General Notes About 2009 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point and a student's solution contains the application of that equation to the problem, but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 3

15 points total	**Distribution of points**

(a) 3 points

For a correct statement of Ohm's law (symbolic or numeric) — 1 point

For a correct statement of Faraday's law (symbolic or numeric) — 1 point

$$I = \frac{\mathcal{E}}{R} = \frac{B\ell v}{R}$$

$$I = \frac{(0.80\ \text{T})(0.52\ \text{m})(1.8\ \text{m/s})}{3.0\ \Omega}$$

For the correct answer — 1 point

$I = 0.25\ \text{A}$

(b) 4 points

For a correct expression for the friction force (symbolic or numeric) — 1 point

$F_f = \mu_k mg$

$F_f = (0.20)(0.22\ \text{kg})\left(9.8\ \text{m/s}^2\right)$

$F_f = 0.43\,\text{N}$ (0.44 N using $g = 10\ \text{m/s}^2$)

For a correct expression for the magnetic force (symbolic or numeric) — 1 point

$F_B = BI\ell$

$F_B = (0.80\ \text{T})(0.25\ \text{A})(0.52\ \text{m})$

$F_B = 0.10\,\text{N}$

For any indication of multiple forces (explicit, implied, free-body diagram, etc.) — 1 point

$F = F_f + F_B$

For a correct answer consistent with the current from part (a) — 1 point

$F = 0.43\ \text{N} + 0.10\ \text{N} = 0.53\ \text{N}$ (0.54 N using $g = 10\ \text{m/s}^2$)

(c) 3 points

For a correct expression for energy (including time) — 1 point

$E_{diss} = Pt$

For a correct expression for power (individually or in another expression) — 1 point

$P = I^2R$ OR $P = IV$ OR $P = V^2/R$

For consistent substitution of current or voltage from part (a) into a correct equation — 1 point

$E_{diss} = I^2Rt$ OR $E_{diss} = IVt$ OR $E_{diss} = V^2t/R$

For example:

$E_{diss} = (0.25\ \text{A})^2(3.0\ \Omega)(2.0\ \text{s})$

$E_{diss} = 0.38\ \text{J}$

Question 3 (continued)

Distribution of points

(d) 2 points

For a correct expression for distance — 1 point

$d = vt$

$d = (1.8\ \text{m/s})(2.0\ \text{s})$

$d = 3.6\ \text{m}$

For a consistent substitution of force from part (b) — 1 point

$W = Fd$

$W = (0.54\ \text{N})(3.6\ \text{m})$

$W = 1.9\ \text{J}$

Full credit could also be given for equivalent solutions (e.g., combining the expression $P = Fv$ for power with the expression $W = Pt$ for work to get $W = Fvt$, followed by consistent substitutions).

(e) 2 points

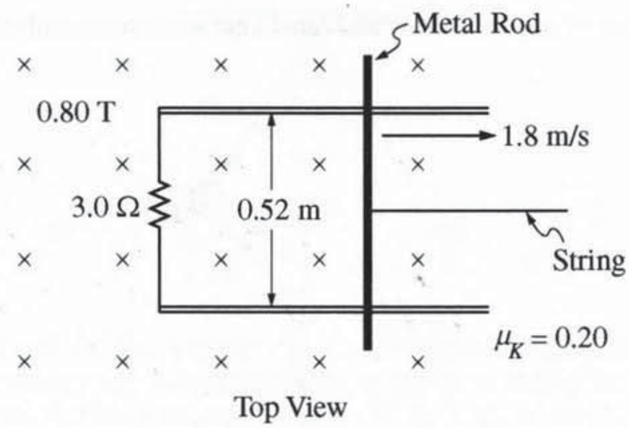
For mentioning the force of friction but not including the concept of work — 1 point

For including a statement that friction does work or dissipates energy — 1 point

Note: If the answer for part (d) is less than or equal to the answer for part (c), no credit was given.

Units point

For correct units on <u>all</u> numerical answers — 1 point



3. (15 points)

A metal rod of mass 0.22 kg lies across two parallel conducting rails that are a distance of 0.52 m apart on a tabletop, as shown in the top view above. A 3.0 Ω resistor is connected across the left ends of the rails. The rod and rails have negligible resistance but significant friction with a coefficient of kinetic friction of 0.20. There is a magnetic field of 0.80 T perpendicular to the plane of the tabletop. A string pulls the metal rod to the right with a constant speed of 1.8 m/s.

(a) Calculate the magnitude of the current induced in the loop formed by the rod, the rails, and the resistor.

$\varepsilon = B\ell v$

$\varepsilon = .8 \cdot .52 \cdot 1.8 = .7488\ V$

$V = IR$

$.7488 = I \cdot 3 \quad I = .2496\ A$

(b) Calculate the magnitude of the force required to pull the rod to the right with constant speed.

$F_B = BI\ell$

Friction $= \mu N = .2 \cdot (.22 \cdot 9.8)$
$= .4312\ N$

$F_B = .8 \cdot .2496 \cdot .52$

$F_B = .104\ N$

$F_T =$ Friction $+ F_B = .5352\ N$

(c) Calculate the energy dissipated in the resistor in 2.0 s.

$P = IV$

$P = .2496 \cdot .7488$

$P = .1869\ W$

$.1869 \cdot 2 = .3738\ W$

(d) Calculate the work done by the string pulling the rod in 2.0 s.

$W = FS$

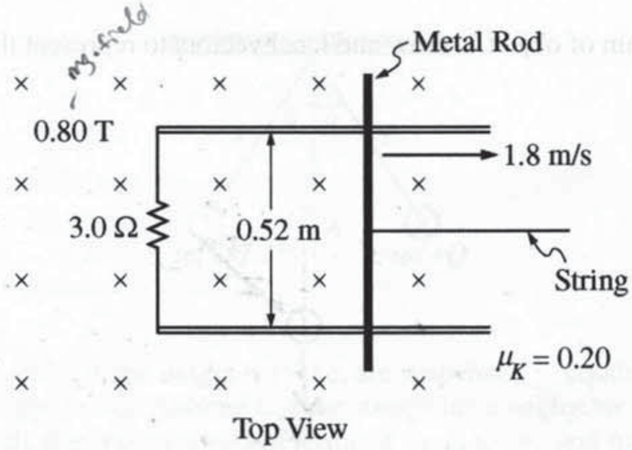
$W = .5352 \cdot (1.8 \cdot 2)$

$W = 1.93\ J$

$1.93 \cdot 2 = 3.86\ J$

(e) Compare your answers to parts (c) and (d). Provide a physical explanation for why they are equal or unequal.

They are unequal because the friction is causing the string to need to exert a greater force to keep a constant speed. The force increases the work done by the string.



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(a) Calculate the magnitude of the current induced in the loop formed by the rod, the rails, and the resistor.

$\mathcal{E} = Blv$

$\mathcal{E} = (.8\,T)(.52\,m)(1.8\,m/s)$

$\mathcal{E} = .748\,V$

$V = IR$

$.748\,V = I(3\,\Omega)$

$I = .250\,A$

(b) Calculate the magnitude of the force required to pull the rod to the right with constant speed.

$F = BIl\sin\theta$

$F = (.8\,T)(.25\,A)(.52\,m)(1)$

$F = .104\,N$

$F_f = \mu F_N$

$= \mu(mg)$

$= .2(.22\,kg)(9.8\,m/s^2)$

$F_f = .431\,N$

$\Sigma F = F + F_f = .104 + .431 =$

$.535\,N$

(c) Calculate the energy dissipated in the resistor in 2.0 s.

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

$= \frac{1}{2}(.22\,kg)(1.8\,m/s)^2$

$E = .356\,J$

(d) Calculate the work done by the string pulling the rod in 2.0 s.

$W = Fd, \; d = vt$

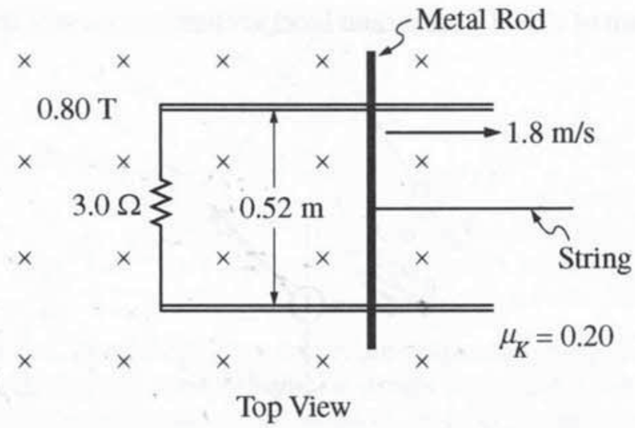
$W = F(vt)$

$W = (.535\,N)(1.8\,m/s)(2\,s)$

$W = 1.93\,J$

(e) Compare your answers to parts (c) and (d). Provide a physical explanation for why they are equal or unequal.

they are not equal because there is less energy dissipated than work done.



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(a) Calculate the magnitude of the current induced in the loop formed by the rod, the rails, and the resistor.

$I = ?$
$m = .22\,kg$
$\ell = .52\,m$
$R = 3\,\Omega$
$\mu = .2$
$B = .8\,T$
$v = 1.8\,m/s$

$\Phi_m = BA\cos\theta$
$\Delta\Phi_m = (.8T)(.52)(1.8\Delta T)$
$\mathcal{E}_{avg} = -\frac{\Delta\Phi_m}{\Delta T} = -\frac{(.8)(.52)(1.8)(\Delta T)}{\Delta T}$
$\mathcal{E}_{avg} = .75$
$F_B = BI\ell\sin\theta$
$.2 = (.8)I(.52)\sin 90$

$A = L \times W$
$A = .52m(1.8t)$

$I = .48$

(b) Calculate the magnitude of the force required to pull the rod to the right with constant speed.

$F = ma$

$F_{frict} \leq \mu N$

$F_{frict} = (.2)(9.8) = 1.96$

(c) Calculate the energy dissipated in the resistor in 2.0 s.

$V = IR$

$V = (.48)(3) = 1.44\,V$

(d) Calculate the work done by the string pulling the rod in 2.0 s.

$W = Fd$

$W = (1.96)(3.6) = 7.1$

$d = vt$

$d = (1.8)(2) = 3.6$

(e) Compare your answers to parts (c) and (d). Provide a physical explanation for why they are equal or unequal.

They are unequal because you can't get more energy than you put in, Law of conservation.

Question 3

Overview

This question assessed students' understanding of Ohm's law, Faraday's law, induced magnetic force, the application of Newton's second law, and the influence of a friction force on the given system.

Sample: B-3A
Score: 13

Part (a) is correct and earned 3 points. Part (b) is correct and earned 4 points. Part (c) is correct except for the units on the final answer, so 3 points were earned. In part (d) 1 point was earned for correctly calculating the distance, but an extra factor of "2" that appears in the subsequent calculation resulted in the loss of the second point. The response to part (e) is satisfactory and earned 2 points. The units point was not earned because of the incorrect units in part (c).

Sample: B-3B
Score: 10

Parts (a) and (b) are correct and earned 3 and 4 points, respectively. Part (c) does not have any expressions related to electrical energy and thus earned no points. Part (d) is correct, earning 2 points. Part (e) makes no statements about physical causes, and so no points were earned. The response earned the units point.

Sample: B-3C
Score: 4

A correct expression for Faraday's law is given in part (a), earning 1 point. In part (b) a correct expression for the force of friction is given, also earning 1 point. No correct expressions for energy or power are given in part (c) so no points were earned. In part (d) the method of solution is correct, using a consistent substitution from part (b), so 2 points were earned. The statement in part (e) earned no points. The units point was also not earned since no correct units are given with any answers.