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امتحانات الشهادة الثانوية العامة
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مسابقة في مادة الفيزياء	الاسم:
المدة: ساعتان	الرقم:

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

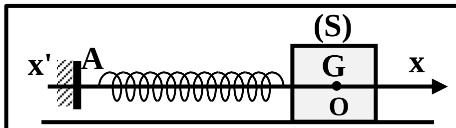
Exercise 1 (7 points) Horizontal elastic pendulum

A mechanical oscillator is formed by a block (S) of mass m and a spring of negligible mass and spring constant k. (S) is attached to one end of the spring, and the other end of the spring is connected to a fixed support A. (S) can move without friction on a horizontal surface (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.



Doc. 1

At the instant $t_0 = 0$, the abscissa of G is x_0 and (S) is launched in the negative direction with an initial velocity $\vec{v_0} = v_0\,\vec{i}$ ($v_0 < 0$) 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.

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) Establish the second order differential equation in x that governs the motion of (S).

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.

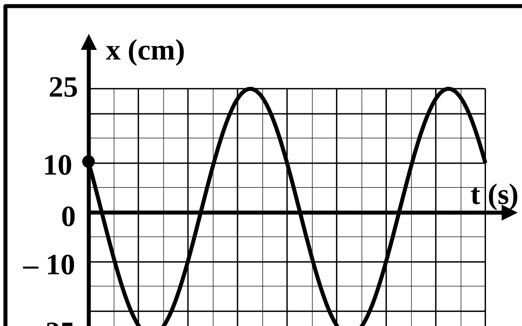
5) Write the expressions of x_0 and v_0 in terms of X_m, ω_0 and φ.

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

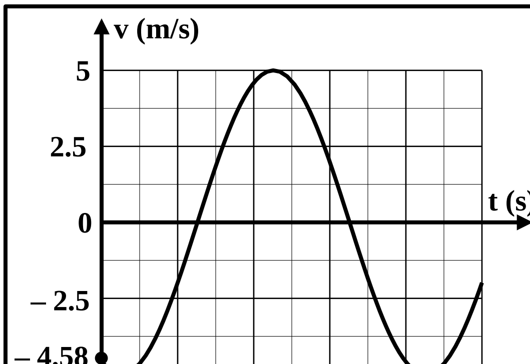
7) An appropriate device traces x and v as functions of time as shown in documents 2 and 3 respectively.
Referring to documents (2) and (3):

7-1) specify the type of the oscillations;

7-2) indicate the values of x_0, v_0, X_m and V_m, where V_m is the amplitude of v.



Doc. 2



Doc. 3

8) Deduce that ω_0 is approximately equal to 20 rad/s.

9) We repeat the same experiment by replacing the block (S) of mass m by another block (S') of mass m' = 0.8 kg.

The new proper angular frequency is $\omega' = \frac{\omega_0}{2}$.

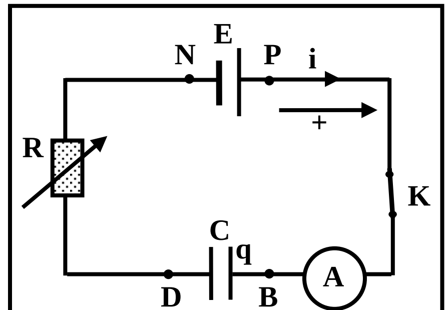
9-1) Write the expression of ω' in terms of m' and k.

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.
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.



Doc.4

Initially the capacitor is uncharged. We close the switch K at the instant $t_0 = 0$. At an instant t, plate B of the capacitor 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) Establish the differential equation that governs the variation of u_C.

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

5) The ammeter (A) indicates a value $I_0 = 5$ mA at $t_0 = 0$. Deduce the value of R.

6) Write the expression of $u_R = u_{DN}$ in terms of E, R, C and t.

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

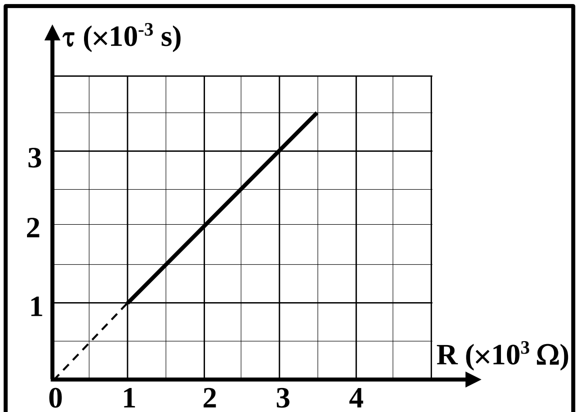
7-1) Show that $t_1 = R\ C\ \ell n\ 2$.

7-2) Calculate the value of C knowing that $t_1 = 1.4$ ms.

8) In order to verify the value of C, we vary the value of R. Document 5 represents τ as a function of R.

8-1) Show that the shape of the curve in document 5 is in agreement with the expression of τ obtained in part 3.

8-2) Using the curve of document 5, determine again the value of C.



Doc. 5

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

The aim of this exercise is to show evidence of the two aspects of light.

1) First aspect

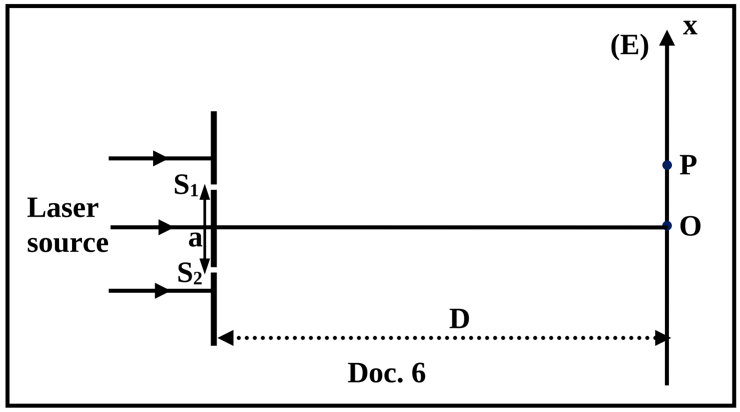
Consider Young's double-slit experiment. The two thin parallel horizontal slits S_1 and S_2 are separated by a distance a = 0.5 mm.

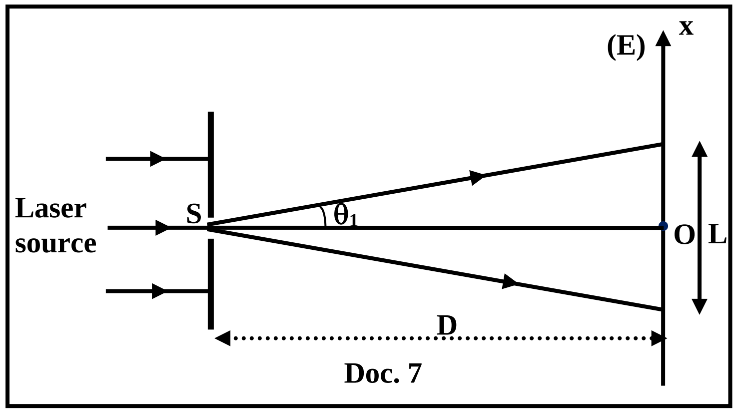
The screen (E) is placed parallel to the plane of the slits at a distance D = 2 m.

A laser source illuminates the two slits by a monochromatic light of wavelength λ = 600 nm 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 mm (Doc. 6).





1-1) Calculate the inter-fringe distance i.

1-2) Specify the nature and the order of the fringe whose center is point P.

1-3) Slits S_1 and S_2 are replaced by a horizontal slit S of width a_1 = 0.1 mm. O is the center of the central bright fringe and $\alpha = 2\,\theta_1$ where α is the angular width of the central bright fringe (θ_1 is a small angle) (Doc. 7).

1-3-1) Name the phenomenon that takes place at the slit S.

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

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

1-3-4) 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) Define the work function (extraction energy) of a metal.

2-2) Calculate, in eV, the energy of a photon in this radiation.

2-3) 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, in eV, the maximum kinetic energy of the liberated electrons.

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

أسس التصحيح – مادة الفيزياء - إنكليزي

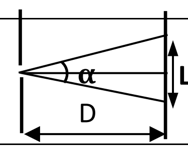
Exercise 1 (7 points) Horizontal elastic pendulum

Partie		Answer	Mark
1		$ME = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$	0.5
2		There is no friction therefore the mechanical energy is conserved. ME = constant , then $\frac{dME}{dt} = 0$, hence $m\,v\,v' + k\,x\,x' = 0$ with $v = x'$ and $v' = x''$ $x'(mv + kx) = 0$, but $x' = 0$ is rejected ; therefore, $x'' + \frac{k}{m}x = 0$	1
3		The differential equation is of the form: $x'' + \omega_0^2\, x = 0$ then : $\omega_0 = \sqrt{\frac{k}{m}}$	0.5
4		$v = X_m\, \omega_0 \cos(\omega_0 t + \varphi)$	0.25
5		$x_0 = X_m \sin\varphi$ $v_0 = \omega_0\, X_m \cos\varphi$	0.25 0.25
6		$\sin\varphi = \frac{x_0}{X_m}$ and $\cos\varphi = \frac{v_0}{\omega_0 X_m}$ $\sin^2\varphi + \cos^2\varphi = 1$ $\frac{x_0^2}{X_m^2} + \frac{v_0^2}{\omega_0^2\, X_m^2} = 1$, so $X_m^2 = x_0^2 + \frac{v_0^2}{\omega_0^2}$ Therefore, $X_m = \sqrt{x_0{}^2 + \frac{v_0{}^2}{\omega_0{}^2}}$	1
7	7.1	Free undamped mechanical oscillations since the amplitude x_m is constant	0.5
	7.2	$x_0 = 10$ cm ; $v_0 = -\,4.58$ m/s $X_m = 25$ cm ; $V_m = 5$ m/s	0.25 0.25 0.25 0.25
8		Substituting the values of x_0, v_0 and X_m into the expression of X_m gives : $0.25 = \sqrt{0.1^2 + \frac{-4.58^2}{\omega_0{}^2}}$, then $\omega_0 = 19.98 \cong 20$ rad/s **<u>Or</u>** : $V_m = \omega_0 X_m$, then $\omega_0 = \frac{V_m}{X_m} = \frac{5}{0.25} = 20$ rad/s	0.5
9	9.1	$\omega' = \sqrt{\frac{k}{m'}}$	0.25
	9.2	$\omega' = 10$ rad/s $k = m' \times \omega'^2 = 0.8 \times 10^2 = 80$ N/m $m = \frac{k}{\omega_0^2} = \frac{80}{400} = 0.2$ kg	0.5 0.5

Exercise 2 (7 points) **Capacitance of a capacitor**

Part		Answer	notes
1		$i = \frac{dq}{dt}$, but $q = C \times u_C$, then $i = C\frac{du_C}{dt}$	0.5
2		$E = u_{BD} + u_{DN} = u_C + Ri$, but $i = C\frac{du_C}{dt}$; therefore, $E = u_C + RC\frac{du_C}{dt}$	0.75
3		$\frac{du_C}{dt} = -\frac{b}{\tau}e^{-\frac{t}{\tau}}$; Substituting u_C and $\frac{du_C}{dt}$ in the differential equation gives : $E = a + b\,e^{-\frac{t}{\tau}} + RC\,(-\frac{b}{\tau}\,e^{-\frac{t}{\tau}})$, so $E = a + b\,e^{-\frac{t}{\tau}}(1 - \frac{RC}{\tau})$ By comparison we obtain : $a = E$ and $be^{-\frac{t}{\tau}}(1 - \frac{RC}{\tau}) = 0$, but $be^{-\frac{t}{\tau}} = 0$ is rejected ,then $1 - \frac{RC}{\tau} = 0$ Therefore, $\tau = RC$ At $t_o = 0$, the charge is $q_o = 0$, then $u_{C0} = 0$. Substituting $u_{C0} = 0$ into the expression of u_C gives: $0 = a + b$, so $b = -a = -E$	2
4		$i = C\frac{du_C}{dt} = C\frac{E}{\tau}e^{-\frac{t}{\tau}} = \frac{E}{R}e^{-\frac{t}{\tau}}$	0.5
5		A $t_0 = 0$: $i = I_0 = \frac{E}{R}e^0$, then $I_0 = \frac{E}{R}$, thus $R = \frac{E}{I_0} = \frac{10}{5 \times 10^{-3}} = 2 \times 10^3\ \Omega$	0.5
6		$u_R = Ri = RC\frac{du_C}{dt} = RC\frac{E}{\tau}e^{-\frac{t}{\tau}}$, then $u_R = E\ e^{-\frac{t}{\tau}}$	0.5
7	7.1	$u_C = u_R$ $E - Ee^{-\frac{t_1}{\tau}} = E\ e^{-\frac{t_1}{\tau}}$, so $E = 2E\ e^{-\frac{t_1}{\tau}}$, then $\frac{1}{2} = e^{-\frac{t_1}{\tau}}$, hence $-\ell n2 = -\frac{t_1}{\tau}$ Then, $t_1 = \tau\ \ell n2$; therefore, $t_1 = RC\ \ell n2$	0.75
	7.2	$C = \frac{t_1}{R\,\ell n2} = \frac{1.4 \times 10^{-3}}{2 \times 10^3 \times \ell n\,2} = 1 \times 10^{-6}$ F	0.5
8	8.1	The curve is a straight line passing through the origin with a positive slope, then it is in agreement with the expression $\tau = RC$.	0.5
	8.2	Slope $= C = \frac{\Delta\tau}{\Delta R} = \frac{3 \times 10^{-3}}{3 \times 10^3} = 1 \times 10^{-6}$ F	0.5

Exercise 3 (6 points) Aspects of Light

Part			Answer	Mark
1	1.1		$i = \frac{\lambda D}{a} = \frac{600 \times 10^{-9} \times 2}{0.5 \times 10^{-3}} = 24 \times 10^{-4}$ m = 2.4 mm	0.5
	1.2		x_P = 9.6 mm = 4 i , then P is the center of the 4th bright fringe. **Or**: P is the center of a bright fringe if $x_P = \frac{k \lambda D}{a}$ with $k \in Z$. $x_P = \frac{k \lambda D}{a}$, then $k = \frac{a x_P}{\lambda D} = \frac{0.5 \times 10^{-3} \times 9.6 \times 10^{-3}}{600 \times 10^{-9} \times 2} = 4 \in Z$, then P is the center of the 4th bright fringe.	1
	1.3	1.3.1	Diffraction of light	0.25
		1.3.2	From the figure: $\tan \frac{\alpha}{2} = \frac{L/2}{D}$, but α is small then $\tan \alpha \cong \alpha$ So $\frac{\alpha}{2} = \frac{L}{2D}$ But $\alpha = \frac{2\lambda}{a_1}$; therefore, $L = \frac{2 \lambda D}{a_1}$  	0.75
		1.3.3	$d = \frac{L}{2} = \frac{2 \times 600 \times 10^{-9} \times 2}{2 \times 0.1 \times 10^{-3}} = 0.012$ m = 12 mm	0.5
		1.3.4	$x_P < d = \frac{L}{2}$, then it is neither the center of a bright nor the center of a dark fringe.	0.25
	1.4		Wave aspect of light	0.25
2	2.1		W_o is the minimum energy needed to extract an electron from the surface of a metal.	0.5
	2.2		$E_{ph} = \frac{h c}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9}} = 3.3 \times 10^{-19}$ J $E_{ph} = \frac{3.3 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.0625$ eV	0.75
	2.3		$E_{ph} < W_o$, then there is no photoelectric emission.	0.25
	2.4		$E'_{ph} = W_o + KE_{max}$, then $KE_{max} = E'_{ph} - W_o = \frac{h c}{\lambda'} - W_o$ $KE_{max} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{500 \times 10^{-9} \times 1.6 \times 10^{-19}} - 2.39 = 0.085$ eV	0.75
	2.5		Corpuscular (particle) aspect of time	0.25