This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls
Loueizeh - Baabda

Stage Exam 05

12MAY2023

Do NOT write in this box. Your MARK will be placed here.

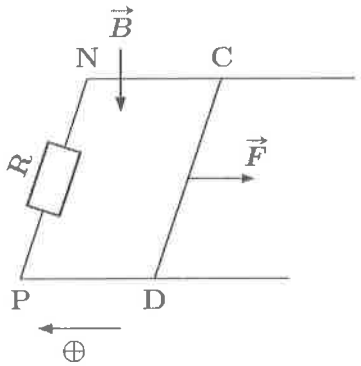
Subject :	Physics	
Class :	12M	
Teacher :	Mr. Ali Moukalled	
Duration :	1 hour	
Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

- Do not open this paper until the teacher in charge instructs you to do so.
- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

EXERCISE 1 (10points)

Electromagnetic Induction

Two straight and horizontal rails are placed at a distance $\mathbf{PN = 10cm}$.
A uniform magnetic field $\vec{B}$ of magnitude $\mathbf{B = 0.2T}$ is perpendicular to the plane of the rails. A rectilinear conductor CD moves along the rails under the action of a force of constant magnitude $\mathbf{F}$, with a constant speed $\mathbf{V = 0.5m/s}$. The frictional force that opposes the motion of the conductor has a constant value of $\mathbf{f_r = 2 \times 10^{-5}N}$.
A resistor of resistance $\mathbf{R = 2\Omega}$ is connected to the terminals PN of the rails. Assume that the internal resistance of the circuit NCDP (rails and conductor) is constant and of value $\mathbf{r = 0.5\Omega}$.



1. What is the name of the phenomenon produced in the above circuit ? Determine, according to Lenz's law the direction of the induced current in the circuit.
2. Determine according to the chosen positive direction, the expression of the flux crossing the circuit as a function of time $\mathbf{t}$, knowing that at $\mathbf{t_0 = 0}$, the flux crossing the circuit is zero.
3. Determine the emf $\mathbf{e}$ induced in the circuit.
4. Deduce the magnitude and the direction of the induced current. Compare this direction to that determined in part 1.
5. Determine the potential difference $\mathbf{V_{PN}}$ across the resistor $\mathbf{R}$.
6. Calculate the value of the electromagnetic force acting on the rod.
7. Apply Newton's second law to determine the magnitude of the force F..
8. Compare the mechanical power of the force $\vec{F}$ to that of the total electric power induced in the circuit. Explain this result.
9. Calculate the heat power in the resistor $\mathbf{R}$.

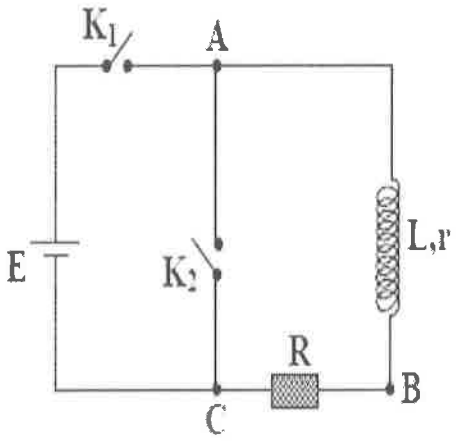
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EXERCISE 2 (10points)

Self-Induction

The set up represented by the adjacent figure consists of an ideal generator of emf $\mathbf{E = 12V}$, a coil of resistance $\mathbf{r = 10\Omega}$ and of inductance $\mathbf{L = 40mH}$, a resistor of resistance $\mathbf{R = 40\Omega}$ and two switches $\mathbf{K_1}$ and $\mathbf{K_2}$.

A- At the instant $\mathbf{t_0 = 0}$, we close the switch $\mathbf{K_1}$ and we leave $\mathbf{K_2}$ open. At an instant t , the circuit carries a current $\mathbf{i_1}$ in the transient state.



1. Derive the differential equation that governs the variation of $\mathbf{i_1}$ as a function of time.
2. $\mathbf{I_0}$ is the current in the steady state. Determine the expression of $\mathbf{I_0}$ in terms of E,r and R and calculate its value.
3. The solution of the differential equation is of the form: $\mathbf{i_1 = I_0(1 - e^{\frac{-t}{\tau}})}$.
   (a) Determine the expression of τ in terms of L, r and R and calculate its value.
   (b) Give the physical significance of τ .
4. (a) Determine the expression of the self-induced emf $\mathbf{e_1}$ as a function of time t.
   (b) Calculate the algebraic value of $\mathbf{e_1}$ at the instant $\mathbf{t_0 = 0}$.

B- After a few seconds, the steady state being reached, we open $\mathbf{K_1}$ and we close $\mathbf{K_2}$ at the same instant. We consider the instant of closing $\mathbf{K_2}$ as a new origin of time $\mathbf{t_0 = 0}$. The circuit (L, R, r) thus carries an induced current $\mathbf{i_2}$ at an instant t.

1. Determine the direction of $\mathbf{i_2}$.
2. Derive the differential equation that governs the variation of $\mathbf{i_2}$ as a function of time .
3. Verify that $\mathbf{i_2 = I_0 e^{\frac{-t}{\tau}}}$ is the solution of this differential equation.
4. Calculate the algebraic value of the self-induced emf $\mathbf{e_2}$ at the instant $\mathbf{t_0 = 0}$.

GOOD LUCK

SE05: 12M solution

Exercise 1

1) Electromagnetic Induction
Electromagnetic Force $\vec{f_L}$ is opp to $\vec{V}$ By R.H.R

2) $\phi = NBS\cos(\vec{n}, \vec{B})$
$S = d.x$ where $x = vt$
$S = dvt = 10 \times 10^{-2} \times 0.5 \times t$
$= 0.05t$

$\phi = (1)(0.2)(0.05t)\cos 0$

$$\boxed{\phi = 0.01t}$$

3) Due to Faraday's law

$$e = -\frac{d\phi}{dt} = -0.01\,V$$

4) $i = \frac{e}{r+R} = \frac{-0.01}{2.5} = -4 \times 10^{-3}\,A$

$$\boxed{i = -4 \times 10^{-3}\,A}$$

$i < 0$, opposing the $\oplus$ sense

5) $V_{PN} = +Ri = 2(-4 \times 10^{-3}) = -8 \times 10^{-3}\,V$

6) $F = i l B \sin(\vec{i}, \vec{B})$

$= 4 \times 10^{-3} \times 0.1 \times 0.2$

$= 8 \times 10^{-5} N$ (1)

7) $\Sigma \vec{F}_{ext} = m\vec{g} + \vec{N} + \vec{F} + \vec{F_i} + \vec{F_r} = \vec{0}$

project along the (+) sens

$F - F_i - f_r = 0$ (1)

$F = F_i + f_r = 8 \times 10^{-5} + 2 \times 10^{-5}$

$= 10^{-4} N$

8) $P_{mec} = \vec{F} \cdot \vec{V} = F.V \cos 0$

$= 10^{-4} \times 0.5$

$= 5 \times 10^{-5} W$ (1)

$P_{ele} = e.i = 0.01 \times 4 \times 10^{-3} = 4 \times 10^{-5} W$

$P_{elec} < P_{mec}$

the lost due to the presence of friction

9) $P_{heat} = Ri^2 = 2(4 \times 10^{-3})^2 = 32 \times 10^{-6} W$ (1)

Second Exercise

A) 1) $E = ri_1 + L\frac{di_1}{dt} + R_1 i$

$E = (r+R)i_1 + L\frac{di_1}{dt}$ (2)

2) $i_1 = cte$

$\Rightarrow \frac{di_1}{dt} = 0$ (1)

$I_0 = \frac{E}{R+r}$

3) a) $\frac{di_1}{dt} = \frac{I_0}{\tau} e^{-t/\tau} \Rightarrow E = (r+R)I_0\left(1 - e^{-t/\tau}\right) + \frac{LI_0}{\tau} e^{-t/\tau}$ (2)

$\frac{L}{\tau} = (r+R) \Rightarrow \tau = \frac{L}{R+r} = \frac{0.04}{50} = 0.8ms$

b) The time constant characterizes the duration of the growth of the current in a $(R+r, L)$ component. (1)

4) a) $e_1 = -L\frac{di}{dt} = -L\frac{I_0}{\tau} e^{-t/\tau} = -E e^{-t/\tau}$ (1)

b) For $t=0$, $e_1 = -E = -12V$

B_1) i_2 is the same as i_1 (1)

2) $u_{AC} = u_{AB} + u_{BC} \Rightarrow 0 = ri_2 + L\frac{di_2}{dt} + Ri_2$

$\Rightarrow L\frac{di_2}{dt} + (R+r)i_2 = 0$ (1)

3) $\frac{di_2}{dt} = -I_0/\tau e^{-t/\tau} \Rightarrow -\frac{LI_0}{\tau} e^{-t/\tau} + (R+r)I_0 e^{-t/\tau} = 0$ (1)

4) $e_2 = -L\,di_2/dt \Rightarrow E = 12V$ (1)

(3)