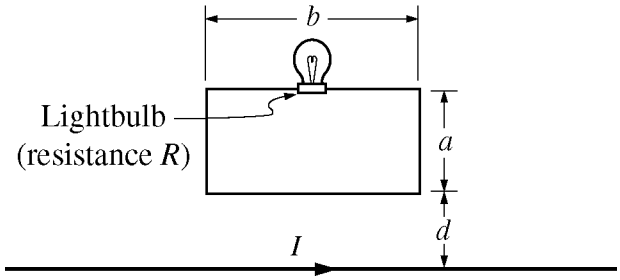

E&M. 3.

The long straight wire illustrated above carries a current I to the right. The current varies with time t according to the equation $I = I_0 - Kt$, where I_0 and K are positive constants and I remains positive throughout the time period of interest. The bottom of a rectangular loop of wire of width b and height a is located a distance d above the long wire, with the long wire in the plane of the loop as shown. A lightbulb with resistance R is connected in the loop. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Indicate the direction of the current in the loop.

____Clockwise ____Counterclockwise

Justify your answer.

(b) Indicate whether the lightbulb gets brighter, gets dimmer, or stays the same brightness over the time period of interest.

____Gets brighter ____Gets dimmer ____Remains the same

Justify your answer.

(c) Determine the magnetic field at $t = 0$ due to the current in the long wire at distance r from the long wire.

(d) Derive an expression for the magnetic flux through the loop as a function of time.

(e) Derive an expression for the power dissipated by the lightbulb.

END OF EXAM

AP® PHYSICS C: ELECTRICITY AND MAGNETISM
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Question 3

15 points total **Distribution of points**

(a) 4 points

For a correct indication that the current in the loop is in the counterclockwise direction — 1 point
For indicating that the magnetic field through the loop is directed out of the page (which can be done on the diagram) — 1 point
For indicating that the current in the wire is decreasing, either explicitly or by indicating a decrease in field or flux through the loop — 1 point
For indicating that the direction of the induced current is such as to oppose the change in flux — 1 point
Example: The flux due to current I is out of the plane of the page (by the right-hand rule) and is decreasing with time. The induced current will be in the direction that will produce a compensating flux (by Lenz's law). Again using a right-hand rule, the current must be counterclockwise.

(b) 2 points

For a correct indication that the brightness of the lightbulb remains the same — 1 point
For a correct justification — 1 point
Example: The field and the flux both vary linearly with time. The emf, which is the time derivative of the flux, must then be constant. Since the power output of the lightbulb depends only on the emf and resistance (which are both constant), the power must be constant.

(c) 2 points

$$\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$$

$$B 2\pi r = \mu_0 I$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$B = \left.\frac{\mu_0 I}{2\pi r}\right|_{t=0}$$

For the correct answer — 2 points

$$B = \frac{\mu_0 I_0}{2\pi r}$$

One point partial credit could be earned for either correctly applying Ampere's law and leaving the result in terms of I, or obtaining an incorrect expression for B in terms of I_0.