Electromagnetic Induction — Self-Inductance

A Physics ETT Induction

A 12V supply is connected to an ammeter, a switch, an inductor (inductance 8 Henries, resistance 4Ω) and a resistor ($R = 20\Omega$), all in series.

The inductor and resistor each have a voltmeter across them. (The voltmeters each have a high but not infinite resistance.)

(a) Draw the circuit. (6)

(b) At the moment the switch is closed....
what is (b) – current ?
(c) – p.d. across coil ?
(d) – pd across the resistor? (3)

(e) What are the final steady values of these three quantities? (I, V_{coil}, $V_{resistor}$) (2+1+2)

(f) The switch is then opened.
What happens to the readings at end of the 3 meters? (3)

(g) Sketch a graph of current against time (put in suitable scales) (4)

(h) Sketch a graph showing how the 2 voltages change with time. (again, suitable scales) (5)

(i) Can you explain why the p.d. across the coil changes as it does when the switch is opened? ($V_0 = 0$) (3)

(j) Can you sketch a graph to show how current rises from zero to its final value after switching on.
Calculate + show the initial rate of current rise, as well as final current. (5)

11.9 + 11.98

(k) Can you sketch a graph to show how the p.d. across the coil changes after switching on? (think back to part (a)!) (4)

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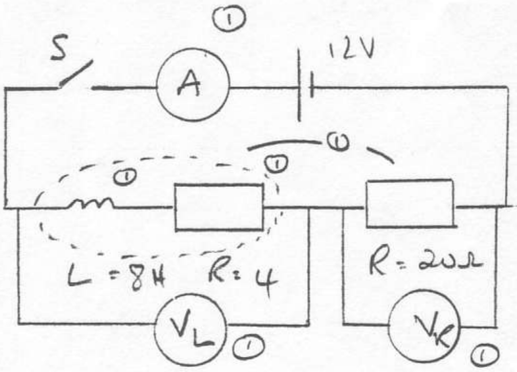
E.M. Induction – Self Inductance – Answers – A Physics

(a) Circuit ⟹



at $t = 0$ (b) $I = 0$ A ①

(c) $V_{coil} = -12$ V opposing cell ①

(d) $V_R = 0$ V (no current!) (1) (3)

(e) final .. $I_f = V/R_{total} = \frac{12}{4+20} = 0.5$ A ① ①

(f) $V_{coil} = I R_{coil} = 0.5 \times 4 = 2$ V (1)

(g) $V_R = I R_{Resistor} = 0.5 \times 20 = 10$ V ① ① (2) (check $V_{coil} + V_{Res.} = 12$V)

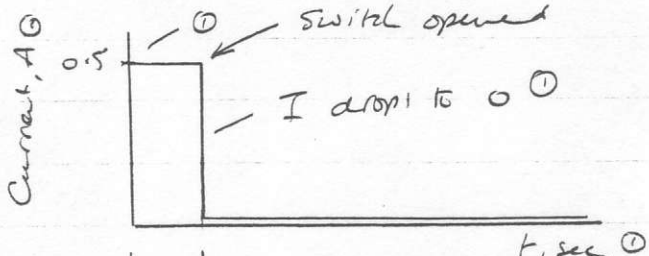
(f) open switch ... ammeter – reading drops instantly to 0. (1)

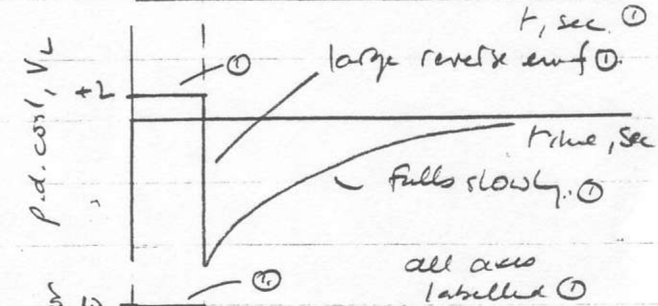
V_{coil} – V_L jumps up briefly to large p.d. (induced back emf) (1)

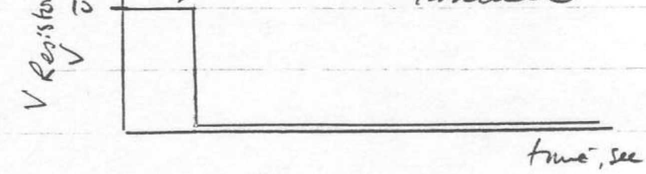
V_R – drops instantly to 0 (1)

(g) current / time (4) ⟶

(h) two pds / time (5) ⟶







(i) Explain ...

current and, therefore magnetic flux change ① v. rapidly ... so this induces a large reverse emf ① across coil, ... that slowly discharges through the voltmeter ① (3)

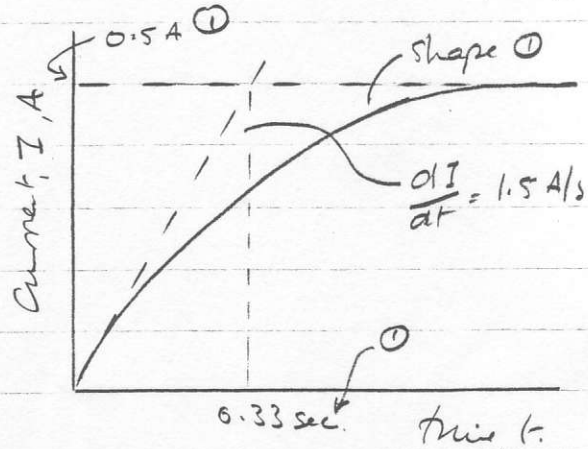
(j) Switching on ...

initially ... at $t = 0$

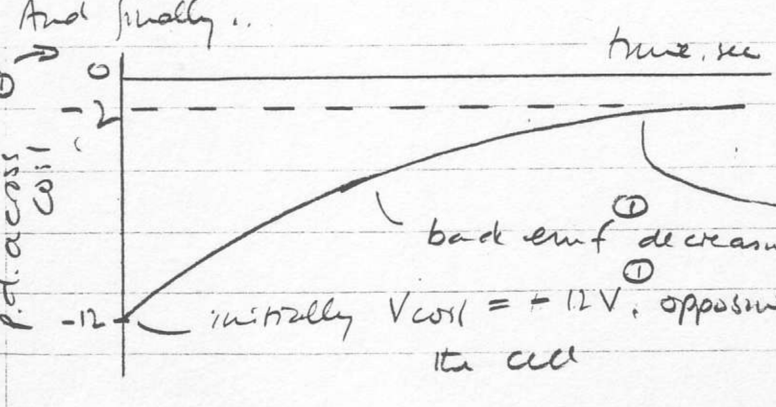
$E = 12\text{V} = L\, dI/dt$ ①

so $dI/dt = 12/L = 12/8 = 1.5$ A/sec ①

I final $= \frac{V}{R_{total}} = \frac{12}{24} = 0.5$ A (see (e))



(k) And finally ..



V_{coil} finally $= -2$V ① with steady 0.5A current.

(4)

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