Lebanese University
Faculty of Technology

الجامعة اللبنانيّة
كلية التكنولوجيا

September 11, 2024

Entrance Exam (Engineering)

Physics Exam

Duration: 1H30

Both exercises 1 and 2 are obligatory.
Choose only one exercise from exercises 3 and 4.

Exercise 1	***(10 points)***

The aim of this exercise is to determine the nature of a collision between two objects. For this aim, an object (A), considered as a particle, of mass $m_A = 2$ kg, can slide without friction on a path situated in a vertical plane and formed of two parts: a circular part DN and a horizontal rectilinear part NM. (A) is released, without initial velocity, from the point D situated at a height $h_D = 0.45$ m above the horizontal part NM (Figure 1).

The horizontal plane passing through MN is taken as the reference level of gravitational potential energy. Take $g = 10$ m/s^2.

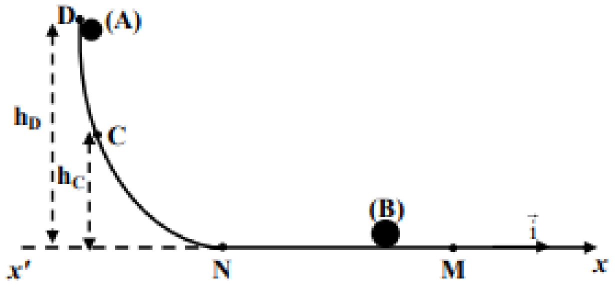

Fig.1

1) Calculate the mechanical energy of the system [(A), Earth] at the point D.

2) Deduce the speed V_{1A} of (A) when it reaches the point N.

3) (A) reaches N and moves along NM with the same velocity $\vec{V}_{1A} = V_{1A}\,\vec{i}$. Another object (B), considered as a particle, of mass $m_B = 4$ kg moves along the horizontal path from M toward N with the velocity $\vec{V}_{1B} = -1\,\vec{i}$ (V_{1B} in m/s).

a) Determine the linear momentum $\vec{P}$ of the system [(A), (B)] before collision.

b) Deduce the velocity $\vec{V}_G$ of the center of inertia G of the system [(A), (B)].

4) After collision, (A) rebounds and attains a maximum height $h_C = 0.27$ m.

a) Determine the mechanical energy of the system [(A), Earth] at the point C.

b) Deduce the speed V_{2A} of the velocity $\vec{V}_{2A}$ of (A) just after collision.

5) Determine, by applying the principle of the conservation of the linear momentum of the system [(A), (B)], the velocity $\vec{V}_{2B}$ of (B) just after collision.

6) Specify the nature of the collision.

Exercise 2	*(10 points)*

A- Principle of functioning of the circuit

Consider a source of DC voltage of value E, a push-button switch, a resistor of resistance R and a capacitor of adjustable capacitance C that is initially neutral represented by the figure 2.

1) Charging of the capacitor

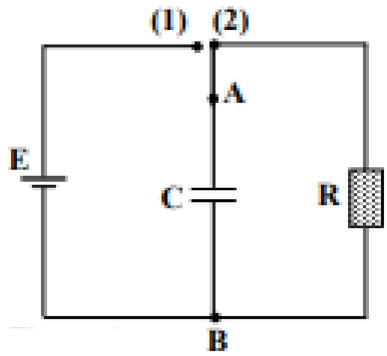

Fig.2

The push-button switch is pushed to position (1). Then capacitor undergoes charging.

a) The duration of the charging of the capacitor is very short. Why?

b) What would the value of the voltage $u_C = u_{AB}$ across the capacitor thus charged be?

2) Discharging of the capacitor

The capacitor being charged, we release the push-button switch that returns automatically to position (2) at the instant $t_0 = 0$. The capacitor undergoes discharging through the resistor.

a) Determine the differential equation that governs the variations of u_c as a function of time

b) The solution of the previous differential equation has the form $u_c = ae^{-\frac{t}{\tau}}$ where a and τ are positive constants. Determine the expressions of a and τ in terms of E, R and C.

c) Show that, for t = τ, the voltage across the capacitor is equal to 37 % of its value at the instant $t_0 = 0$.

B - Use of the circuit

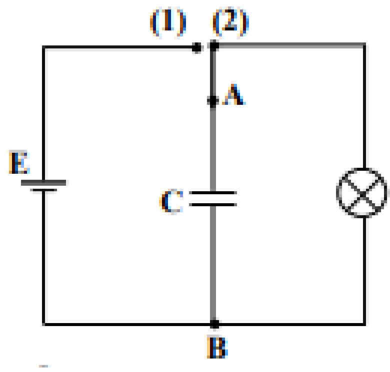

Fig.3

For the circuit of figure 3, E = 10V and the resistor is replaced by a lamp of resistance R = 3 kΩ. The lamp illuminates as long as the voltage across its terminals is greater or equal to a limiting voltage denoted by U.

1) a) Using the solution of the differential equation (given in the question **A-2-b**), determine the expression of the duration t_1 of illumination of the lamp in terms of U, E and τ.

b) Calculate t_1 for U = 3.7 V and C = 2 $\times 10^{-2}$ F.

2) We keep the same lamp and the same DC source. Which component of the circuit must be modified and how in order to increase the duration of illumination of the lamp?

Exercise 3	**_(10 points)_**

Consider Young's experiment set-up that is formed of two very thin parallel slits F_1 and F_2, separated by a distance $a = 1$ mm, and a screen of observation (E) placed parallel to the plane of the slits at a distance $D = 2$ m from the mid-point I of F_1F_2 and a thin slit F, equidistant from F_1 and F_2, situated on the straight line (Δ) whose intersection with (E) is the point O (figure 4).

The object of this exercise is to study the interference pattern observed on the screen (E) in two cases.

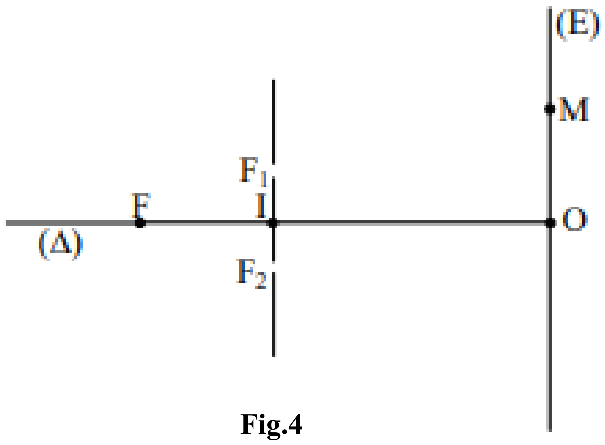

Fig.4

A – First case

The slit F is illuminated with a monochromatic light of wavelength $\lambda = 0.64$ µm in air.

1) Describe the interference pattern observed on (E).

2) Consider a point M on the screen at a distance d_1 from F_1 and d_2 from F_2.

Specify the nature of the fringe thus formed at point M in each of the following cases:

a) $d_2 - d_1 = 0$;

b) $d_2 - d_1 = 1.28$ µm;

c) $d_2 - d_1 = 0.96$ µm.

3) F is moved along (Δ). We observe that the interference fringes remain in their positions. Explain why.

4) F is moved perpendicularly to (Δ) to the side of F_2. We observe that the central fringe is displaced. In which direction and why?

B – Second case

Now the slit F is illuminated with white light.

1) We observe at point O a white fringe. Justify.

2) Specify the color of the bright fringe that is the nearest to the central fringe.

Exercise 4	*(10 points)*

Sodium vapor lamps are used to illuminate roads. These lamps contain sodium vapor under very low pressure. This vapor is excited by a beam of electrons that cross the tube containing the vapor. The electrons yield energy to the sodium atoms which give back this received energy during their downward transition towards the ground state in the form of electromagnetic radiations.
Given: $h = 6.62\times10^{-34}$ J.s; $c = 3\times10^{8}$ ms^{-1}; $e = 1.60\times10^{-19}$ C; 1 nm = 10^{-9}m.

1) What do each of the quantities h, c and e represent?

2) The analysis of the emission spectrum of a sodium vapor lamp shows the presence of lines of well-determined wavelengths λ. The figure 5 represents some of the lines of this spectrum.

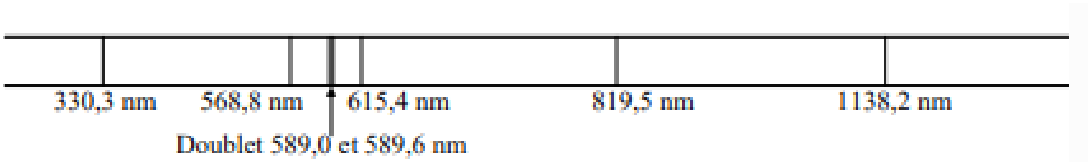

Fig.5

a) The yellow doublet of wavelengths, in vacuum, $\lambda_1 = 589.0$ nm and $\lambda_2 = 589.6$ nm is more intense than the other lines.

i) To what range: visible, infrared or ultraviolet, does each of the other lines of the spectrum belong?

ii) The sodium vapor lamps are characterized by the emission of yellow light. Why?

b) Is the visible light emitted by the sodium lamp monochromatic or polychromatic? Justify your answer.

3) a) Referring to the diagram of the energy levels of the sodium atom in the figure below (figure 6):

i) Specify an indicator that justifies the discontinuity of the emission spectrum of the sodium vapor lamp.

ii) Verify that the emission of the line of wavelength λ_1 corresponds to the downward transition from the energy level E_2 to the ground state.

b) In fact, the energy level E_2 is double, i.e., it is constituted of two energy levels that are very close to each other. Draw a diagram that shows the preceding downward transition as well as the downward transition corresponding to the emission of the radiation of wavelength λ_2.

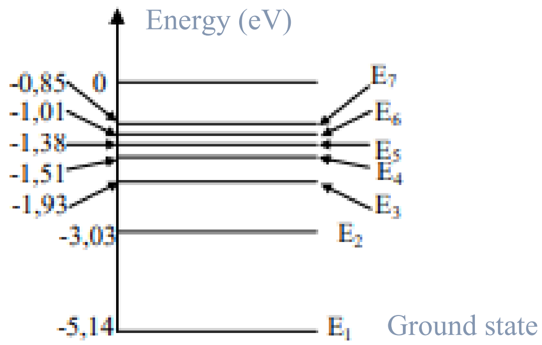

Fig.6

4) The sodium atom, being in the ground state, is hit successively by the electrons (a) and (b) of respective kinetic energies 1.01 eV and 3.03 eV.

a) Determine the electron that can interact with the sodium atom.

b) Specify the state of the sodium atom after each impact.

c) Deduce, after impact, the kinetic energy of the electron that interacts with the sodium atom.