3^{rd} *Romanian Master of Sciences 2010*

Physics – Theoretical Tour

A. ELECTRICITY

a) $I_F < 200$ **mA** (the fuse is intact):

The fuse F acts as a short-circuit, and the voltage across it vanishes. No electric current I_1 flows in R_1, $I_1 = 0$.
0.25 p

No electric current flows in L_2 for $t = 0$, the voltage across the fuse is zero, the electric current I_2 is zero, $I_2 = 0$.
0.25 p

Across the inductance L_1 a constant voltage V causes I to increase at a constant rate V/L_1=1000 A/s.
0.25 p

All electrical current I flows in the fuse, $I_F=I$.
0.25 p

The melting condition is realized for $t = L_1 I_F / V$ = 0.2 ms
0.5 p

total a) 1.5 p

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b) Once the fuse melts, the current I_F vanishes, $I_F = 0$.
0.25 p

Right after the fuse melts, the electric current I conserves its value before melting, I**=200mA**.
0.25 p

The current flowing in L_2 is free of jumps (discontinuities). Then, right after melting the fuse I_2**=0**.
0.25 p

As a consequence of Kirchhoff's first law, right after melting the fuse, the current I_1 flowing in R_1 is 200 mA, causing a voltage drop across R_1 of 200 V, with the "+" pole in the right hand side.
0.25 p

As a consequence, a voltage across L_1 develops $V - R_1 I_F$ =200V-10V=190V, causing the variation of I at a rate $\Delta I/\Delta t$ given by $\left(V - R_1 I_F\right)/L_1$ =**19000A/s**. Right after the fuse melts, the voltage polarity causes I to decrease at the rate above.
0.5 p

The 200 V voltage drop across R_1 produces an increase of I_2. Right after the fuse melts, the voltage drop across R_2 is zero, therefore, immediately after melting the fuse, I_2 raises at a rate of **40000A**/s.
0.25 p

From the first Kirchhoff law, it follows that immediately after the fuse melts, the current I_1 falls at a rate of **59000** A/s.
0.5 p

total b) 2.25 p

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c) For t approaching infinity:

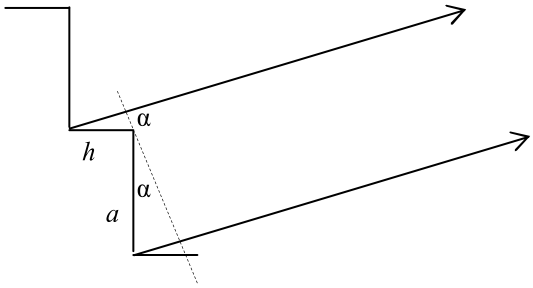
I_1**=10 mA**
0.25 p

I_2**=50 mA**
0.25 p

I**=60 mA**
0.25 p
total c) 0.75 p

B. MICHELSON'S "LADDER"

a. 1.5p



It is obvious that for α = 0, the path length difference δ between two neighboring light rays is $(n-1)h$. This difference increases with α.

$$\delta = nh + a\sin\alpha - h\cos\alpha = (n-1)h + a\sin\alpha + h(1-\cos\alpha) \ .$$

$$\delta = k\lambda \ , \ k \in \mathbb{N} \ .$$

One can see that in our specific example we get a diffraction maximum for α = 0 and k_0 = 10,000. So the condition for the principal maxima can be written:

$$a\sin\alpha + h(1-\cos\alpha) = p\lambda \ , \ p = k - k_0 > 0 \ .$$

b. 1.5p

One knows that the intensity of the light diffracted by a slit with aperture a depends on the deflecting angle according to:

$$I(\alpha) = I_0 \left[\frac{\sin\left(\frac{\pi a \sin\alpha}{\lambda}\right)}{\frac{\pi a \sin\alpha}{\lambda}} \right]^2 \ .$$

The first diffraction minimum occurs for

$$\frac{\pi a \sin\alpha}{\lambda} = \pi \Rightarrow \sin\alpha = \frac{\lambda}{a} = 5 \cdot 10^{-5} \ .$$

For such a small angle,

$$\delta \approx a\alpha + h\frac{\alpha^2}{2} \approx a\alpha \approx a\sin\alpha = p\lambda \ .$$

$$\sin\alpha < \frac{\lambda}{a} \Rightarrow p < 1 \Rightarrow p = 0 \Rightarrow k = k_0 \ .$$

So the only principal maximum that can be seen is the "central" one.

c. 1.5p

Increasing the wavelength of the light stream by Δλ can lead to the overlapping of two such central maxima.

$$k_0\lambda = (k_0 - 1)(\lambda + \Delta\lambda) \Rightarrow \Delta\lambda \approx \frac{\lambda}{k_0} = 0.5\text{A} \ .$$