<u>This exam is formed of three obligatory exercises in nine pages.</u>
<u>The use of non-programmable calculators is recommended.</u>

مسابقة في مادة الفيزياء

المدة: ساعتان

(إنكليزي)

الاسم:..................................

الرقم:..................................

Exercise 1 (7 points) Horizontal elastic pendulum

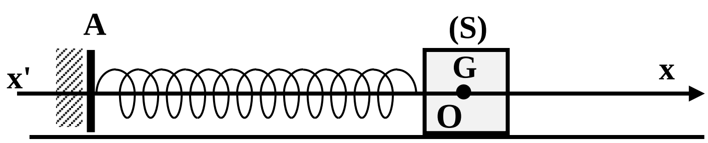
A mechanical oscillator is formed by :

- a block **(S)** of mass **m**
- a spring of negligible mass and spring constant **k**.

– **(S)** is attached to one end of the spring.

– the other end of the spring is connected to a fixed support **A**.

– **(S)** can move without friction on a horizontal surface (Doc. 1).



Doc. 1

The aim of this exercise is to determine the values of **m** and **k**.

– At equilibrium, the center of mass **G** of **(S)** coincides with the origin **O** of the **x- axis**.

– **(S)** is displaced horizontally in the positive direction.

- At the instant $t_0 = 0$, taken as an initial time,
  - the abscissa of **(S)** is x_0 and **(S)** is launched in the negative direction with an initial velocity $\overrightarrow{v_0} = v_0 \vec{i}$ ($v_0 < 0$) where $\vec{i}$ is the unit vector of the **x-axis.**
- At an instant **t**,
  - the abscissa of **G** is **x** and the algebraic value of its velocity is $v = x' = \frac{dx}{dt}$.

The horizontal plane containing **G** is taken as a reference level for gravitational potential energy.

Given :

$KE = \frac{1}{2} mv^2$;	$GPE = mgh$;	$EPE = \frac{1}{2} kx^2$;	$ME = KE + EPE + GPE$

1) **Write**, at an instant **t**, the expression of the mechanical energy of the system (Oscillator, Earth) in terms of **x, m, k** and **v.**

2) Knowing that **(S)** moves without friction, **deduce** that the second order differential equation in **x** that describes the oscillations of **(S),** is $x'' + \frac{k}{m}x = 0$.

3) **Deduce** the expression of the proper angular frequency ω_0 of the oscillations in terms of **m** and **k**.

4) The solution of the obtained differential equation is:

   $x = X_m \sin(\omega_0 t + \varphi)$, where X_m , ω_0 and φ are constants.

   Write the expression of **v** in terms of X_m , ω_0 , φ and **t**.

5) **Write** the expression of x_0 in terms of X_m and φ.

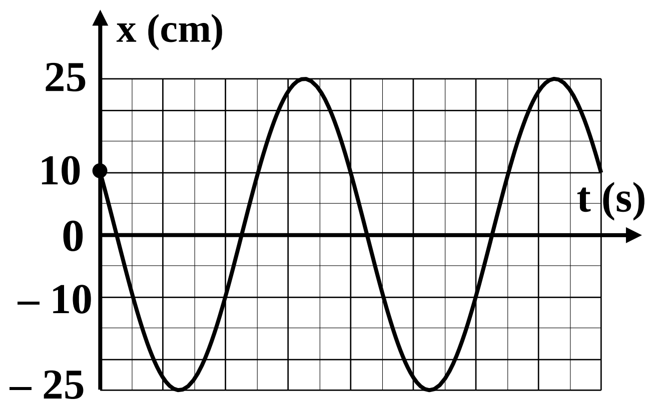
   Write the expression of v_0 in terms of X_m , ω_0 and φ.

6) **Deduce that** $X_m = \sqrt{x_0^2 + \frac{v_0^2}{\omega_0^2}}$ **.**

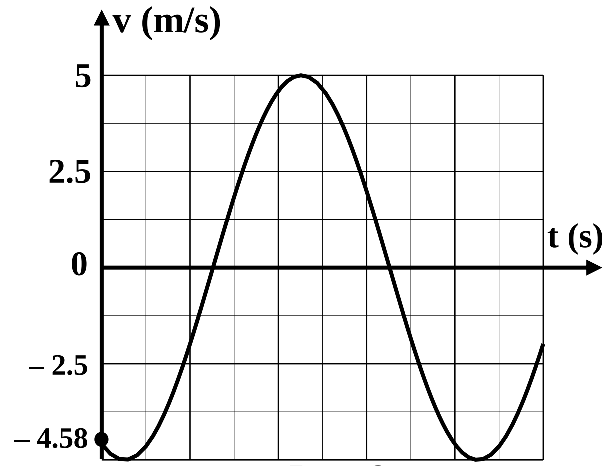
   Given:

$\sin^2\varphi + \cos^2\varphi = 1$

7) An appropriate device traces **x** and **v** as functions of time as shown in documents 2 and 3 respectively.



Doc. 2



Doc. 3

Referring to documents (2) :

7-1) **specify** the type of the oscillations;

7-2) **indicate** the values of x_0 and X_m.

Referring to document (3):

7-3) **indicate** the values of v_0 and V_m where V_m is the amplitude of **v**.

8) Using the relations of questions **6** $\left(X_m = \sqrt{x_0^2 + \frac{v_0^2}{\omega_0^2}}\right)$:

Show that $\omega_0 = 20$ rad/s.

9) We repeat the same experiment by replacing block **(S)** of mass m by another block **(S')** of mass **m' = 0.8 kg**. The new proper angular frequency is $\omega' = \frac{\omega_0}{2}$

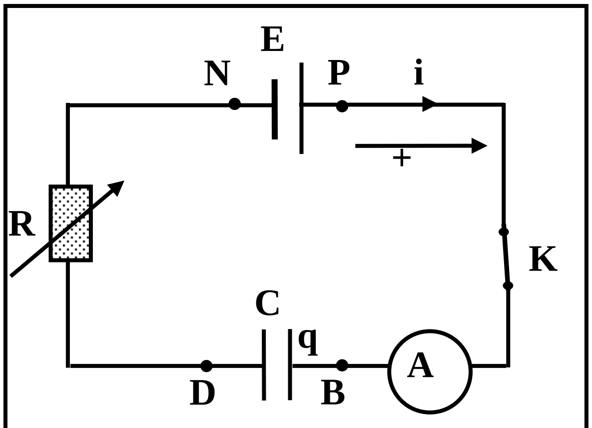
9-1) Write the expression of **ω'** in terms of **m'** and **k**.

9-2) Deduce the values of **k** and **m**.

Exercise 2 (7 points) Capacitance of a capacitor

The aim of this exercise is to determine the capacitance **C** of a capacitor.

We set-up the series circuit of document 4.



Doc.4

This circuit includes:

- an ideal battery of electromotive force **E = 10 V**;
- a rheostat of resistance **R** ;
- a capacitor of capacitance **C**;
- an ammeter **(A)** of negligible resistance;
- a switch **K**.

Initially the capacitor is uncharged.

- We close the switch **K** at the instant $t_0 = 0$.
- At an instant **t**, plate **B** carries a charge **q** and the circuit carries a current **i** as shown in document 4.

1) Write the expression of **i** in terms of **C** and u_C, where $u_C = u_{BD}$ is the voltage across the capacitor.

2) Prove that the differential equation that governs the variation of u_C is:

$$E = u_C + RC\frac{du_C}{dt}.$$

3) The solution of this differential equation is of the form: $\mathbf{u_C = a + b e^{-\frac{t}{\tau}}}$.

Determine the expressions of the constants **a, b** and **τ** in terms of **E, R** and **C**.

4) **Deduce that** the expression of the current is: $\mathbf{i = \frac{E}{R} e^{-\frac{t}{RC}}}$ **.**

5) The ammeter **(A)** reads a value $\mathbf{I_0 = 5 \times 10^{-3}}$ **A** at $\mathbf{t_0 = 0}$.

Deduce the value of **R**.

6) **Write,** <u>using Ohm's law,</u> the expression of $\mathbf{u_R = u_{DN}}$ in terms of **E, R, C** and **t**.

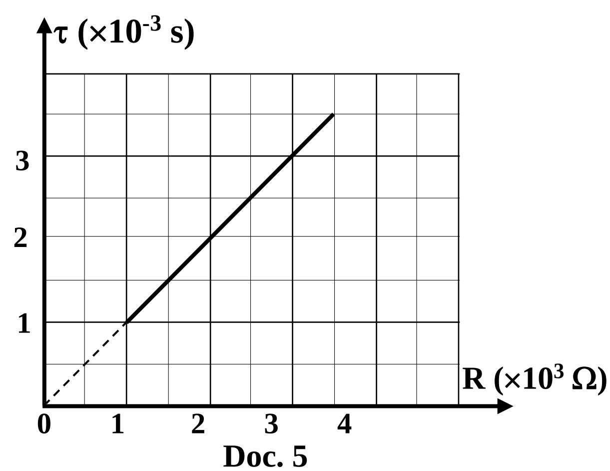
7) At an instant $\mathbf{t = t_1}$, the voltage across the capacitor is $\mathbf{u_C = u_R}$.

7-1) **Show that $\mathbf{t_1 = R\,C\,\ell n\,2}$.**

7-2) **Calculate** the value of **C** knowing that $\mathbf{t_1 = 1.4 \times 10^{-3}}$ **s**.

8) **In order** to <u>verify the value</u> of **C**, we change the value of **R**.

<u>Document 5</u> represents **τ** as a function of **R**.



Doc. 5

8-1) **Show that** the shape of the curve in <u>document 5</u> is in agreement with the expression of **τ** obtained in question **3**.

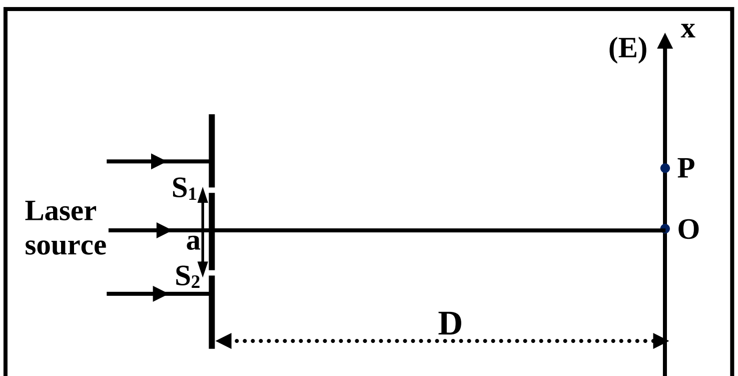
8-2) Using the curve of <u>document 5</u>, **determine** again the value of **C**.

Exercise 3 (6 points) **Aspects of Light**

The aim of this exercise is <u>to show evidence</u> of the two aspects of light.

1) First aspect

- Consider Young's double-slit experiment.
- The two thin parallel horizontal slits S_1 and S_2 are separated by a distance $\mathbf{a = 0.5\times10^{-3}\ m}$.
- The screen **(E)** is placed parallel to the plane of the slits at a distance **D = 2 m.**
- A laser source illuminates the two slits by a monochromatic light of wavelength $\lambda = 600$ nm ($1\text{nm} = 1\times10^{-9}$ m), in air, under normal incidence.
- **O** is the point of intersection between the perpendicular bisector of $[S_1S_2]$ and the screen **(E)**.
- **P** is a point on the screen having an abscissa $x_P = \overline{OP} = 9.6\times10^{-3}$ m (<u>Doc. 6</u>).



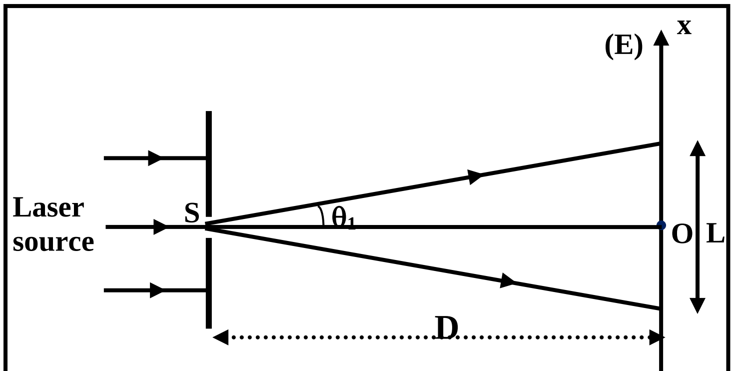
Doc. 6

1-1) Prove that the value of the inter-fringe distance **i** is $\mathbf{2.4\times10^{-3}\ m}$.

1-2) P is the center of a bright fringe, **why?**

1-3) Slits $\mathbf{S_1}$ and $\mathbf{S_2}$ are replaced by a horizontal slit **S** of width $\mathbf{a_1 = 0.1\times10^{-3}}$ **m**.

O is the center of the central bright fringe and $\boldsymbol{\alpha = 2\,\theta_1}$ where $\boldsymbol{\alpha}$ is the angular width of the central bright fringe (θ_1 is a small angle) Doc. 7.



Doc. 7

1-3-1) Choose the right answer:

The phenomenon that takes place at the slit **S** is:

a- Interference

b- Diffraction

c- Refraction

1-3-2) Show, using document 7, that the width **L** of the central bright fringe is given by the expression: $\mathbf{L} = \frac{\mathbf{2\,\lambda\,D}}{\mathbf{a_1}}$.

1-3-3) Deduce the distance **d** between **O** and the center of the first dark fringe.

1-3-4) Knowing that $\mathbf{x_P = 9.6\times10^{-3}}$ **m, deduce** that **P** is neither the center of a bright fringe, nor the center of a dark fringe.

1-4) The previous two experiments show evidence of an aspect of light.

Name this aspect.

2) Second aspect

The monochromatic radiation, of wavelength **λ = 600 nm** in air, emitted by the laser source, illuminates now the surface of a lithium metal of work function **W_0 = 2.39 eV.**

Given:

- Planck's constant **$h = 6.6\times10^{-34}$ J.s** ;
- **1 eV = 1.6×10^{-19} J** ;

Take: The speed of light in air **$c = 3\times10^{8}$ m/s**.

2-1) **Complete** the following sentence:

The work function (extraction energy) of a metal is the …………… ………….. of a ………… to extract an electron from the surface of a metal.

2-2) **Write**, the expression of the energy of the photon in terms of **h**, **c** and **λ**.

Prove that its value is **E_{ph} = 2.0625 eV**.

2-3) **Compare E_{ph} and W_0.**

Deduce that there is no photoelectric emission from the surface of the lithium metal.

2-4) In order to extract electrons from the surface of the lithium metal, the laser source is replaced by another one emitting a radiation of wavelength **λ' = 500 nm** in air.

Determine, using the relation **$E_{ph} = W_0 + KE$,** the maximum kinetic energy of the liberated electrons.

2-5) This experiment shows evidence of an aspect of light.

Name this aspect.