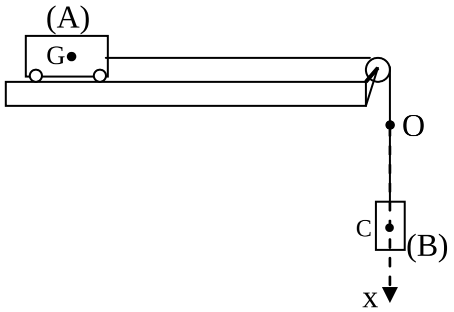
الدورة الإستثنائية للعام 2010	امتحانات الشهادة الثانوية العامة الفرع : علوم عامة	وزارة التربية والتعليم العالي المديرية العامة للتربية دائرة الامتحانات
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ثلاث ساعات	

<u>This exam is formed of four exercises in four pages</u>
<u>The use of non-programmable calculator is recommended</u>

<u>First Exercise</u>: *(7 ½ points)* **Moment of inertia of a pulley**



In order to determine the moment of inertia of a pulley with respect to its axis of rotation, we use the system of the adjacent figure that is formed of a trolley (A), of mass M = 1 kg, connected to a block (B), of mass m = 0.18 kg, by means of an inextensible string of negligible mass. The string passes over a pulley of radius r = 5 cm.
A convenient device can record, at equal and successive intervals of time τ = 50 ms, the abscissa $x = \overline{OC}$ of the different positions of the center of inertia C of (B).
Neglect all forces of friction and use g = 10 m/s^2.
The table below gives the abscissa x of the position of C and its speed V at different instants.

t (ms)	t_0 = 0	t_1 = 50	t_2 = 100	t_3 = 150	t_4 = 200
x (cm)	0	0.175	0.7	1.575	2.8
V (m/s)	0	0.07	0.14	0.21	0.28

A – Energetic study

1) Calculate the kinetic energy of (B) at the instant t_4 = 200 ms.
2) Calculate the variation of the kinetic energy of (B) between the instants t_0 and t_4.
3) Applying the theorem of kinetic energy (ΔK.E = ΣW), calculate the work done by the tension $\vec{T}_1$ applied by the string on the block (B).
4) Show that the value T_1 of $\vec{T}_1$, supposed constant, is equal to 1.548 N.

B – Dynamical study

1) Calculate the values P_0, P_1, . ….. .P_4 of the linear momentum $\vec{P}$ of the trolley (A) at the instants t_0, t_1, . . . t_4 respectively.
2) ***a)*** Draw the graph representing the variation of P as a function of time.
b) Show that the equation of the corresponding graph may be written in the form:
P = k t + b where k and b are constants to be determined.
3) Applying Newton's second law on trolley (A):
a) determine the relation among the constants k, M and the algebraic value a of the acceleration of motion and deduce the value of a;
b) show that the value T_2 of the tension $\vec{T}_2$ applied by the string on the trolley (A) is equal to 1.40 N.

C – Determination of the moment of inertia of the pulley

1) Specify the forces acting on the pulley.
2) Applying the theorem of angular momentum, determine the moment of inertia of the pulley with respect to its axis of rotation.

Second Exercise: *(7 ½ points)* **Identifying two electric components**

Consider a generator G that maintains across its terminals a constant voltage E , a generator G' that maintains across its terminals an alternating sinusoidal voltage of expression:
$u = 5\sqrt{2}\sin 2\pi ft$ (u in V and t in s) of adjustable frequency f, an ammeter (A) of negligible resistance, a switch K , connecting wires and two electric components (D_1) and (D_2) where one of them is a coil of inductance L and of resistance r, and the other a capacitor of capacitance C. (Take $\frac{1}{\pi} = 0.32$)
In order to identify each of these two components and to determine their characteristics, we perform the following experiments, the measurements being taken after attaining the steady state in the circuit.

A – First experiment
Each of the two components, taken separately, is fed by the generator G.
In the steady state:

- the circuit containing (D_1) does not carry any current;
- the circuit containing (D_2) carries a current I = 1 A and consumes a power of 5 W.

1) Determine the nature of (D_1).
2) Determine the resistance r of the coil.

B – Second experiment
Each of the two components, taken separately, is fed by the generator G' , the voltage u being of frequency f = 50 Hz.
In the steady state:

- the circuit containing the capacitor carries an alternating sinusoidal current i_1 of effective value I_1 = 50 mA and does not consume any power (Fig. 1);
- the coil carries an alternating sinusoidal current i_2 of effective value $I_2 = \frac{\sqrt{2}}{2}$ A, and consumes an average power of 2.5 W (Fig. 2).

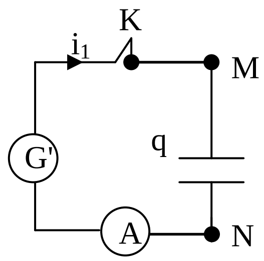


Fig1

1) Determine the phase difference between i_1 and u and that between i_2 and u.
2) Write down, with justification, the expressions of i_1 and i_2 as a function of time.
3) ***a)*** Show that $i_1 = C\frac{du}{dt}$.
b) Deduce the value of C.
4) ***a)*** Write down the relation among u, i_2, r and L.
b) Using the expressions of u and i_2 as a function of time and giving t a particular value, determine the value of L.

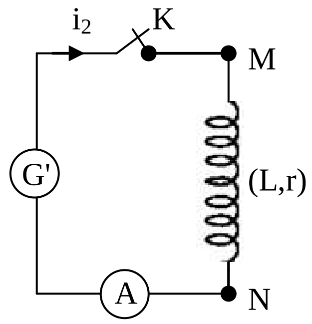


Fig 2

C – Third experiment
In fact, the values of r and L are labeled on the coil. To verify the value of C, we connect the coil and the capacitor in series across G'. By giving f different values, we notice that the effective current in the circuit attains a maximum value for $f = f_0 = 225$ Hz
1) For the frequency f_0, the circuit is the seat of a particular electric phenomenon. Give the name of this phenomenon.
2) Determine the value of C.

***Third Exercise*: (7 ½ points)** **Wave aspect of light and its applications**

The object of this exercise is to show evidence of exploiting an optical phenomenon in the measurement of small displacements.

A- Diffraction

A laser beam illuminates, under normal incidence, a straight slit F, of width a, cut in an opaque screen (P). The light through F is received on a screen (E), parallel to (P) and found at 3 m from (P) (Fig.1).

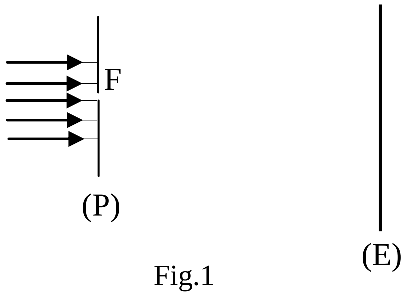


Fig.1

1) Describe what would be observed on (E) in the two following cases:

a) $a = a_1 = 1$ cm.

b) $a = a_2 = 0.5$ mm.

2) It is impossible to isolate a luminous ray by reducing the size of the slit. Why?

3) We use the slit of width $a_2 = 0.5$ mm. The width of the central fringe of diffraction observed on (E) is 7.2 mm. Show that the wavelength of the light used is $\lambda = 600$ nm.

4) We remove the screen (P). A hair of diameter d is stretched in the place of the slit F. We obtain on the screen a diffraction pattern. The measurement of the width of the central fringe of diffraction gives 12 mm. Determine the value of d.

B- Interference

In order to measure a small displacement of an apparatus, we fix the screen (P) on this apparatus.
In a screen (P'), we cut two parallel and very thin slits F_1 and F_2 separated by 1 mm.
We repeat the previous experiment by introducing (P') between (P) and (E). (P) and (P') are parallel and are at a distance D' = 1 m from each other.
The slit F, cut in (P), is equidistant from the two slits F_1 and F_2. The slit F is illuminated by the laser source of wavelength $\lambda = 600$ nm. A phenomenon of interference is observed on the screen (E) located at a distance D = 2 m from (P').

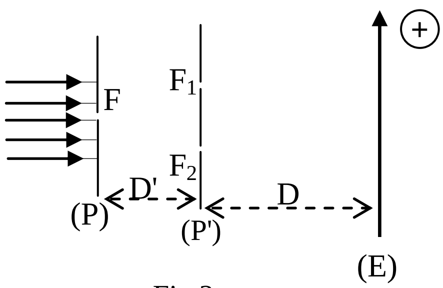


Fig.2

1) Show on a diagram the region where interference fringes may appear.

2) Specify, with justification, the position O, the center of the central fringe.

3) A point M on the screen is at a distance d_1 from F_1 and at a distance d_2 from F_2 such that: $d_2 = d_1 + 1500$ nm. The point M is the center of the third dark fringe. Why?

4) We count on (E) 11 bright fringes. Calculate the distance d between the centers of the farthermost bright fringes.

5) We move the apparatus and hence the slit F a distance z to the side of F_2 normal to the perpendicular bisector of F_1F_2, the new position of F being denoted by F' . We observe that the central fringe occupies now the position that was occupied by the third bright fringe.

a) Explain why the central fringe is displaced on the screen and determine the direction of this displacement.

b) For a point N of (E), of abscissa x with respect to O, we can write:

$$(F'F_2N) - (F'F_1N) = \frac{ax}{D} + \frac{a\,z}{D'}$$ **.** Calculate the value of z.

<u>Fourth Exercise</u>: (7 ½ points) **The neutrons and the nuclear fission in a reactor**

Given: m ($^{235}_{92}U$) = 234.99332 u; m (I) = 138.89700 u; m (Y) = 93.89014 u ; m_n = m($^{1}_{0}n$) = 1.00866 u;
1 u = 931.5 MeV/c^2.

In a uranium 235 reactor, the fission of a nucleus ($^{235}_{92}U$) under the impact of a thermal neutron gives rise to different pairs of fragments with the emission of some neutrons. The most probable pairs of fragments have their mass numbers around 95 and 140. One of the typical fission reactions is the one which produces the iodine ($^{A}_{53}I$), the yttrium ($^{94}_{Z}Y$) and 3 neutrons.

A – Determine Z and A.

B – ***1)*** Show that the mass defect in this reaction is Δm = 0.18886 u.

2) Determine, in MeV, the energy E liberated by this fission reaction.

3) Knowing that each neutron formed has an average kinetic energy E_0 = 1% E. Calculate E_0.

4) For a neutron, produced by the fission reaction, to trigger a new nuclear fission of a uranium nucleus 235, it must have a low kinetic energy around E_{th} = 0.025 eV (thermal neutron). In order to reduce the kinetic energy of a produced neutron from E_0 to E_{th}, this neutron must undergo successive collisions with heavier nuclei at rest of mass M = 2 m_n , called, "moderator" nuclei; these collisions are supposed elastic and all the velocities are collinear.

a) Using the laws of conservation of linear momentum and kinetic energy, show that after each collision, the neutron rebounds with one third (1/3) of its initial speed.

b) Determine, in terms of E_0, the expression of the kinetic energy E_1 of the neutron after the first collision. Deduce, in terms of E_0, the expression of the kinetic energy K.E of the neutron after the k^{th} collision.

c) Calculate the number k of collisions needed for the energy of a neutron to decrease from E_0 to 0.025 eV.

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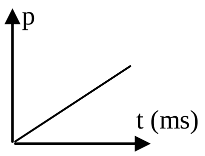
الاسم: الرقم:	مسابقة في مادة الفيزياء المدة ثلاث ساعات	مشروع معيار التصحيح

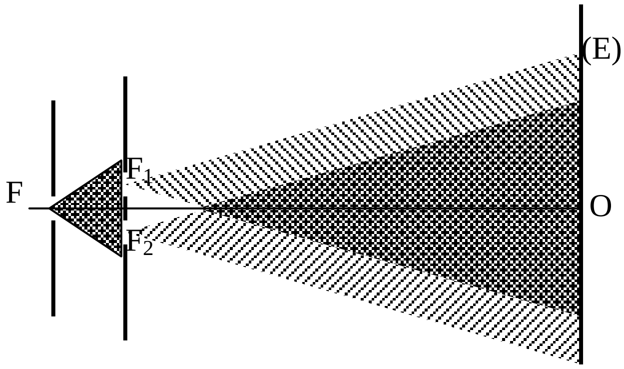
First exercise (7.5 points)

Part of the Q	Answer	Mark
A.1	$KE(t_4) = ½ m V_4^2 = ½0.18×0.87^2 = 7.056 ×10^{-3}$ J	0.5
A.2	Variation of the kinetic energy of B: $\Delta KE = 7,056 ×10^{-3}$ J – 0 = $7.056 ×10^{-3}$ J.	0.5
A.3	The forces acting on (B), are: the tension $\vec{T}_1$ upward and the weight $\vec{W}_1$ of (B) downward. $\Delta KE = W(\vec{T}_1) + W(\vec{W}_1) = W(\vec{T}_1) + mg(x_4 – x_0)$ $\Rightarrow 7.056 ×10^{-3} = W(\vec{T}_1) + 0.18×10×(2.8×10^{-2} – 0)$ $\Rightarrow W(\vec{T}_1) = - 43.344×10^{-3}$ J	1
A.4	$W(\vec{T}_1) = -\vec{T}_1 \cdot \vec{x} = - T_1(x_4 – x_0) \Rightarrow - 43.344×10^{-3} = - T_1(2.8×10^{-2})$ $\Rightarrow T_1 = 1.548$ N	0.5
B.1	P = MV; P_0 = 0 kg·m/s; P_1 = 0.07 kg·m/s; P_2 = 0.14 kg·m/s; P_3 = 0.21 kg·m/s; P_4 = 0.28 kg·m/s.	0.5
B.2.a		1
B.2.b	The graph of P as a function of time is a straight line: P = kt + b. For t = 0, P = 0 = b ; and k = slope of the graph = 1.40 kg·m/s^2.	1
B.3.a	$\sum \vec{F} = \frac{d\vec{P}}{dt} = k = Ma \Rightarrow a = 1.40$ m/s^2	1
B.3.b	The forces acting on the trolley are: $\vec{T}_2$ horizontal and $\vec{W}_2$ the weight of (A) and normal reaction $\vec{R}$. Applying Newton's second law: $\sum \vec{F} = \frac{d\vec{P}}{dt}$. $\vec{T}_2 + \vec{W}_2 + \vec{R} = \frac{d\vec{P}}{dt}$, Horizontal projection: $T_2 = \frac{dP}{dt} = 1.40$ N	0.5
C.1	Forces acting on the pulley: $\vec{T}'_1$, $\vec{T}'_2$, $\vec{W}_p$ and $\vec{R}_N$.	0.5
C.2	$\sum moments(\vec{F}_{ext}) = I\ddot{\theta}$ gives $(T_1 – T_2) r = I\ddot{\theta} = I\frac{a}{r}$, which gives $I = 2.643×10^{-4}$ kg·m^2.	0.5

Second exercise (7.5 points)

Part of the Q	Answer	Mark
A.1	(D_1) is a capacitor, since under constant voltage, in the steady state mode, the circuit does not carry any current at the end of its charging.	0.5
A.2	$P = I_2^2 r \Rightarrow r = 5\ \Omega$	0.5
B.1	The power $P = UI\cos\varphi$. - For the capacitor: $P = 0 \Rightarrow \cos\varphi_1 = 0 \Rightarrow \lvert\varphi_1\rvert = \frac{\pi}{2}$ rd. - For the coil : $P = 2.5$ W and $I_2 = \frac{\sqrt{2}}{2}$ A $\Rightarrow 2.5 = 5\frac{\sqrt{2}}{2}\cos\varphi_2$ $\Rightarrow \lvert\varphi_2\rvert = \frac{\pi}{4}$ rd.	0.5 0.5
B.2	In the case of C circuit only i leads u by $\frac{\pi}{2}$, $i_1 = 0.05\sqrt{2}\sin(100\pi t+\frac{\pi}{2})$; For a RL circuit i lags u by $\frac{\pi}{4}$, $i_2 = \frac{\sqrt{2}}{2}\sqrt{2}\sin(100\pi t-\frac{\pi}{4})$	0.5 0.5
B.3.a	$i_1 = \frac{dq}{dt}$ and $q = Cu \Rightarrow i_1 = C\frac{du}{dt}$.	0.5
B.3.b	$i_1 = C\frac{du}{dt} = 5\sqrt{2}C\times 100\pi\cos 100\pi t$ $\Rightarrow i_1 = 500\,\pi\,C\sqrt{2}\sin(100\pi t+\frac{\pi}{2})$ By comparing the amplitudes: $500\,\pi\,C\sqrt{2} = 0.05\sqrt{2}$ $\Rightarrow C = 32\times 10^{-6}$ F or 32 μF	1.5
B.4.a	$u = ri_2 + L\frac{di_2}{dt}$.	0.5
B.4.b	$5\sqrt{2}\sin 100\pi t = 5\sin(100\pi t-\frac{\pi}{4}) + L\times 100\pi\cos(100\pi t-\frac{\pi}{4})$ For t = 0: $0 = -5\frac{\sqrt{2}}{2} + L\times 100\pi\frac{\sqrt{2}}{2} \Rightarrow L = 0.016$ H or 16 mH.	1
B.5.a	Current Resonance	0.5
B.5.b	$LC\omega_0^2 = 1 \Rightarrow C = \frac{1}{4\pi^2 f_0^2 L} \Rightarrow C = 31.6\ \mu F$	0.5

Third exercise (7.5 points)

Part of the Q	Answer	Mark
A.1.a	$a = a_1 = 1cm$: we observe a luminous spot.	0.5
A.1.b	$a = a_2 = 0.5$ mm: we observe a diffraction pattern: alternating bright and dark fringes located on both sides of a central fringe which is the brightest and of width double any other bright fringe.	0.75
A.2	To isolate a ray of light, a beam must pass through a tiny hole of very small diameter. Because of the diffraction of light, this beam diffracts and the ray is not isolated	0.25
A.3	The angular width of the central fringe of diffraction is : $\alpha = \frac{2\lambda}{a_2} = \frac{\ell}{D}$ + Figure $\Rightarrow \lambda = 600$ nm.	1
A.4	$\alpha = 2\frac{\lambda}{d} = \frac{\ell'}{D}$ $\Rightarrow d = 3\times10^{-4}$ m = 0.3 mm	0.5
B.1	See figure 	0.50
B.2	The central fringe is characterized by $\delta = 0$, hence its position O is the intersection of the perpendicular bisector of F_1F_2 with the screen. Nature: bright because $\delta = 0$ is justified by $\delta = k\lambda$ for $k = 0$.	0.5
B.3	$\delta = d_2 - d_1 = 1500$ nm; $\frac{\delta}{\lambda/2} = 5 = (2k + 1) \Rightarrow k = 2$; first dark fringe $\Rightarrow k = 0$; $k = 2 \Rightarrow 3^{rd}$ dark fringe,	1
B.4	$d = 10\, i = 10\frac{\lambda D}{a} = 12$ mm	0.5
B.5.a	Since the central fringe is characterized by $\delta = 0$ and since the path $OF_1F' > OF_2F'$, then the path difference at O is not zero, so the central fringe is no longer at O. Let O' be the new position: $O'F_1F' = O'F_2F'$, since FF_2 is smaller than FF_1 $\Rightarrow O'F_2$ must be larger than $O'F_1$, O' $\Rightarrow$ above O	1
B.5.b	If O 'coincides with N, then $\delta_N = 0$ and consequently $\frac{ax}{D} + \frac{az}{D'} = 0$ $\Rightarrow z = -\frac{D'x}{D}$; the bright fringe of order 3 forms at the point of of abscissa $x = 3\frac{\lambda D}{a} = 3.6\times10^{-3}$ m or 3.6 mm. Thus $z = \frac{-1\times3.6}{2} = -1.8$ mm.	1

Fourth exercise (7.5 points)

Part of the Q	Answer	Mark
A	${}_0^1n + {}_{92}^{235}U \longrightarrow {}_{53}^{A}I + {}_{Z}^{94}Y + 3{}_0^1n$ $1 + 235 = A + 94 + 3 \Rightarrow A = 139$; $0 + 92 = 53 + Z + 0 \Rightarrow Z = 39$.	0.5
B.1	$\Delta m = 1.00866 + 234.99332 – 138.89700 – 93.89014 - 3\times1.00866$ $\Delta m = 0.18886$ u	2
B.2	The energy $E = \Delta m\, c^2 = 0.18886\times931.5 = 175.92$ MeV.	1
B.3	$E_0 = 1.759$ MeV.	0.5
4.a	Conservation of linear momentum: $m_nV_0 + 0 = m_nV_1 + 2m_n V' \Rightarrow V_0 – V_1 = 2 V'$ (1); Elastic collision: $\frac{1}{2} m_n V_0^2 = \frac{1}{2} m_n V_1^2 + \frac{1}{2} 2m_nV'^2 \Rightarrow V_0^2 - V_1^2 = 2 V'^2$ (2); (1) and (2) $\Rightarrow V_1 = \frac{-V_0}{3}$	2
4.b	$\frac{1}{2} m_n V_1^2 = \frac{1}{2} m_n \frac{V_0^2}{9} \Rightarrow E_1 = \frac{E_0}{9}$ and $E_k = (\frac{1}{9})^k E_0 = \frac{E_0}{9^k}$	1
4.c	$0.025 = \frac{1.76\times10^6}{9^k} \Rightarrow (k)\ln9 = \ln(\frac{1.76\times10^6}{0.025}) \Rightarrow k = 8$.	0.5