 \times 10^{8} \text{ m/s}\right)}{\left(7.5 \times 10^{14} \text{ Hz}\right)}$$

$\lambda = 4.0 \times 10^{-7}$ m or 400 nm

(b) 3 points

For using a correct expression relating frequency f, work function ϕ, and maximum electron kinetic energy K_{max} — 1 point

$K_{max} = hf - \phi$ or $\phi = hf - K_{max}$

For recognizing that the maximum electron kinetic energy is equal to $e\mathcal{E}$. — 1 point

$\phi = hf - e\mathcal{E}$

For correctly calculating the answer (with or without the correct units) — 1 point

$\phi = \left(4.14 \times 10^{-15} \text{ eV}\bullet\text{s}\right)\left(7.5 \times 10^{14} \text{ Hz}\right) - e\bullet(0.65 \text{ V}) = 3.10 \text{ eV} - 0.65 \text{ eV}$

$\phi = 2.45 \text{ eV} \quad \left(\text{or } 3.92 \times 10^{-19} \text{ J}\right)$

Note: ϕ can also be calculated using $f = c\lambda$ and $hc = 1240$ eV•nm

$\phi = hf - K_{max} = hc/\lambda - K_{max}$

$= (1240 \text{ eV}\bullet\text{nm})/(400 \text{ nm}) - 0.65 \text{ eV}$ (or use wavelength obtained in part (a))

$= 3.10 \text{ eV} - 0.65 \text{ eV}$

$\phi = 2.45 \text{ eV} \quad \left(\text{or } 3.92 \times 10^{-19} \text{J}\right)$

(c) 2 points

For an expression or statement that K_{max} is zero at the threshold frequency — 1 point

$K_{max} = 0 = hf_0 - \phi$

For correctly substituting the answer from part (b) into a correct expression to calculate the threshold frequency — 1 point

$f_0 = \phi/h = (2.45 \text{ eV})\big/\left(4.14 \times 10^{-15} \text{ eV}\bullet\text{s}\right)$ or $\left(3.92 \times 10^{-19} \text{ J}\right)\big/\left(6.63 \times 10^{-34} \text{ J}\bullet\text{s}\right)$

$f_0 = 5.92 \times 10^{14}$ Hz

Question 6 (continued)

Distribution of points

(c) continued

Alternate solution	*Alternate points*
For using a correct expression containing the threshold frequency	*1 point*
$K_{max} = h(f - f_0)$	
$f_0 = f - (K_{max}/h)$	
Converting from eV to joules and substituting values	
$K_{max} = (0.65\ \text{eV})\left(1.60 \times 10^{-19}\ \text{J/eV}\right) = 1.04 \times 10^{-19}\ \text{J}$	
$f_0 = 7.5 \times 10^{14}\ \text{Hz} - \left(1.04 \times 10^{-19}\ \text{J}/6.63 \times 10^{-34}\ \text{J•s}\right)$	
For a correct answer with units	*1 point*
$f_0 = 5.93 \times 10^{14}\ \text{Hz}$	
Note: The conversion to joules is shown for illustrative purposes and not required.	

(d) 2 points

The correct choice is "Remains the same". Selecting it earned no points, but was required in order to earn credit for the justification.	
For indicating that the energy of the photons (and hence the zero-current emf) depends on frequency or wavelength	1 point
For indicating that the intensity does NOT change the energy of the photons or photoelectrons (it only affects the number of photoelectrons produced) so it does not affect the zero-current emf (stopping potential)	1 point
Example: The maximum kinetic energy of emitted electrons, and therefore the emf to stop the current, depends on the frequency (or wavelength) of the light source and the metal's work function. It does not depend on the intensity of the light.	

(e) 2 points

The correct choice is "Decreases". Selecting it earned no points, but was required in order to earn credit for the justification.	
For indicating that shorter wavelength (or higher frequency) photons have more energy	1 point
For indicating that (since the photons have more energy and the intensity stays the same) there must be fewer photons; therefore fewer electrons are emitted	1 point
Example: As the wavelength of the light source decreases, the frequency and energy of each photon increases and therefore fewer photons are incident on the metal to maintain a constant intensity. Fewer photons result in fewer photoelectrons.	

Question 7

10 points total | **Distribution of points**

(a) 1 point

The wavelength and frequency are related by $c = \lambda f$

$$f = \frac{c}{\lambda} = \frac{\left(3 \times 10^{8}\ \text{m/s}\right)}{\left(520 \times 10^{-9}\ \text{m}\right)}$$

For a correct answer — 1 point

$$f = 5.77 \times 10^{14}\ \text{Hz}$$

(b) 1 point

The frequency does not change when light travels in a different medium

For an answer that is consistent with part (a) — 1 point

$$f = 5.77 \times 10^{14}\ \text{Hz}$$

(c) 2 points

For using a correct expression for the wavelength in oil — 1 point

$$\lambda_{\text{oil}} = \frac{\lambda_{\text{air}}}{n} \quad \text{or} \quad \lambda = \frac{\upsilon_{\text{oil}}}{f}$$

The second equation can be manipulated to obtain the first equation:

$$\lambda_{oil} = \frac{\upsilon}{f} = \frac{c/n}{f} = \frac{c}{f}\frac{1}{n} = \frac{\lambda_{air}}{n}$$

$$\lambda_{oil} = \frac{(520\ \text{nm})}{1.52}$$

For a correct numerical answer — 1 point

$$\lambda_{oil} = 342\ \text{nm}$$

Units 1 point

For correct units in two of the calculated responses in parts (a), (b), and (c) — 1 point

(d) 3 points

For selecting "Greater than" — 1 point

For mentioning that there must be a phase shift upon reflection at both interfaces — 1 point

For mentioning interference — 1 point

Example: There is constructive interference for the observed light. In the oil, the light traverses the oil thickness two times: $2 \times 171\ \text{nm} = 342\ \text{nm}$, or one wavelength in the oil. For constructive interference, reflections at the two interfaces must then have the same phase shift. Since the refractive index increases at the air-to-oil surface, it must also increase at the oil-to-plate surface, so $n_{\text{plate}} > n_{\text{oil}}$.

Question 7 (continued)

	Distribution of points
(e) 2 points	
For mentioning that the color shifts toward the red end of the visible spectrum	1 point
For mentioning that the light's path length in the oil increases	1 point

Example:

As the observer views the film from a larger angle, the light must travel a greater distance in the film. This creates constructive interference for a longer wavelength of light and causes the apparent film color to shift toward the red end of the visible spectrum.