2022

AP® | CollegeBoard

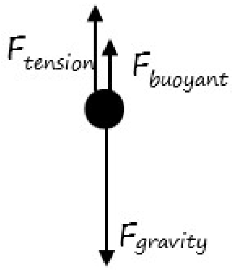
AP® Physics 2: Algebra-Based

Scoring Guidelines

Question 1: Short Answer Paragraph Argument — 10 points

(a)(i) For correctly drawing and labeling the gravitational, buoyant, and tension forces with no extraneous forces — **1 point**

Example Response



(a)(ii) For an application of Newton's laws that is correct or consistent with the diagram in part (a)(i) and indicates zero net force — **1 point**

For a correct substitution of the buoyant force into a solution that is consistent with the previous equation — **1 point**

Scoring Note: A correct answer with no supporting work earns this point.

Example Response

$$\Sigma\vec{F} = m\vec{a}$$

$$F_T + F_B - F_g = 0$$

$$F_T + F_B = F_g$$

$$F_T = F_g - F_B$$

$$F_T = m_b g - \rho_w V_b g$$

Total for part (a) 3 points

(b) For correctly relating the speed of the light in the new medium to the index of refraction — **1 point**

For indicating that the frequency does not change — **1 point**

For a correct relationship between speed and wavelength — **1 point**

For a correct relationship between wavelength and fringe separation — **1 point**

For a logical, relevant, and internally consistent argument that addresses the question asked and follows the guidelines described in the published requirements for the paragraph-length response — **1 point**

Example Response

The speed of light in the new fluid is less than the speed of light in water because the fluid has a greater index of refraction. This means that the wavelength of the light in the beam will be smaller because the frequency does not change. Since the wavelength is smaller, the angular separation of the bright fringes will decrease, as described by the equation $m\lambda = d\sin\theta$.

Total for part (b) 5 points

(c)	For explicitly indicating that the amount of refraction at the fluid-prism interface depends on the ratio of the indices of refraction of the materials **Scoring Note:** Basing the explanation on the difference in refractive indices is acceptable.	**1 point**
	For correctly relating a larger angle of refraction to the beam hitting the screen below point P	**1 point**

Example Response

The beam refracts more when the air is present because the difference between the indices of refraction between the prism and the surrounding medium is greater. So, the beam hits the screen below point P.

Total for part (c) 2 points

Total for question 1 10 points

Question 2: Experimental Design — 12 points

(a) For a correct ranking — **1 point**

__1__ ΔV_A __1__ ΔV_B __3__ ΔV_C __2__ ΔV_D

For indicating that the resistors in parallel will have the same potential difference — **1 point**

For a justification that indicates $\Delta V_D > \Delta V_C$ because $R_D = 2R_C$ — **1 point**

Total for part (a) — 3 points

(b)(i) For calculating the correct value of the charge on the $200\,\mu\text{F}$ capacitor, including units — **1 point**

Example Response

$$\Delta V = \frac{Q}{C}$$

$$Q = C\Delta V = (200\,\mu\text{F})(0.91\text{ V})$$

$$Q = 1.82 \times 10^{-4}\text{ C}$$

(b)(ii) For indicating one of the following as evidence that the capacitors are in series: — **1 point**

- the potential differences across the capacitors are different
- the sum of the potential differences across the capacitors is constant
- the sum of the potential differences across the capacitors is approximately equal to the potential difference across the battery

(b)(iii) For an explanation that correctly addresses one of the following: — **1 point**

- that the potential differences across the known and unknown capacitor will always be the same
- that the charge on the unknown capacitor cannot be determined

Example Response

Both charge and potential difference across the capacitor are needed to determine C. Arranging the capacitors in parallel will mean both capacitors will have the same potential difference. However, capacitors in parallel will have differing amounts of charge, making it impossible to determine the charge, and, therefore, the capacitance of the unknown capacitor.

Total for part (b) — 3 points

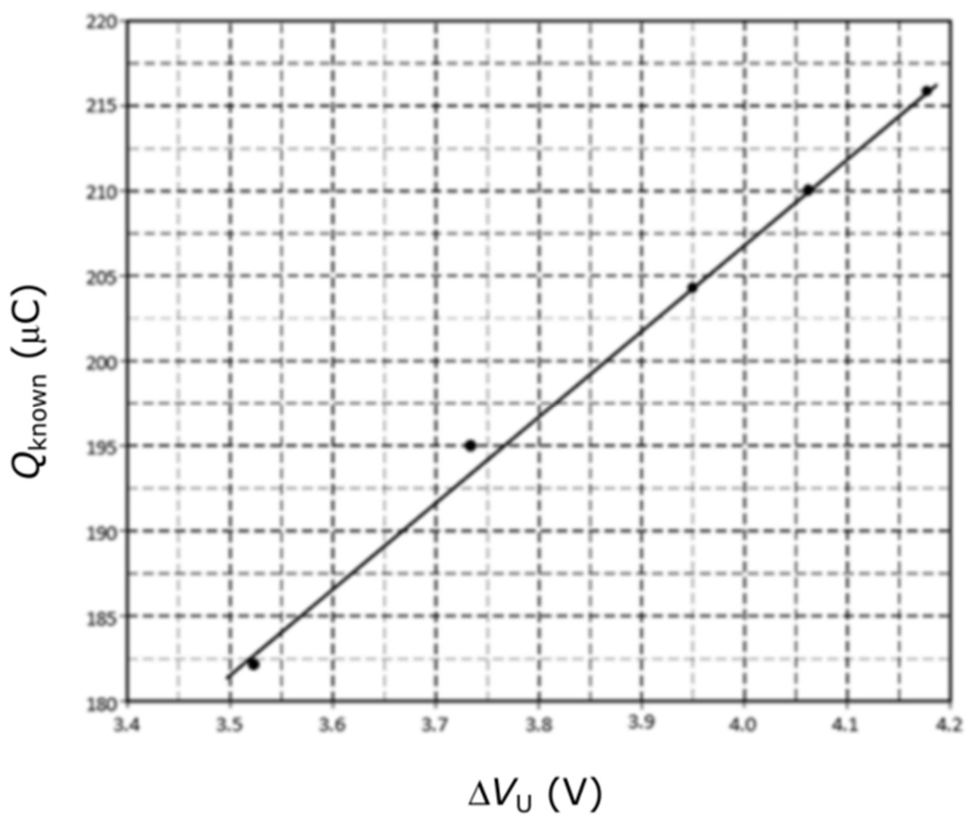
(c)(i)	For choosing two quantities that will produce a linear plot that can be used to find C_U	**1 point**

Example Responses

- Q_{known} $(C_{known}\Delta V_{known})$ and ΔV_U
- Q_U and ΔV_U
- C_{known} and $\dfrac{\Delta V_U}{\Delta V_{known}}$

(c)(ii)	For labeling the axes and including appropriate units consistent with Part (c)(i)	**1 point**
	For correctly plotting points (with valid scaling consistent with units) so that the plotted points cover at least half of the grid's width and height	**1 point**
	For drawing an appropriate linear best-fit line	**1 point**

Example Response



(c)(iii)	For using points on the best-fit line to calculate the slope of the line	**1 point**
	For correctly determining the capacitance from the slope of the line	**1 point**

Example Response

Capacitance is equal to slope

$$C_U = \frac{212\ \mu C - 190\ \mu C}{4.10\ V - 3.67\ V}$$
$$C_U = 51.2\ \mu F$$

Total for part (c) 6 points

Total for question 2 12 points

Question 3: Quantitative/Qualitative Translation — 12 points

(a) For indicating that the electrostatic force is equal to the net (centripetal) force on the electron, with a correct expression for each — **1 point**

Example Response

$$\Sigma\vec{F} = m\vec{a}$$
$$F_E = F_C$$
$$\frac{kq^2}{r^2} = \frac{mv^2}{r}$$

Scoring Note: An incorrect mass label is acceptable to earn this point.

For using the expressions for the electrostatic and net forces to determine the speed v of the electron (responses must indicate that the mass in the expression represents the mass of the electron and the charge in the expression represents the charge of the electron) — **1 point**

Example Response

$$\frac{ke^2}{r^2} = \frac{m_e v^2}{r}$$
$$v^2 = \frac{ke^2}{m_e r}$$
$$v = \sqrt{\frac{ke^2}{m_e r}}$$

Scoring Note: q_e and q_p are acceptable.

Total for part (a) — 2 points

(b) For a correct expression for electric potential energy, using charges consistent with charges from part (a) — **1 point**

Example Response

$$U = -\frac{ke^2}{r}$$

For a correct expression for kinetic energy of the electron, including a substitution consistent with the expression from part (a) to eliminate speed from the equation — **1 point**

Example Response

$$K = \frac{1}{2}m_e\left(\frac{ke^2}{m_e r}\right) = \frac{1}{2}\frac{ke^2}{r}$$

	For indicating that the total energy of the atom is the sum of the electric potential energy and the kinetic energy of the electron	**1 point**

Example Response

$$E = U + K$$

$$E = -\frac{ke^2}{r} + \frac{1}{2}\frac{ke^2}{r}$$

$$E = -\frac{ke^2}{2r}$$

	Total for part (b)	**3 points**
(c)	For correctly indicating consistency between the equation in part (b) and the description with an explanation that references the equation in part (b)	**1 point**
	For correctly addressing functional dependence of the energy equation from part (b) to the orbital radius of the electron	**1 point**

Example Response

The equation from part (b) indicates that as the radius increases, the total energy of the atom becomes less negative, which is an increase in the total energy. This is consistent with the given description of the atom absorbing a photon.

	Total for part (c)	**2 points**
(d)(i)	For a correct calculation of the energy of the photon	**1 point**

Example Response

$$E = hf$$

$$E = (6.63 \times 10^{-34} \text{ J} \cdot \text{s})(3.2 \times 10^{15} \text{ Hz})$$

$$E = 2.12 \times 10^{-18} \text{ J}$$

(d)(ii)	For a correct calculation of the mass-energy of an electron	**1 point**

Example Response

$$E = mc^2$$

$$E = (9.11 \times 10^{-31} \text{ kg})(3.00 \times 10^{8} \text{ m/s})^2$$

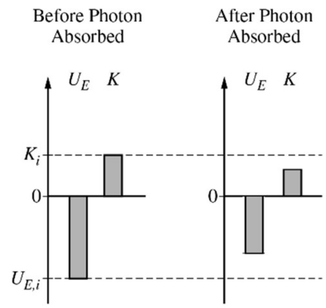
$$E = 8.20 \times 10^{-14} \text{ J}$$

	For correctly indicating that the photon energy is negligible compared to the mass energy of the electron (or an answer that is consistent with the energies calculated in part (d)(i) and part (d)(ii))	**1 point**

Scoring Note: The energy comparison must be from the unit of joules to joules or the unit of electron volts to electron volts in order for this point to be earned.

(d)(iii)	For U smaller in magnitude but still negative	**1 point**
	For K smaller in magnitude but still positive	**1 point**

Example Response



Total for part (d) 5 points

Total for question 3 12 points

Question 4: Short Answer — 10 points

(a)	For an appropriate use of Newton's laws to set the magnetic force equal to the electric force	**1 point**
	For using correct expressions for the magnetic and electric forces	**1 point**
	For substituting an expression for the magnetic field to yield a correct expression that includes v and the given quantities	**1 point**

Example Response

$\Sigma\vec{F} = m\vec{a}$

$F_M - F_E = 0$

$F_M = F_E$

$qvB = qE$

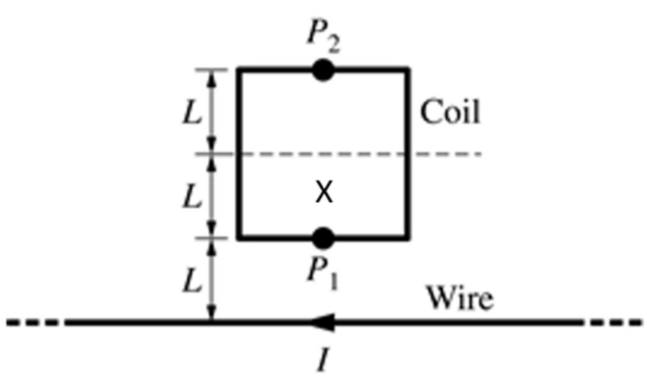
$v\left(\frac{\mu_0 I}{2\pi d}\right) = E$

$v = \frac{2\pi dE}{\mu_0 I}$

Total for part (a) — 3 points

(b)(i)	For an "X" between point P_1 and the dashed line	**1 point**

Example Response



For indicating that the magnetic field strength is inversely proportional to the distance from the wire — **1 point**

Example Response

Magnetic field is inversely proportional to the distance from a long, straight current carrying wire: $B = \frac{\mu_0 I}{2\pi r}$ *. Doubling the distance from the wire from* L *to* $2L$ *would reduce the magnetic field from* $3B_0$ *to* $1.5B_0$*. Therefore, the magnetic field would be equal to* $2B_0$ *somewhere between* L *and* $2L$ *.*

(b)(ii)	For using the change in flux, with correct substitutions, to determine the emf	**1 point**
	For correctly applying Ohm's law with correct substitutions	**1 point**

Scoring Note: It is not necessary to independently calculate a numerical value for the emf.

Example Response

$$|\mathcal{E}| = \left|-\frac{\Delta\Phi_B}{\Delta t}\right| = \frac{\left(5.0\times10^{-5} - 1.0\times10^{-5}\right)\ \text{T}\bullet\text{m}^2}{2.0\ \text{s}} = 2.0\times10^{-5}\ \text{V}$$

$$I = \frac{|\mathcal{E}|}{R} = \frac{2.0\times10^{-5}\ \text{V}}{10\ \Omega} = 2.0\times10^{-6}\ \text{A}$$

Total for part (b) 4 points

(c)	For indicating that the current in the round coil produces a magnetic field	**1 point**
	For indicating that the magnetic field from the round coil produces a flux through the square coil	**1 point**
	For indicating that the changing flux produces an emf or current in the square coil circuit	**1 point**

Scoring Note: A response that indicates that the magnetic flux only changes during a portion of the entire time interval does not earn this point.

Example Response

The current in the round coil produces a magnetic field. The magnetic field from the round coil passes through the square coil, producing a flux. As the current in the power supply increases, so does the current in the round coil, and, therefore, the magnetic field created by the current increases. Since the magnetic field changes, the flux through the square coil changes. The constantly changing magnetic flux through the square coil produces an emf and, therefore, current in the square coil to light the lightbulb.

Total for part (c) 3 points

Total for question 4 10 points