Physics Pro

Secondary Education

LS

2022-2023

Sammary

+

Exercises

Visit this site

https://physpro-sv-sg.blogspot.com/

Whatsapp : 70396286

Fawaz obeid

Summary + Exercises

LS

Third Year

Chap.1

Mechanical energy

Kinetic form KE

particle

$$KE_{J}=\frac{1}{2}m_{kg}v^2_{m/s}$$

Appication 1 *fig.1*

1

2

General system

$$KE = \sum\frac{1}{2}m_iv_i^2$$

Gravitational Potential Energy PEg

Particle 3

$$PE_{g\,J} = m_{kg}g_{N/kg}z_{m}$$

Appication 2 *fig.2*

Extended object 4

$$PE_g = mgz_G$$

center of mass of object

Elastic Potential Energy PEe

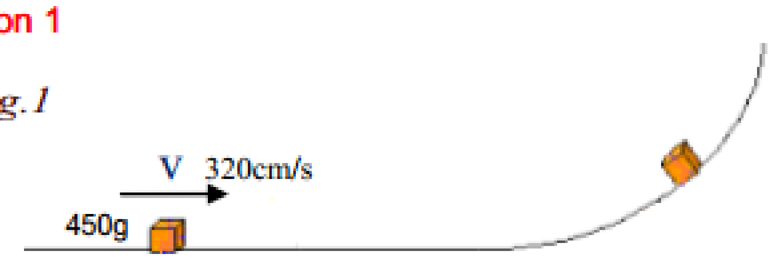
Spring 5

$$PE_{e\,J}=\frac{1}{2}k_{N/m}\Delta l^2_{m}$$

Appication 3 *fig.3*

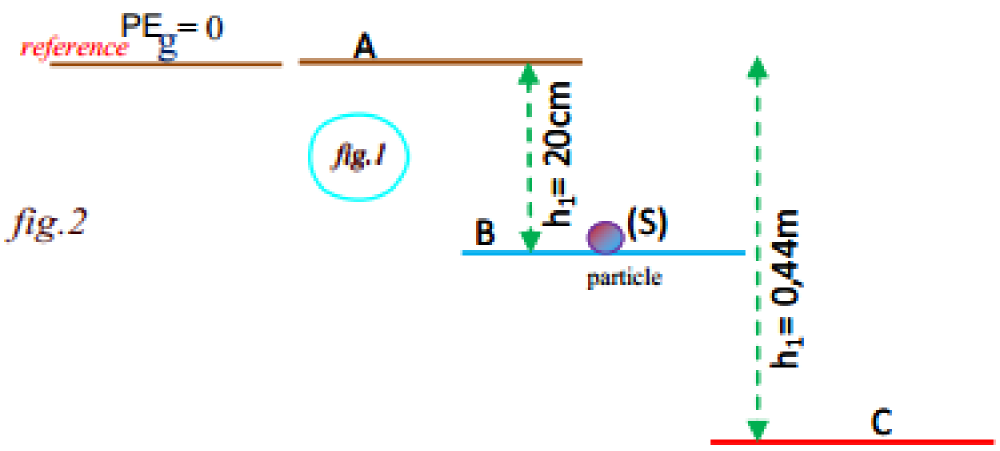
Appication 1

fig.1



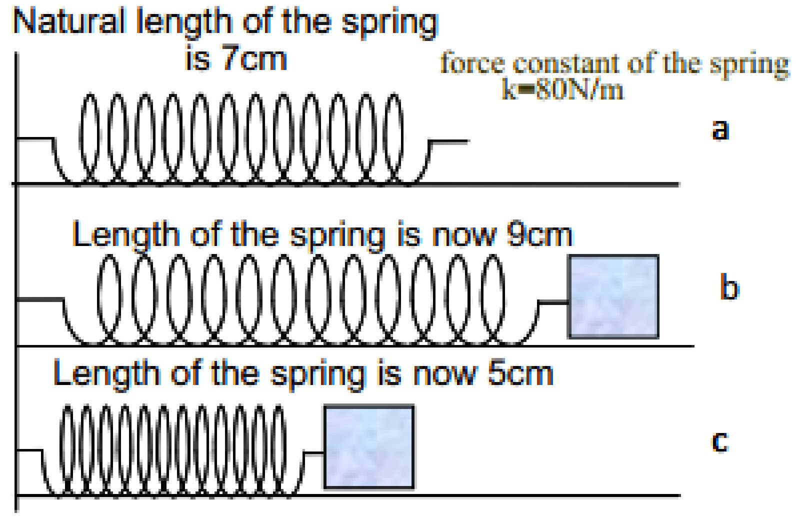
Appication 2

fig.2



Appication 3

fig.3



[redacted]echanical energy of a system

$ME =$ [redacted]$E + PE_g + PE_e$

a[redacted] same instant t

8

isolated system ?

What is meant by «isolated system»?

No exchange of energy between this system and its surrounding.

9

See exercise 2

[redacted]onservation of ME

[redacted]an isolated system

In[redacted]*e (without friction)*

[redacted]$E_1 = ME_2$

10

See exercise 3

Non conservation of ME

For an isolated system

In case where (friction exists)

$ME_2 - ME_1 = -\Delta U$

11

wih ΔU (is the variation of internal energy of the system).

We can write :

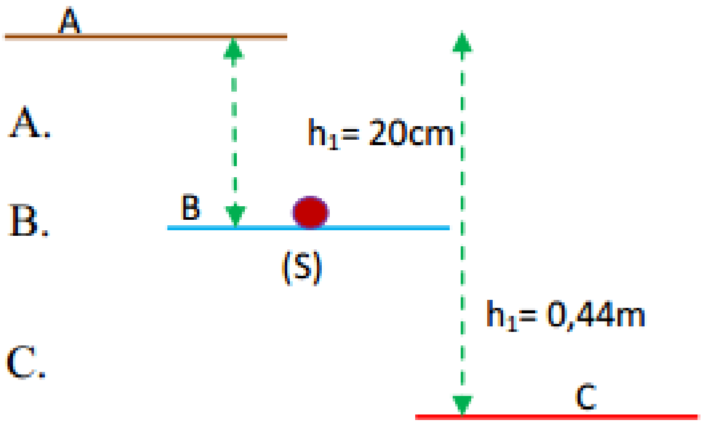
$ME_2 - ME_1 = W_{\vec{f}}$ where : $\vec{f}$ (friction forces) .

$W_{\vec{f}} = -f.d$; *where d : displacement.*

f (constant) and d (rectlilinear).

Exercise 1 :

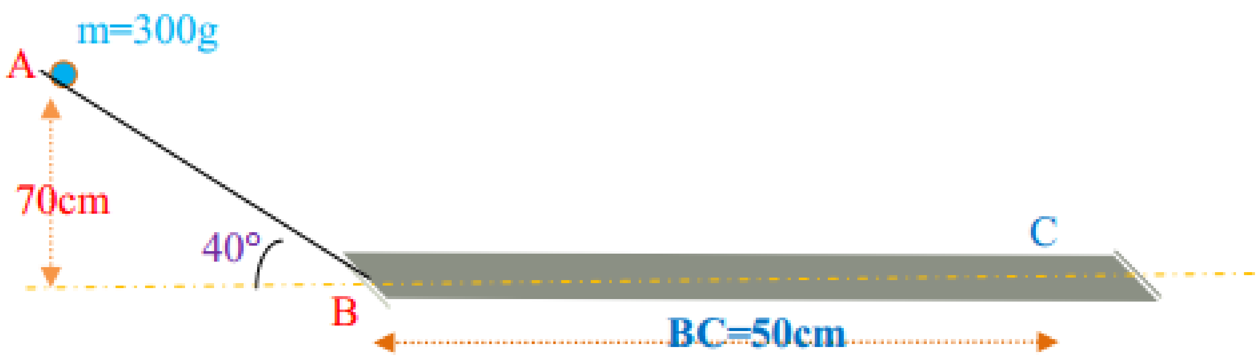
A ball (S) has a mass m=300g, is placed at level B as indicated in the figure below.
Determine the gravitational potential energy E_{pg} of the system (S ; earth) in each of the following cases :



1. The reference level for gravitational potential energy is at A.
   Ans. - 0,4J.
2. The reference level for gravitational potential energy is at B.
   Ans. 0J.
3. The reference level for gravitational potential energy is at C.
   (Take g = 10m/s²). Ans. 0,48 J.

Exercise 2 : Conservation of E_m

A small spherical particle, considered as a particle of mass m=300g,

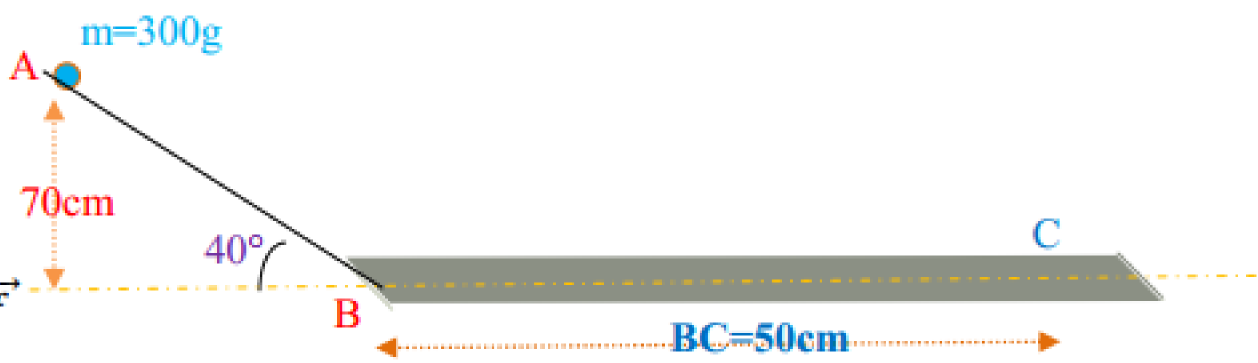


Initially at rest at point A.
When we release this particle, it moves down the track without inial speed, continues its motion without friction to reach the point C with a velocity $\vec{V}_C$.
Apply the principle of conservation of mechanical energy to determine the speed V_C at point C.

Answer : V_C=3,74m/s.

Exercise 3 : Non-conservation of E_m

Take the same given of the above application, but in this example we suppose that the friction is negligible on the part BC, while it has a constant value on AB such that the average magnitude of $\vec{f}$ is f = 0.4N.

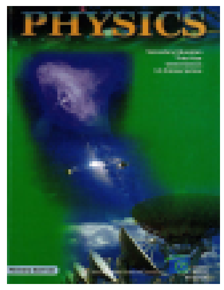


1) Determine the new value of V'_C and compare its value to the previous one V_C (without friction).

   Answer : V'_C =3,33m/s

2) Where is the lost mechanical energy ? Deduce the variation of the internal energy.

Exercise 3:



A parachutist (S), of total mass 100 kg, jumps from an airplane flyi[redacted]t an altitude of 1000 m with a speed of 270km/h with respect[redacted]he ground.

(S) reaches t[redacted]round with a speed of 18km/h.

a) Is the me[redacted]ical energy of the system ((S), Earth) conserved during th[redacted]p? Interpret.

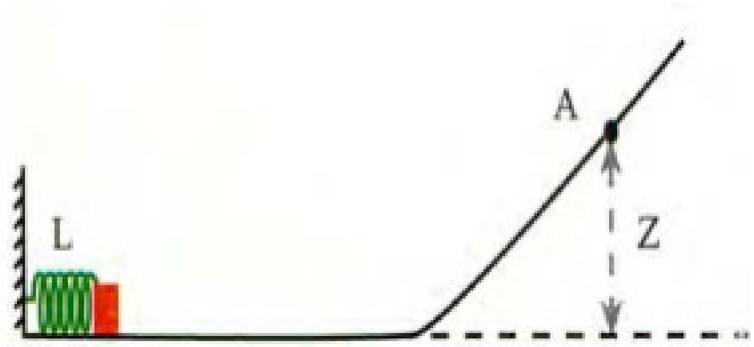
b) Calculate [redacted]hermal energy produced.

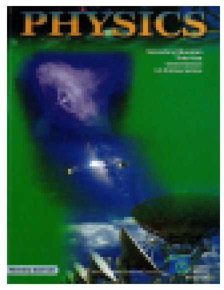
Exercise 4 :

To launch [redacted]id of mass m on an inclined slide, we use the apparatus shown in figure 1.

The natura[redacted]gth of the spring is L_0. Before launching, the spring is compressed to a lengt[redacted]

After laun[redacted], the center of mass of t[redacted]lid reaches the point A of altitude Z [redacted]a velocity v. Neglect friction.



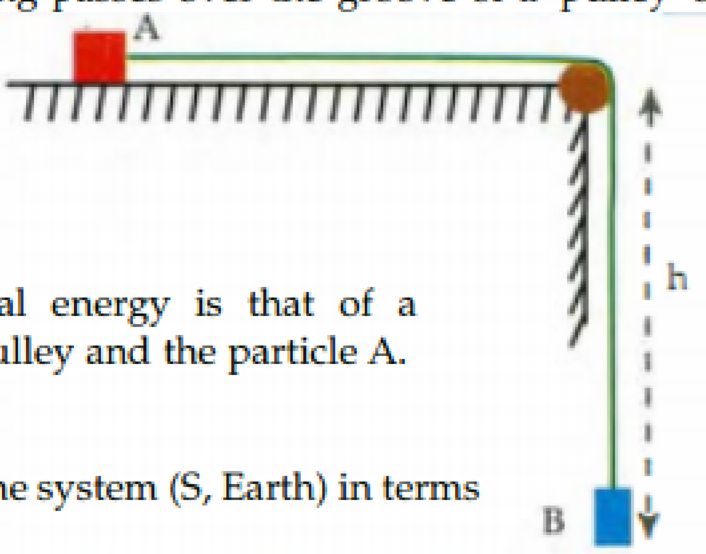


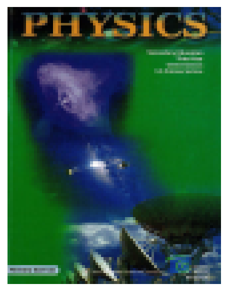
a) Determin[redacted] relation among L_0, L, m,v, Z, g, and [redacted]onstant k of the spring.

b) Calculate[redacted]f the maximum altitude reached i[redacted] cm. Take m=600g, L = 25 cm[redacted]d L=20cm.

Exercise 5:

Two particles[redacted]nd B, of respective masses m_A and m_B, are connected together by means of an inextensible [redacted]g of negligible mass. The string passes over the groove of a pulley of negligible mass as sh[redacted]in the figure





At instant t_0 [redacted]the system S (pulley, mass, string) is le[redacted]thout initial velocity, with particle B be[redacted]t a distance h from the axis of the pu[redacted]

The referen[redacted]evel of gravitational potential energy is that of a horizontal p[redacted]containing the axis of the pulley and the particle A.

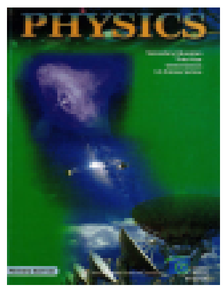
(Neglect fric[redacted]

a) Calculate[redacted]= 0, the mechanical energy of the system (S, Earth) in terms of m_B, g, [redacted]h.

b) Calculate [redacted]echanical energy of the system (S, Earth) after covering a distance x.

c) Calculate, [redacted]pplying the principle of the conservation of mechanical energy, the velocit[redacted]f A or B in terms of x, m_A m_B and g. Deduce th[redacted]eleration of the motion.

Exercise 5[redacted]



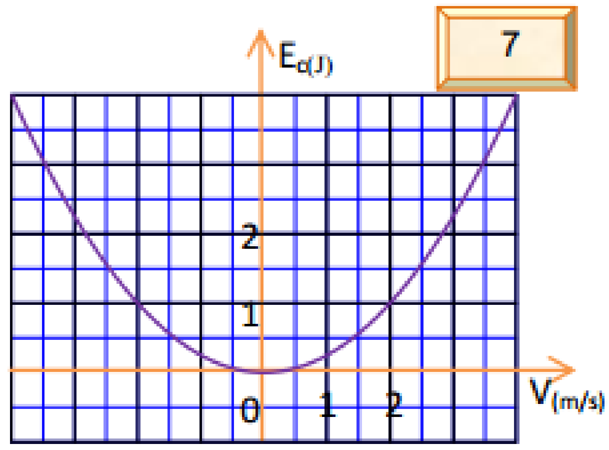
A homogene[redacted]rod, of mass M=20kg, of length L =[redacted], and of negligible cross-section, rests[redacted]lly on the horizontal ground chosen as a r[redacted]nce level for the gravitational potential en[redacted]

The rod is r[redacted]d about one end until it takes a vertical p[redacted]n.

Calculate th[redacted]iation of the mechanical energy of the syste[redacted]d, Earth).

Exercise 5-b :

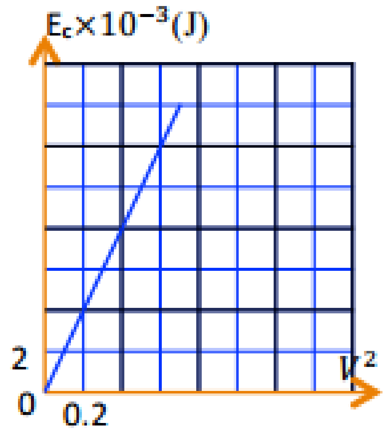
A body moves in translational motion with a speed V. The graph of the kinetic energy as function of V is given in the figure to the right



Deduce the mass of this body. ANS. 0,5Kg.

Exercise 5-c:

A body of mass m moves in translational motion with a speed V.



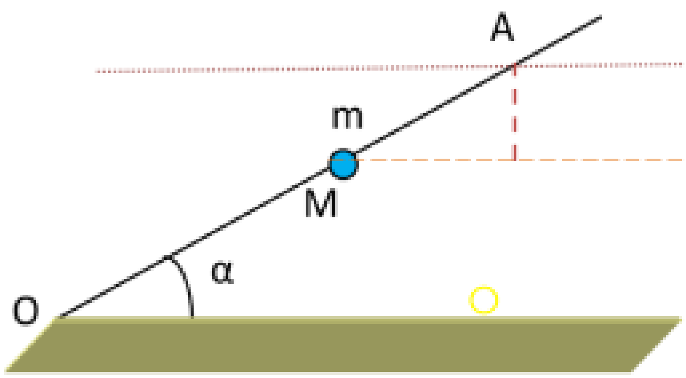
The graph of the kinetic energy as function of V^2 is shown in the figure to the right.

1) Justify the shape of the graph obtained.
2) Deduce the mass of this object. ANS. 40g.

Exercise 5-d:

The horizontal level passing through A is the reference level for gravitational potential energy E_{pg}.

See figure.



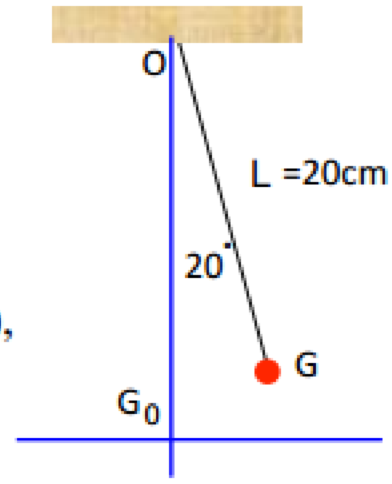
Calculate the gravitational potential energy E_{pg} of the system (Particle ; Earth).

Given: $m_{particle}$=50g ; OA=55cm;OM=30cm and α=40°.

Ans. Epg= – 0,08J.

Exercise 5-e :

A ball of mass 120 g is attached to a string as shown in the figure. Take the horizontal level passing through G_0 as reference level for gravitational potential energy E_{pg} .



Calculate the gravitational potential energy E_{pg} of the system (Particle ; Earth), when the pendulum is at the position G indicated in the figure.

Ans. 14,47mJ

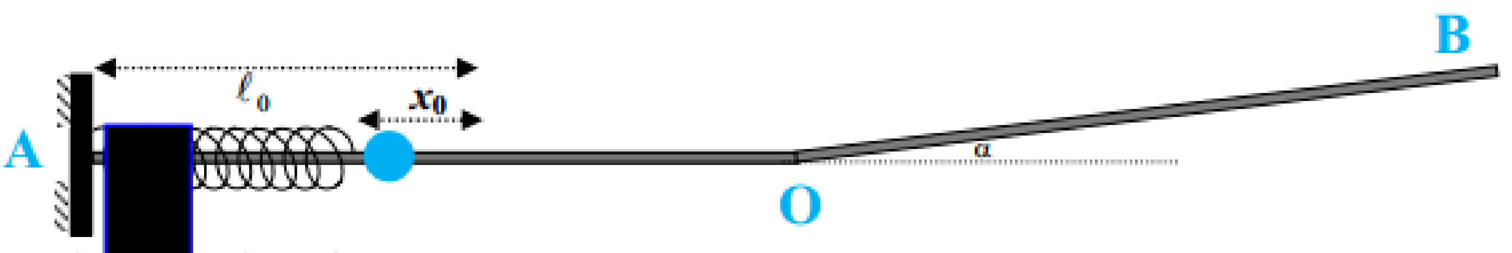
Exercise 6 — Determination of the value of a force of friction

PHYSICS
LS 2005-1

A solid (S) of mass m = 200 g is free to move on a track AOB lying in a vertical plane. This rail is formed of two parts: the first one AO is straight and horizontal and the other OB is straight and inclined by an angle α with respect to the horizontal (sin α = 0.1). Along the part AO, (S) moves without friction, and along the part OB, (S) is acted upon by a force of friction $\vec{f}$ that is assumed constant and parallel to the path. The object of this exercise is to determine the magnitude f of the force $\vec{f}$ of friction.

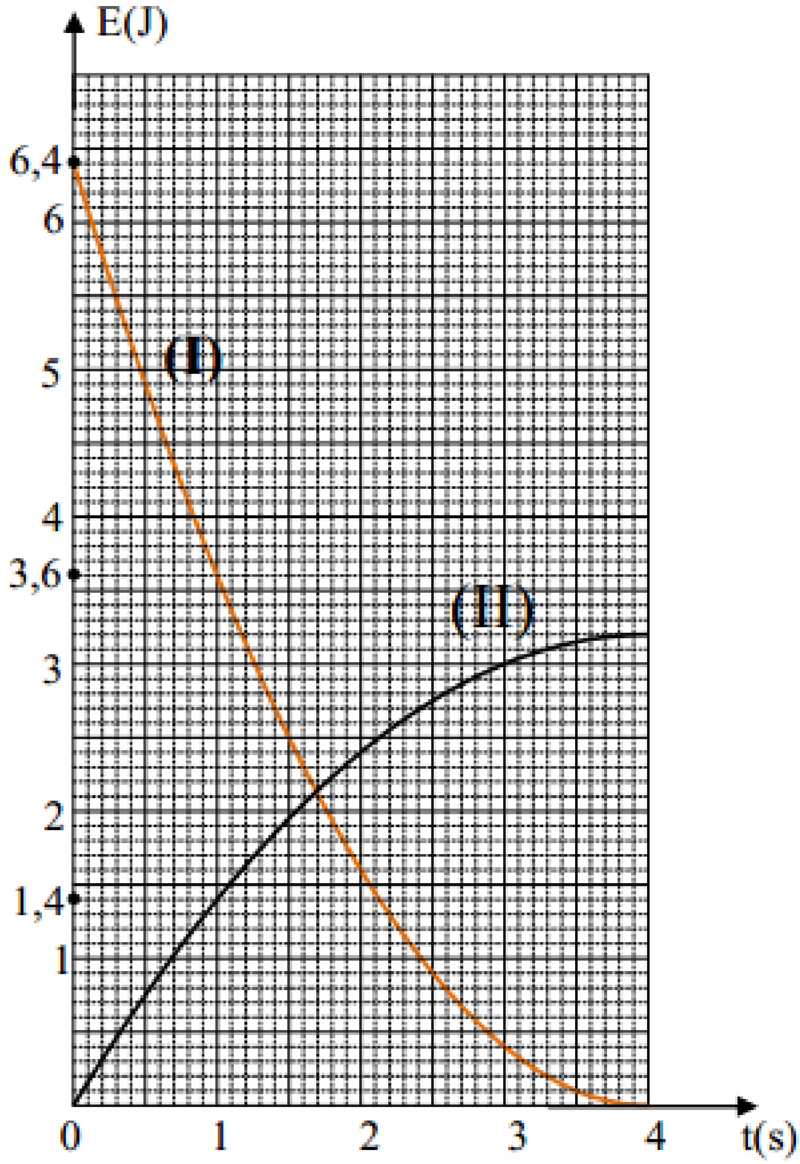
A- Lanching the solid

In order to launch this solid on the part AO, we use a spring of constant k = 320 N / m and of free length ℓ_0 ; one end of the spring is fixed at A to a support. We compress the spring by x_o; we place the solid next to the free end of the spring and then we release them. When the spring attains its free length ℓ_0, the solid leaves the spring with the speed V_0 = 8 m/s; it thus slides along the horizontal part and then rises up at O the inclined part OB.



1) Determin[redacted] value of x_0.
2) The solid[redacted]hes O with the speed $V_0 = 8$ m/s. Justify.

B- Motion [redacted]e solid along the inclined part OB



(S) moves, at [redacted] the inclined part OB with the speed V_0 at the insta[redacted]= 0. A convenient apparatus is used to trace, as a fun[redacted] of time, the curves representing the variations of t[redacted]netic energy K.E of the solid and the gravitational p[redacted]tial energy $P.E_g$ of the system (solid - Earth)[redacted]

These curves [redacted]epresented in the adjacent fig[redacted]tween the instants t_o= 0 and t_4 [redacted] according to the scale:

- 1 division[redacted]e time axis corresponds to 1 s
- 1 division[redacted]e energy axis corresponds to 1 J.

The horizonta[redacted]e through point O is taken as a gravitational potential ener[redacted]ference. Take $g = 10\ m/s^2$.

1) The curve [redacted]epresents the variation of the kine[redacted]ergy K.E of (S) as a function of time. Why?

2) Using the [redacted]s:

a) spec[redacted]e form of the energy of the system at the instant $t_4 = 4$ s. Justify your answer.

b) deter[redacted] the maximum distance covered by the solid along the part OB.

c)i) comp[redacted]he table with the values of the mechanical energy M.E of the system at each instant t.

t (s)	0	1	2	3	4
M.E.(J)		5			

ii) justi[redacted] existence of a force of friction $\vec{f}$.

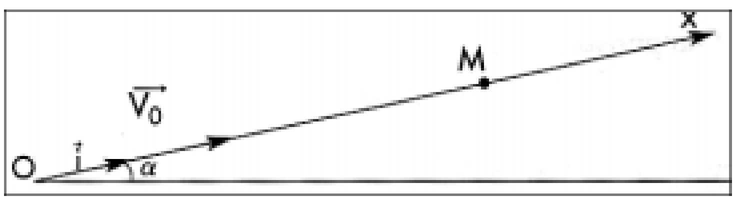
iii) calcu[redacted]the variation in the mechanical energy of the system between the instants t_o=[redacted]d $t_4 = 4$ s.

iv) det[redacted]e f.

Exercise[redacted]

Graphical study of energy exchange

PHYSICS
LS 2003-2



Consider an i[redacted]d plane that makes an angle α with the horizontal ($\sin\alpha = 0.2$) a[redacted]marble (B) of mass m = 100 g, taken as a particle. We intend to [redacted] the energy exchange between the system (marble, Earth) and the[redacted]oundings.

To do that, th[redacted]ble (B) is given, at the instant $t_o = 0$, the velocity $\vec{V_0} = V_o\vec{i}$ along the line of greatest slope OX. Given V[redacted]m.s^{-1} and $g = 10\ m/s^2$.

The horizonta[redacted]e through point O is taken as the gravitational potential energy reference.

A- The forces[redacted]iction are supposed negligible.

1- Determ[redacted]he value of the mechanical energy M.E of the system (marble, Earth).

2- At the [redacted]nt t, the marble passes through a point M of abscissa OM = x. Determine, as a function of x, the exp[redacted]n of the gravitational potential energy $P.E_g$ of the system (marble, Earth) when the marble passes t[redacted]gh M.

3-a) Trace, on the same system of axes, the curves representing the variations of the energies M.E and P.E_g as a function of x.

Scale: - on the axis of abscissas: 1 cm represents 1 m;

- on the axis of energy: 1 cm represents 0.2 J.

b) Determine, using the graph, the speed of the marble for x = 3 m.

c) Determine, using the graph, the value of x_m of x for which the speed of (B) is zero.

B-1. In reality, the speed of the marble becomes zero at a point of abscissa x = 3 m. The forces of friction are no longer negligible. Calculate then the work done by the forces of friction between x = 0 and x = 3 m.

2. The system (marble, Earth) thus exchanges energy with its surroundings. In what form and by how much?

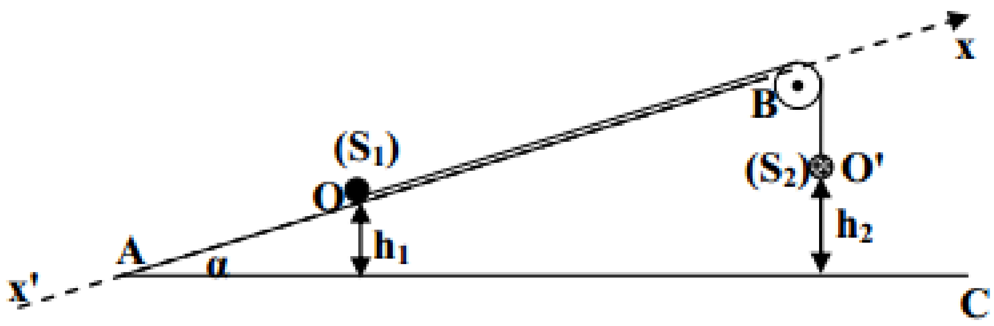
Exercise 8 ***Acceleration of a particle*** PHYSICS LS 2011-2

The object of this exercise is to determine the expression of the magnitude of the acceleration of a particle using two methods. The apparatus used is formed of two particles (S_1) and (S_2) of respective masses m_1 and m_2, fixed at the extremities of an inextensible string passing over the groove of a pulley. (S_1), (S_2), the string and the pulley form a mechanical system (S).

The string and the pulley have negligible mass.

(S_1) may move on the line of greatest slope AB of an inclined plane that makes an angle α with the horizontal AC and (S_2) hangs vertically.

At rest, (S_1) is found at point O at a height h_1 above AC and (S_2) is found at O' at a height h_2 (adjacent figure).



At the instant $t_0 = 0$, we release the system (S) from rest. (S_1) ascends on AB and (S_2) descends vertically.

At an instant t, the position of (S_1) is defined by its abscissa $x = \overline{OS_1}$ on an axis x'Ox confounded with AB, directed from A to B.

Take the horizontal plane containing AC as a gravitational potential energy reference.

Neglect all the forces of friction.

1) Energetic method

a) Write down, at the instant $t_0 = 0$, the expression of the mechanical energy of the system [(S), Earth] in terms of m_1, m_2, h_1, h_2 and g.

b) At the instant t, the abscissa of (S_1) is x and the algebraic value of its velocity is v. Determine, at that instant t, the expression of the mechanical energy of the system [(S), Earth] in terms of m_1, m_2, h_1, h_2, x, v, α and g.

c) Applying the principle of conservation of mechanical energy, show that :

$$v^2 = \frac{2(m_2 - m_1 \sin\alpha)gx}{(m_1 + m_2)}.$$

d) Deduce the expression of the value a of the acceleration of (S_1).

2) Dynamical method

a) Redraw a diagram of the figure and show, on it, the external forces acting on (S_1) and on (S_2). (The tension in the string acting on (S_1) is denoted by $\vec{T}_1$ of magnitude T_1 and that acting on (S_2) is denoted by $\vec{T}_2$ of magnitude T_2).

b) Applying the theorem of the center of mass $\Sigma\vec{F}_{ext} = m\vec{a}$,on each particle, determine the expressions of T_1 and T_2 in terms of m_1 , m_2 , g , α and a .

c) Knowing that $T_1 = T_2$, deduce the expression of a.

Linear momentum

In case of a **particle** or a **solid** in translation motion

1. $\vec{P} = m\vec{V}$

In case of a system of **many particles**

2. $\overrightarrow{P_{(S)}} = \sum \vec{P_i} = \sum m_i \vec{v_i}$

3. Consider G , the center of mass of the system : $\overrightarrow{P_{(S)}} = M\overrightarrow{V_G}$

Theorem of linear momentum

4. $\sum \overrightarrow{F_{ext}} = \frac{\overrightarrow{dp}}{dt}$

Remark : *in case where* $\sum \overrightarrow{F_{ext}} = \overrightarrow{const}$ *we can take* $\frac{\overrightarrow{dp}}{dt} = \frac{\overrightarrow{\Delta p}}{\Delta t}$

Observations we face :

5. Collision with coupling

6. Elastic collision: $KE_{bef\ coll} = KE_{aft\ coll}$

   Inelastic collision: *Decreasing of KE*

7. Explosion of an object

Conservation of $\vec{P}$

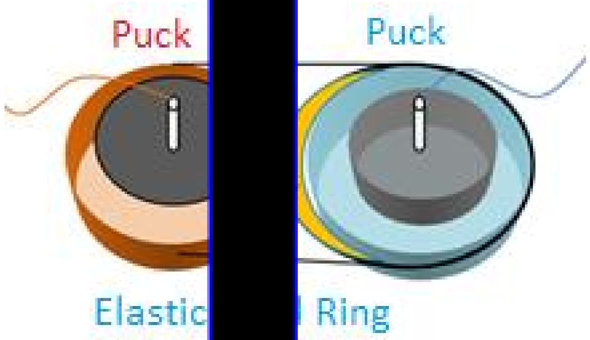
8. $\sum \overrightarrow{F_{ext}} = \vec{0}$ ⟹ $\overrightarrow{P_{before}} = \overrightarrow{P_{after}}$

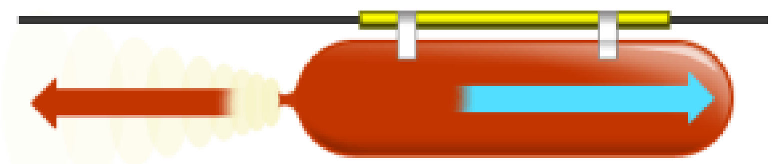
Non-conservation of $\vec{P}$

9. $\sum \overrightarrow{F_{ext}} = \overrightarrow{const} \neq \vec{0}$ ⟹ $\overrightarrow{P_{after}} - \overrightarrow{P_{before}} = \sum \overrightarrow{F_{ext}} \times \Delta t$

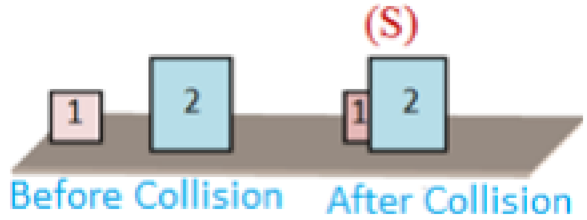
Ap[redacted]ation of the theorem $\sum \overrightarrow{F_{ext}} = \frac{\overrightarrow{dp}}{dt}$; where $\sum \overrightarrow{F_{ext}} = \vec{0}$

Conservation of the linear momentum





1 [redacted]n-elastic Collision: theoretical Study



In the adj[redacted]nt figure, (1) and (2) bind together and form one [redacted]ct after the collision.

System (o[redacted]t 1; object 2) is isolated.

$\overrightarrow{P_{before}} = m$ [redacted] $+m_2\vec{v_2}$ and $\overrightarrow{P_{after}} = (m_1+m_2)\vec{V}$;

Then the [redacted]servation of linear momentum can be written as:

[redacted] $\overrightarrow{P_{before}} = \overrightarrow{P_{after}}$; finally ; $\vec{V} = \frac{m_1\vec{v_1}+m_2\vec{v_2}}{(m_1+m_2)}$

2 [redacted]stic Collision: theoretical study

- An ob[redacted]B₁ hits elastically another statio[redacted] object B₂, the last object is set in mo[redacted]
- If the [redacted]objects are on the same line when they enter into collision, (front collisi[redacted]the first object may stop.

Verificati[redacted]

Conside[redacted]e isolated system (object 1; object 2) during the collision (since $\sum \overrightarrow{F_{ext}} = \vec{0}$), the[redacted] linear momentum is **conserved.**

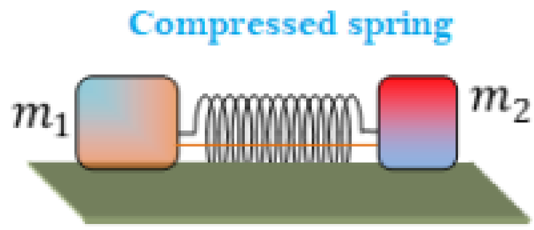
$\overrightarrow{P_{before}} =$ [redacted] $_1 + \vec{0}$ and $\overrightarrow{P_{after}} = m_1\overrightarrow{v_1'} + m_2\overrightarrow{v_2'} \Rightarrow m_1\overrightarrow{v_1} = m_1\overrightarrow{v_1'} + m_2\overrightarrow{v_2'}$ **(1)**

Elastic C[redacted]**sion** $\Rightarrow KE_{Before} = KE_{after} \Rightarrow \frac{1}{2}m_1v_1^2 + 0 = \frac{1}{2}m_1v_1'^2 + \frac{1}{2}m_2v_2'^2$ **(2)**

Frome t[redacted]e equation we can deduce that : speed of object (1) after the collision is:

$v_1' = \frac{m_1 -}{m_1 +}$ [redacted] v_1 **and that of object (2) after the collision is** $v_2' = \frac{2m_1}{m_1+m_2} v_1$

3 [redacted]losion: Theoretical study



The two [redacted]t (m_1 ; m_2) are bound together around a compress[redacted]pring taut by a string.

The syst[redacted]spring, m_1, m_2) being at rest; we burn the string at an instant t.

- $\overrightarrow{P_{be}}$[redacted] $= \vec{0}$ and $\overrightarrow{P_{after}} = m_1\vec{v_1} + m_2\vec{v_2}$.
- The[redacted]tem is isolated since $\sum \overrightarrow{F_{ext}}$ is null during the explosion.
- The[redacted]re, there is a conservation of the linear momentum, written as:
- $\overrightarrow{P}$[redacted]ore $= \overrightarrow{P_{after}}$; *finally* ; $\vec{v_2} = -\frac{m_1}{m_2}\vec{v_1}$

2.4- [redacted]plication of the theorem $\sum \overrightarrow{F_{ext}} = \frac{\overrightarrow{dp}}{dt}$ where $\sum \overrightarrow{F_{ext}} \neq \vec{0}$

[redacted]Non-conservation of the linear momentum

In the case[redacted]re the given system is not isolated, $\sum \overrightarrow{F_{ext}} \neq \vec{0}$.

We [redacted]focus only on the special case where $\sum \overrightarrow{F_{ext}} = \overrightarrow{constant}$.

In this spe[redacted]*ase:*

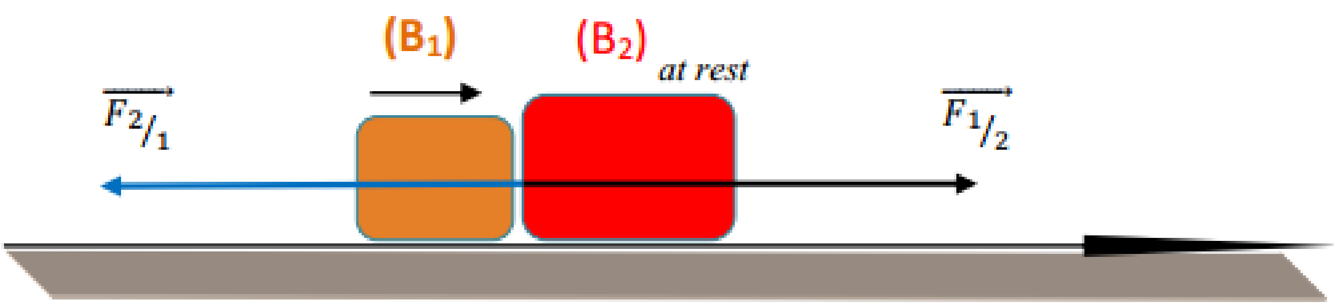
$\overrightarrow{P_{after}} - \overrightarrow{P}$[redacted]re $= \sum \overrightarrow{F_{ext}} \times \Delta t$. *(see application in the question 3)*

Question [redacted]etermine the reaction forces $\overrightarrow{F_{1/2}}$ exerted by the object (B_1) on the object (B_2). And t[redacted]pposite force $\overrightarrow{F_{2/1}}$ exerted by (B_2) on (B_1) during the elastic collision between the[redacted] objects knowing that this collision lasts for 0.3 sec.

Given: th[redacted]eeds just before collision: $v_1 = 2 m/s$; $v_2 = 0$ and the speeds just after collision ar[redacted]$_1 = -\frac{2}{3} m/s$ et $v'_2 = \frac{4}{3} m/s$.

Fig[redacted]

During t[redacted]
collision[redacted]



$m_1 = 100g$ and $m_2 = 200g$

Answer:

[redacted]$_2 = +\frac{8}{9}\vec{i}$ et $\overrightarrow{F_{2/1}} = -\frac{8}{9}\vec{i}$. Note that:

$\overrightarrow{F_{1/2}} = -\overrightarrow{F_{2/1}}$ (verification of Newton's 3rd law) .

Exercises

Linear momentum

Exercises

Chap. 2

Exercise 1: Skaters and collision.

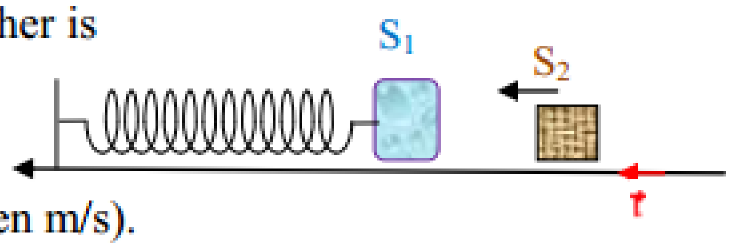
A skater of mass 60kg is at rest. Another skater of mass 40kg rushes into his hand with a speed 12 km/h. After holding his hand, the two skaters thus form one body (S) moving with a velocity $\vec{V}$.

1) Calculate V. *Answ.* 4,8km/h
2) Calculate the kinetic energy of (S) after collision. *Answ.* Before 222,22J ; after 88.88J
3) Specify the nature of this collision.

Exercise 2 : Compression of spring

Given a spring of negligible mass and stiffness k=10 N/m. The spring rests horizontally with one of its extremities is fixed to a vertical support while the other is attached to a solid (S_1) of mass M_1 = 300 g,

The solid (S_1) being at rest, is hit by another solid (S_2) of mass M_2= 100 g, moving with a velocity $\vec{V_2} = 1{,}0\vec{i}$ (en m/s).



After collision (S_2) sticks to (S_1) thus forming one body. We neglect frictional forces.

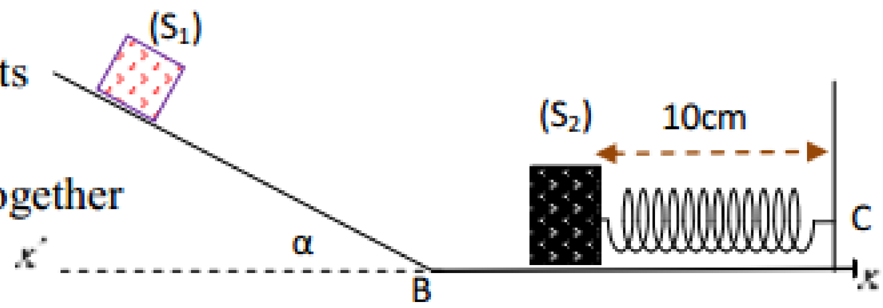
1) Calculate the velocity of the system just after collision.
2) Determine the value of the maximum compression of the spring.

Exercise 3 : Collision and conservation of mechanical energy

A solid (S_1) of mass m_1= 50 g, is launched without initial speed from point A. The solid slides on an inclined plane making an angle α =30° with the horizontal (see figure).

After covering distance AB=1m, (S_1) reaches the horizontal plane where it continue sliding before striking a solid (S_2) of mass m_2 = 200 g, initially at rest

We suppose frictional forces are negligible.

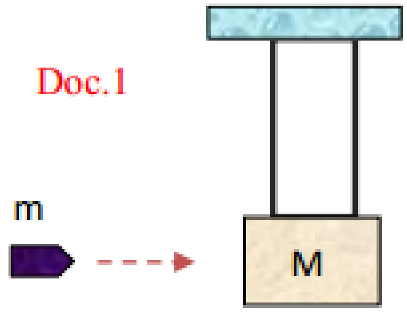


1) Determine the speed v_1 of (S_1) just before it hits (S_2).
2) At the moment of impact (S_1) and (S_2) stick together to form a single body (S).
   Calculate the speed of (S) just after impact.
3) Knowing that the length of the spring become 7 cm after maximum compression, calculate the stifness of the spring.

Exercise 4-a : Ballistic Pendulum

A projectile of mass **m** moving at a speed V_1 100m/s, hits a Bag filled with sand of masse **M**=90 **m**. The bag is suspended vertically From two wires of negligible masses . Doc.1

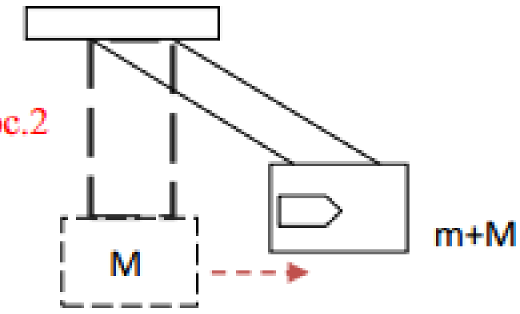
Doc.1



The projectile thus embedded in the sand and the whole system (m+M) goes up to a maximum height h. (see doc.2).

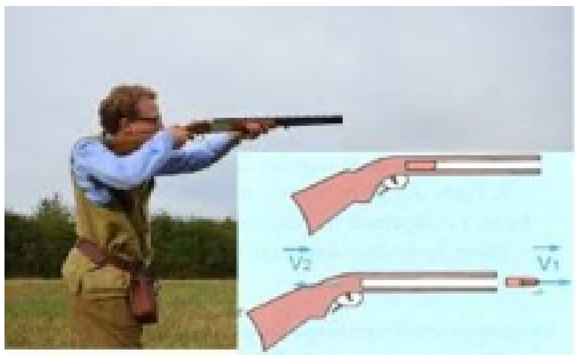
1) Calculate the speed of the system just after collision.
2) Neglecting all frictional forces, determine h.
3) This setup can be used to determine the speed of a projectile. Explain how.

Doc.2



Exercise 4-b : Formula $\overrightarrow{p_{before}} = \overrightarrow{p_{after}}$ in case of recoil of a gun

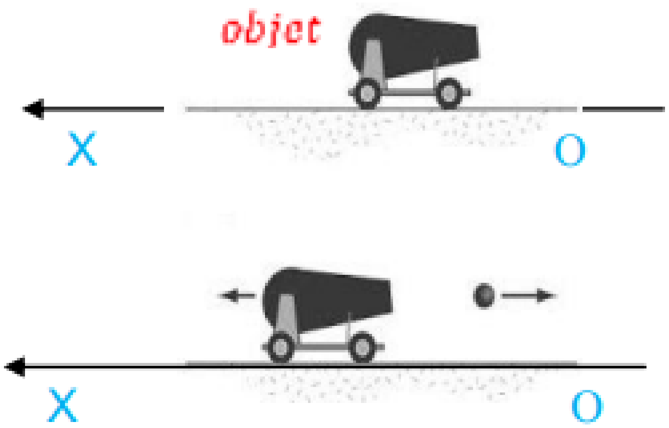
A gun of mass m_1=1,5kg initially at rest is placed horizontally.
The gun launches a bullet of mass m_2 = 15 g with a velocity $\overrightarrow{V_2}$ of magnitude V_2 =750 m/s.
Let $\overrightarrow{V_1}$ be the velocity of the gun just after firing.



1. Show that $\overrightarrow{V_1}$ cannot be null and its sense is opposite to $\overrightarrow{V_2}$
2. Determine $\overrightarrow{V_1}$. *Answ.* 7,5m/s
3. Explain why the recoil will be less sensitive if the gun is well supported.

Exercise 4-c : Explosion

An object of mass m, initially at rest on a horizontal axis $\overline{x'Ox}$, explodes into two pieces.
Just after explosion one piece of mass m/3 moves on $\overline{x'Ox}$, with a speed 5 m/s.
Determine the velocity vector of the second piece Just after explosion.

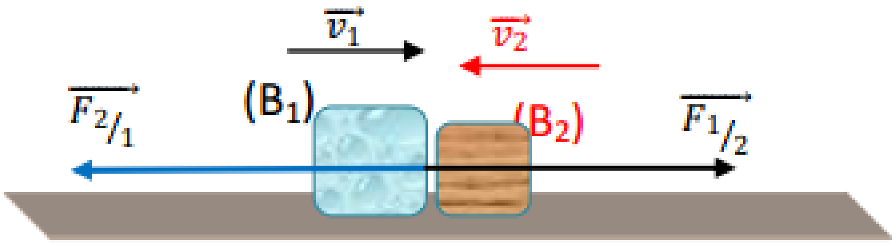


Exercise 4-d : Principle of interaction

Determine $\overrightarrow{F_{1/2}}$ and $\overrightarrow{F_{2/1}}$ the forces of interaction exerted by (B_1) on (B_2) and by (B_2) on (B_1) during the elastic collision
Of the two blocks knowing that it lasts 0.3 s.

Given: speed of the two blocks before collision: v_1=2m/s ; v_2=0 and their speed after collision $v'_1 = -\frac{2}{3} m/s$ and $v'_2 = \frac{4}{3} m/s$.

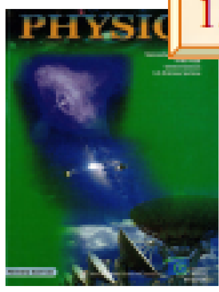
Figure
During collision



Answer : $\overrightarrow{F_{1/2}} = +\frac{8}{9}\vec{\imath}$ et $\overrightarrow{F_{2/1}} = -\frac{8}{9}\vec{\imath}$.

m_1= 100g et m_2 =200g

Note : $\overrightarrow{F_{1/2}} = -\overrightarrow{F_{2/1}}$ (verification of priniciple of interaction (Newton's 3rd law))



Application in the case where $\Sigma\overrightarrow{F_{ext}}=\overrightarrow{const} \neq \vec{0}$

conservation of linear momentum

Exercise 4-e :

Theorem of the center of inertia

A skier of mass 80 kg descends along a line of greatest slope of an inclined plane making an angle α with the horizontal such that $\sin\alpha = 0.1$.

He started with a speed 15 m/s at the top of the track, and his speed becomes 18 m/s after covering a distance100 m.

1. Determine $\overrightarrow{\Delta P}$, the variation of the linear momentum of the skier. **Answer** 240kg.m/s
2. 2.1 Show that the skier is subjected to a force of friction $\vec{f}$ supposed constant. **Answer** ME not conserved
   2.2 Calculate the value of $\vec{f}$. **Answer** 40,40N
3. Determine $\sum\vec{F}$ the sum of external forces acting on the skier. **Answer**
4. The duration of the distance covered by the skier is $\Delta t = 6{,}06\text{s}$, verify that : $\sum\vec{F} \times \Delta t = \overrightarrow{\Delta P}$.

Exercise 5

Verification of Newton's second law

PHYSICS
LS - LS - 2006-1

A puck (S) of mass M = 100 g and of center of mass G, may slide along an inclined track that makes an angle α with the horizontal so that $\sin\alpha = 0.40$. Thus G moves along an axis *x'x* parallel to the track as shown in figure (1). Take $g = 10\ m/s^2$.

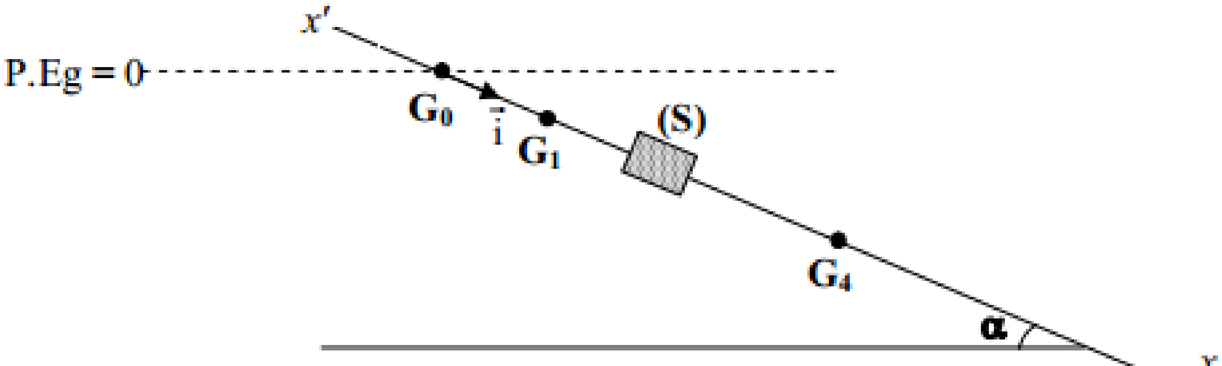


Figure 1

We release (S) without initial velocity at the instant $t_o = 0$ and at the end of each interval of time $\tau = 50$ ms, some positions G_o , G_1 , G_2 , …G_5 of G are recorded at the instants $t_o = 0$,t_1 , t_2 , … t_5 respectively.
The values of the abscissa *x* of G (x = $\overline{G_oG}$) are given in the table below.

t	0	τ	2τ	3τ	4τ	5τ
x (cm)	0	G_oG_1= 0.50	G_oG_2= 2.00	G_oG_3 = 4.50	G_oG_4 = 8.00	G_oG_5 =12.50

1) Verify that the speed of the puck at the instants $t_2 = 2\tau$ and $t_4 = 4\tau$ are $V_2 = 0.40$ m/s and $V_4 =$ 0.80 m/s respectively.

2) a) Calculate the mechanical energy of the system (puck-Earth) at the instants t_0, t_2 and t_4 knowing that the horizontal plane through G_0 is taken as a gravitational potential energy reference.

b) Why can we suppose that the puck moves without friction along the rail?

3) Determine the variation in the linear momentum $\overrightarrow{\Delta P} = \overrightarrow{P_4} - \overrightarrow{P_2}$ of (S) during $\Delta t = t_4 - t_2$.

4) a) Name the forces acting on (S) during its motion.

b) Show that the resultant $\Sigma\vec{F}$ of these forces may be written as $\Sigma\vec{F} = (Mg \sin\alpha)\ \vec{i}$.

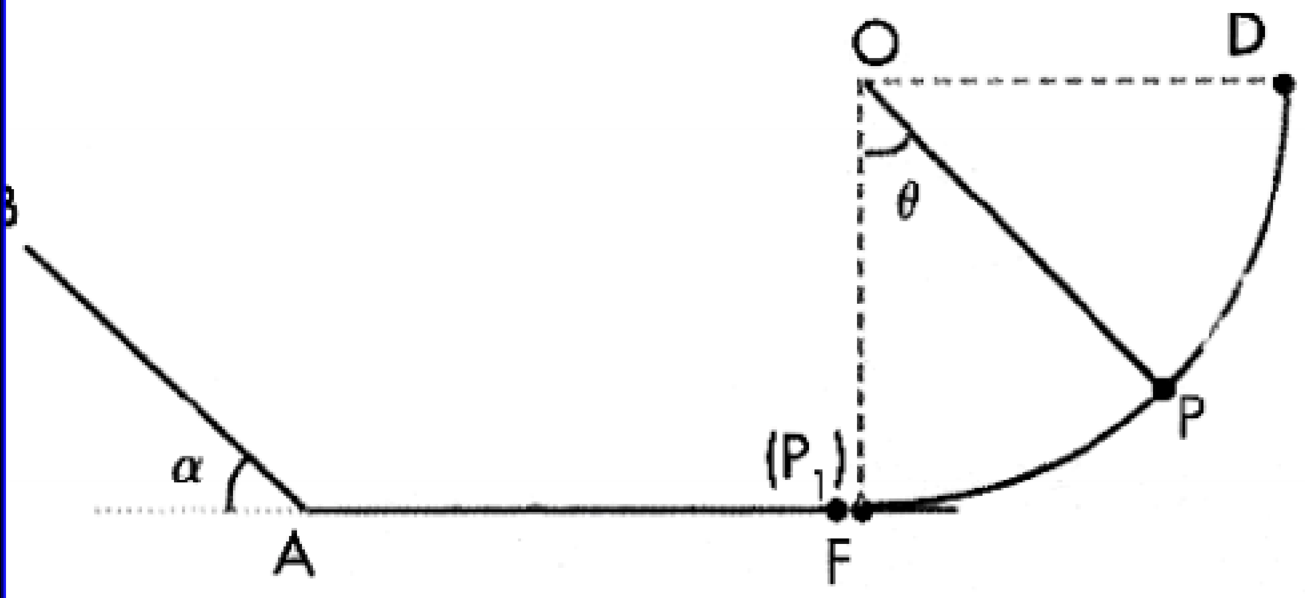
5) Assumin[redacted]t Δt is very small, $\frac{\Delta \vec{P}}{\Delta t}$ may be considered equal to $\frac{d\vec{P}}{dt}$. Show that Newton's

Exercise [redacted]

Conservation and non conservation of the mechanical energy

PHYSICS
GS - LS - 2002-1

Consider a ma[redacted]l system (S) formed of an inextensible and mass less[redacted]g of length $l = 0.45$ m, having one of its ends O fixed [redacted] the other end carries a particle (P) of mass m = 0.1 [redacted]Take $g = 10\ m/s^2$.



1) (S) is shi[redacted]rom its equilibrium position by $\theta_m = 90°$, while the st[redacted]s under tension, and then released without initial veloc[redacted]
Take the ho[redacted]tal plane containing FA as a gravitational potential energy reference for the system [(S), Earth]. We [redacted]ct friction on the axis through O and air resistance.

a) Calc[redacted] the initial mechanical energy of the system [(S), Earth] when (P) was at D.

b) Dete[redacted]e the expression of the mechanical energy of the system [(S), Earth] in terms of l, m, g, V and [redacted]ere V is the speed of (P) when the string passes through a position making an angle θ with[redacted]vertical.

c) Dete[redacted] the value of θ, ($0° < \theta < 90°$), for which the kinetic energy of (P) is equal to the gravi[redacted]al potential energy of the system [(S), Earth].

d) Calc[redacted]the magnitude V_o of the velocity $\vec{V}_o$ of (P) as it passes through its equilibrium position.

2) Upon pa[redacted] through the equilibrium position, the string is cut, and (P) enters in a head-on collision with a stati[redacted] particle (P_1) of mass ml= 0.2 kg. As a result, (P_1) is projected with a velocity $\vec{V}_1$ of magnitude [redacted]2m/s. Determine the magnitude V of the velocity $\vec{V}$ of (P) right after impact knowing that $\vec{V}_o$, $\vec{V}_1$, and[redacted]re collinear.

Is the collis[redacted]lastic? Justify your answer.

3) (P_1), bei[redacted]ojected with a speed $V_1 = 2$m/s, moves along the frictionless horizontal track FA, and rises at A with t[redacted]eed V_1, along the line of greatest slope of the inclined plane AB that makes an angle $\alpha = 30°$ wi[redacted] horizontal.

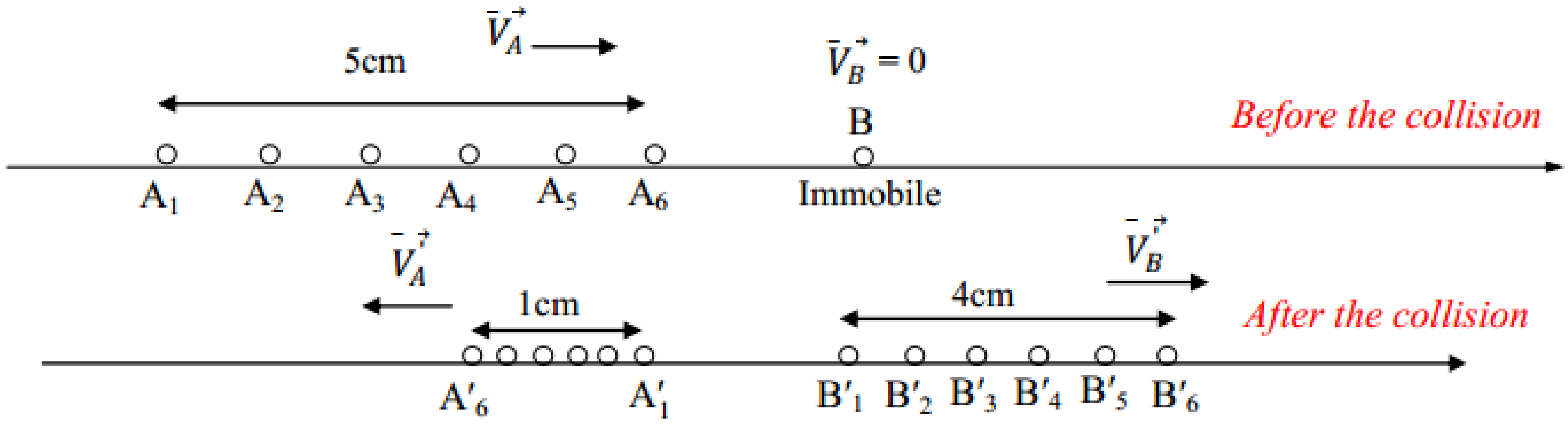
a) Suppose n[redacted]hat the friction along AB is negligible. Determine the position of the point M a[redacted]ch (P_1) turns back.

b) In fact, A[redacted]ot frictionless; (P_1) reaches a point N and turns back, where AN = 20 cm. Calculate the variation in t[redacted]echanical energy of the system [(P_1), Earth] between A and N, and then deduce the magnitude o[redacted]force of friction (assumed constant) along AN.

Exercise 7 : Collision and the laws of conservation

PHYSICS
GS - 2002-2

In order to study the collision between two bodies, we use a horizontal air table that is equipped with a launcher and two pucks (A) and (B) of respective masses $m_A = 0.2$ kg and $m_B = 0.3$ kg.



(A), thrown with the velocity $\vec{V}_A = V_A \vec{i}$, enters in a head-on collision with (B), initially at rest. (A) rebounds with the velocity $\vec{V}'_A = V'_A \vec{i}$, and (B) is projected with the velocity $\vec{V}'_B = V'_B \vec{i}$.

The figure below shows, in real dimensions, a part of the dot-prints, that register the positions of the centers of masses of (A) and (B), obtained when the time interval separating two successive dots is $\tau = 20$ ms.

A) Law related to the linear momentum

I) 1) Show, using the above dot-prints, that the velocities V_A, V'_A and V'_B are constant and calculate the algebraic values $\vec{V}_A$, $\vec{V}'_A$ and $\vec{V}'_B$.

2) Determine the linear momentums $\vec{P}_A$ and $\vec{P}'_A$ of the puck (A), before and after collision respectively and that $\vec{P}'_B$ of the puck (B) after collision.

3) Deduce the linear momentums, $\vec{P}$ and $\vec{P}'$, of the center of mass of the system [(A) and (B)] before and after collision respectively.

4) Compare $\vec{P}$ and $\vec{P}'$ then conclude.

II) 1) Name the forces acting on the system [(A), (B)].

2) What is the value of the resultant of these forces?

3) This result agrees with the conclusion of (I - 4). Why?

B) **Law related to the kinetic energy**

1) Calculate the kinetic energy of the system [(A), (B)] before and after collision.

2) Deduce the nature of this collision.

Exercise 8: Mechanical interaction

PHYSICS
LS 2007-2

The object of this exercise is to study some physical quantities of a system whose parts are in mechanical interaction

For that, we use two pucks (A) and (B), of respective masses m_A=100g and m_B= 120g, that may move without friction on a horizontal table. Each puck is surrounded by an elastic steel shock ring of negligible mass. The two pucks are connected by a massless and inextensible taut thread thus compressing the steel shock rings. The system (S) thus formed is at rest. (Figure 1)

We burn the thread; the shock rings stretch and the pucks repel each other. The system (S) thus formed of the two pucks and the shock rings is said to "*explode*".

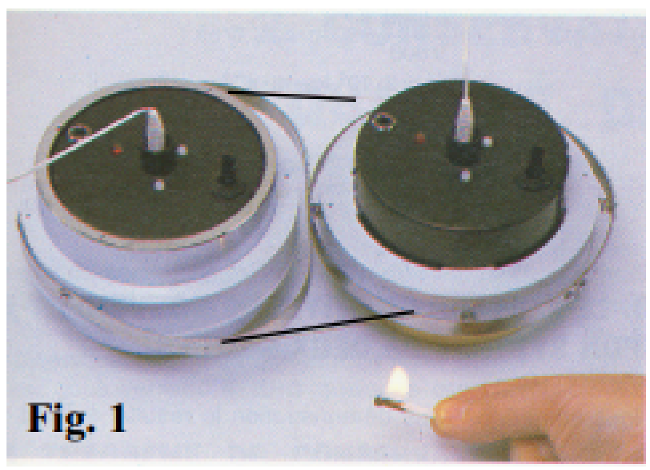
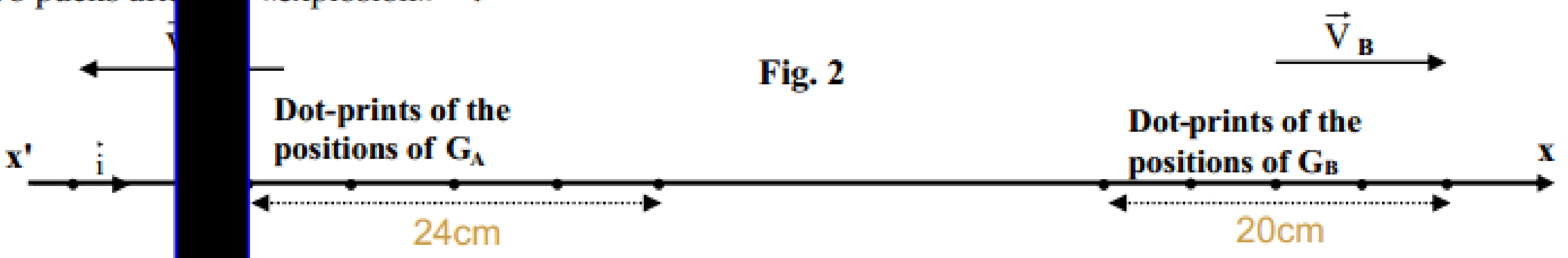


Fig. 1

The positions of the center of mass of each puck are registered at successive instants separated by a constant time interval $\tau = 50$ ms.

Figure (2) represents, on the axis x'x, the dot-prints of the positions of the centers of masses G_A and G_B of the two pucks aft[redacted] «explosion» .

Fig. 2



1) Using the[redacted]ment of figure (2) , show that , after explosion:

a- The m[redacted]n of each puck is uniform;

b- The s[redacted]s of (A) and (B) are $V_A = 1.2$ m/s and $V_B = 1$ m/s respectively.

2) Verify th[redacted]servation of the linear momentum of the system (S) during explosion.

3) Applying[redacted]ton's second law $\frac{d\vec{P}}{dt} = \sum \overline{F_{ext}}$ on each puck and assuming that the time interval of the

explosi[redacted] = 0.05 s is so small that $\frac{\Delta \vec{P}}{\Delta t}$ has the same value as $\frac{d\vec{P}}{dt}$,

a- Det[redacted]e the forces $\vec{F}_{A \to B}$ and $\vec{F}_{B \to A}$ exerted respectively by (A) on (B) and by (B) on (A).

b- Ver[redacted]e principle of interaction.

4) The syst[redacted]S) possesses a certain energy before the explosion.

a- [redacted]ify the part of (S) storing this energy.

b- [redacted]hat form is this energy stored?

c D[redacted]mine the value of this energy

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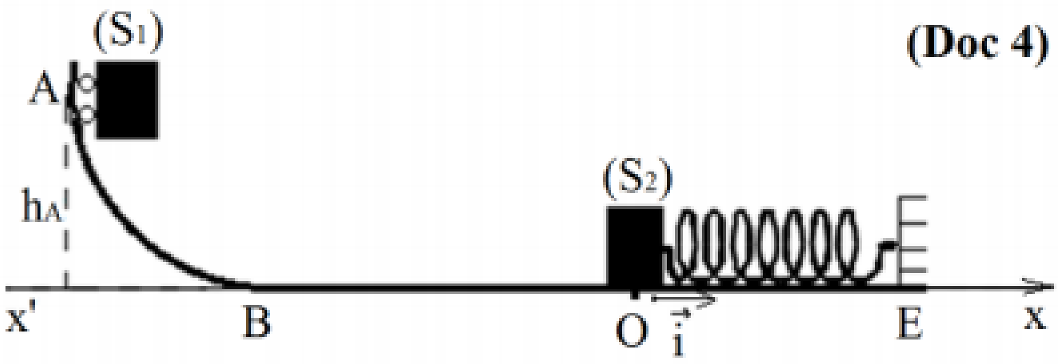
2016-2017

Exercise [redacted] **Energies and collision**

A particle [redacted] of mass $m_1 = 200$ g, is released fr[redacted]est at the point A on a track ABOE, foun[redacted] a vertical plane, as shown in the adjace[redacted]cument (Doc 4).
The part AB[redacted]y smooth, along which we can neglect[redacted] force of friction, has the shape of[redacted]cular arc of radius h_A, and the part BO[redacted] rough part, along which the force of[redacted]on $\vec{f}$ is supposed constant, is a rectiline[redacted]l horizontal path with BO = 1 m.

(Doc 4)



The particle [redacted]eaches the point B with the speed $v_{1B} = 4$ m/s, then it covers the track BO to reach the point O with the s[redacted]$v_{1O} = 2$ m/s.
At O, (S_1) [redacted] into a head-on collision with a particle (S_2), of mass $m_2 = 400$ g, initially at rest and connected to[redacted]end of a horizontal spring of stiffness k = 100 N/m whose other end is fixed at E.
Take the hori[redacted]l plane containing BO as a gravitational potential energy reference level.
Take g = 10 [redacted]

1) Conser[redacted]n and non-conservation of the mechanical energy.

1-1) A[redacted]ng the principle of conservation of the mechanical energy of the system $[(S_1)$, Earth$]$, d[redacted]ine h_A.

1-2) D[redacted]nine the work done by the force of friction $\vec{f}$ along BO.

1-3) D[redacted]e the magnitude f of the force of friction $\vec{f}$ along BO.

2) Elastic[redacted]sion.

The co[redacted]n between the particles (S_1) and (S_2) is perfectly elastic. All the velocities, before and after the col[redacted], are along the horizontal axis x'Ox.

2-1) D[redacted]nine the speed v'_{1O} of (S_1) and v'_{2O} of (S_2) just after the collision.

2-2) Neglecting the force of friction between (S_2) and the track, just after the collision, calculate the maximum compression $x_m = OD$ of the spring.

2-3) In fact, the force of friction $\vec{f}$ between (S_2) and the track, just after the collision, is not negligible and the maximum compression of the spring is $x'_m = OD' = 6.4$ cm.

2-3-1) Determine the decrease in the mechanical energy of the system [(S_2), Earth, spring], between O and D'.

2-3-2) In what form of energy does this decrease appear?

Exercise 10: **Study of the motion of a solid**

PHYSICS
LS 2021-2

Consider :

• a rail AOB located in a vertical plane composed of two straight parts: a horizontal part AO and an inclined part OB making an angle $\alpha = 30°$ with the horizontal;

• two objects S_1 and S_2 assimilated to particles, and of the same mass m = 80 g

• a spring (R) of negligible mass, of force constant k = 200 N/m and of natural length l_0, attached by one of its two ends to a fixed support A and the other end is free.

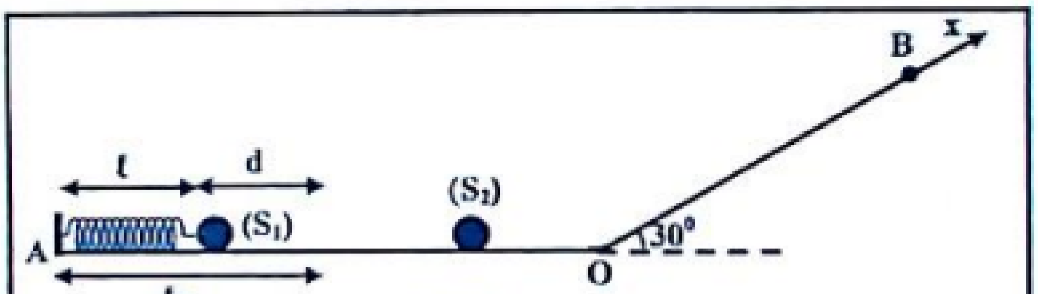
Take :

• The horizontal plane containing O as the level of reference of the potential energy of gravity;

• $g = 10\ m/s^2$.

I. Launching particle (S_1)

To launch (S_1), we place it against the free end of the spring, we compress (R) by a distance d, and then we release the system [spring, (S_1)] without initial speed (Doc. 3) .



Doc. 3

When the string returns to the natural length l_o, (S_1) leaves the spring with a velocity $\vec{V}_1$, parallel to AO.

After launch, (S_1) moving at velocity $\vec{V}_1$, collides head-on with (S_2) initially at rest on the AO rail.

Just after the collision, (S_1) stops and (S_2) moves with a velocity $\vec{V}_2$ parallel to AO and of value $V_2 = 5$ m/s.

(S_1) and (S_2) move without friction on the AO part of the rail.

1-1) Applying the law of conservation of momentum during collision, show that the value of $\vec{V}_1$ is $V_1 = 5$ m/s.

1-2) Deduce that the collision between (S_1) and (S_2) is elastic.

1-3) Determine the value of d.

II. Movement of (S_2) on the inclined part

At the instant $t_o = 0$, (S_2) approaches the inclined plane OB at O with a velocity $\vec{V}_o = V_o\,\vec{i} = 5\vec{i}$ (m/s), with $\vec{i}$ the unit vector of the x'x axis parallel to the OB part of the rail.

On this part, (S_2) is submitted to the action of a friction force $\vec{f}$, parallel to OB, in the direction opposite to the displacement and of constant value f.

2-1) Name the external forces acting on (S_2) along the path OB,

2-2) Show that the sum of the external forces exerted on (S_2), during its upward movement on OB is : $\sum \vec{F} = -(f + mg\sin\alpha)\,\vec{i}$.

2-3) The expression of the linear momentum of (S_2) during its upward movement on OB is : $\vec{P} = (-0{,}9\,t + 0{,}4)\,\vec{i}$ (SI). Knowing that $\frac{d\vec{P}}{dt} = \sum \vec{F}$, determine f.

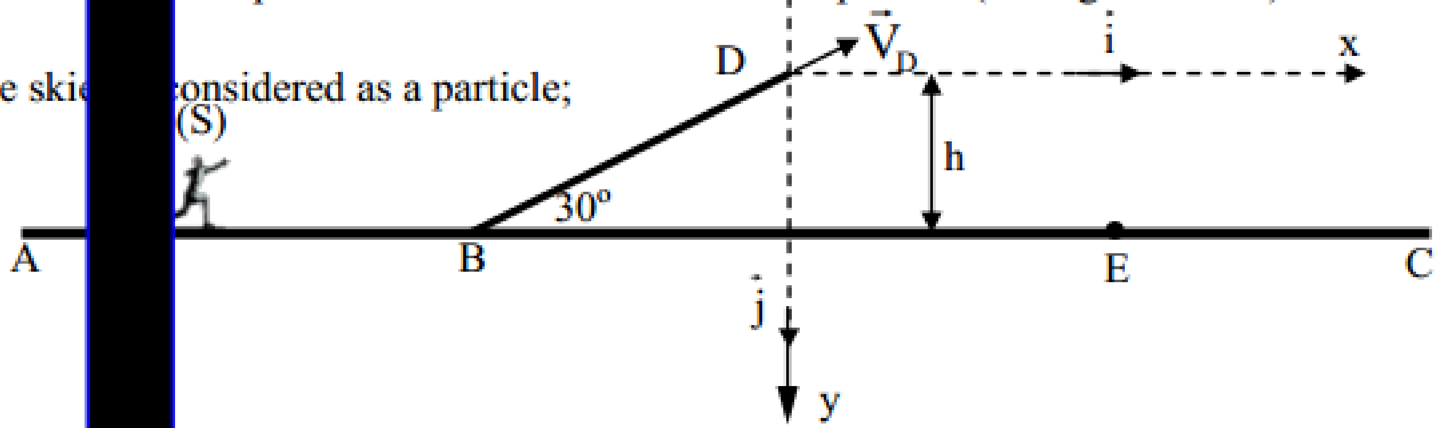
Exercise 11[redacted] Study of the motion of a skier

PHYSICS
LS 2012-2

A skier (S), [redacted]ss $m=80kg$, is pulled by a boat using a rope parallel to the surface of water. He starts from point A[redacted]e instant $t_0 = 0$ without initial velocity.
The skier pa[redacted]point B at the instant t = 60 s with a speed V_B=6m/s. , then he releases the rope. He continues his[redacted]ion along a board BD inclined by an angle of 30° with respect to the horizontal surface of water. Su[redacted] that during the passage from AB to BD the speed at point B does not change.
The skier ar[redacted]point D, situated at an altitude h = 1.6 m from the water surface, with a velocity $\vec{V}_D$, then he leaves the[redacted]d at point D to hit the water surface at point E (see figure below).

Given:

- the ski[redacted]onsidered as a particle;



- on the p[redacted]B, the force of traction $\vec{F}$ exerted by the rope on the skier has a constant magnitu[redacted] and the whole forces of friction are equivalent to a single force $\vec{f}$ opposit[redacted]he displacement, of magnitude f = 100 N;
- friction [redacted]gligible along the path BDE;
- after lea[redacted]point D the motion of the skier takes place in the vertical plane Dxy containing $\vec{V}_D$;
- the hori[redacted]l plane passing through AB is the reference level of the gravitational potential energy;

A– Motion [redacted] skier between A and B

1) What a[redacted]e external forces acting on (S) along the path AB? Draw, not to scale, a diagram of these f[redacted].
2) Applyi[redacted]ewton's second law $\frac{d\vec{P}}{dt} = \Sigma\vec{F}_{ext}$ on the skier, between the points A and B, express the accele[redacted] a of the motion of the skier in terms of F, f and m.
3) Determi[redacted]e expression of the speed V of the skier in terms of F , f , m and the time t.
4) Deduce[redacted]

B – Motion[redacted]e skier on the board BD

1) Why [redacted]e apply the principle of conservation of the mechanical of energy of system [(S), Earth] on the[redacted] BD?
2) Deduc[redacted]at V_D =2m/s.

C – Motion [redacted]e skier between D and E

The skier[redacted]es the board at point D, at an instant t_0, taken as a new origin of time.

1) Apply N[redacted]on's second law on the skier to show that, at an instant t, the vertical component P_y of the line[redacted]omentum of the skier is of the form: $P_y = 800\,t - 80$ (In SI unit).
2) Deduce[redacted]arametric equation y(t) of the motion of the skier in the frame of reference Dxy.
3) Determ[redacted]e duration taken by the skier to pass from D to E.

Exercis[redacted]: Determination of the speed of a bullet

PHYSICS
LS 2004-2

A gun is us[redacted] shoot bullets, each of mass m = 20 g, with a horizontal velocity $\vec{V_0}$ of value V_0.
In order to[redacted]rmine V_0, we consider a setup formed of a wooden block of mass M = 1 kg, suspended from the e[redacted]f two inextensible sting of negligible mass and of the same length (figure 1).
This setup[redacted]e taken as a block of wood suspended from the free end a string of length ℓ = 1 m, initially at[redacted]in the equilibrium position at G_1.

A bullet having the velocity V_0 hits the block and is embedded in at the level of the center ofmassGof the bloc.

Just after impact, the system (block, bullet) moves with a horizontal velocity $\vec{V_1}$.
The pendulum thus attains a maximum angular deviation $\alpha = 37^{o}$.

G_1 and G_2 are the respective positions of G in the equilibium position and in the highest position.
Take the horizontal plane throug G_1 as a gravitational potential energy reference (figure 2).
Neglect friction with air and take $g = 9{,}8\ m/s^2$.

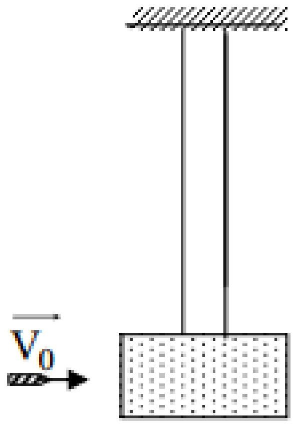


Figure 1

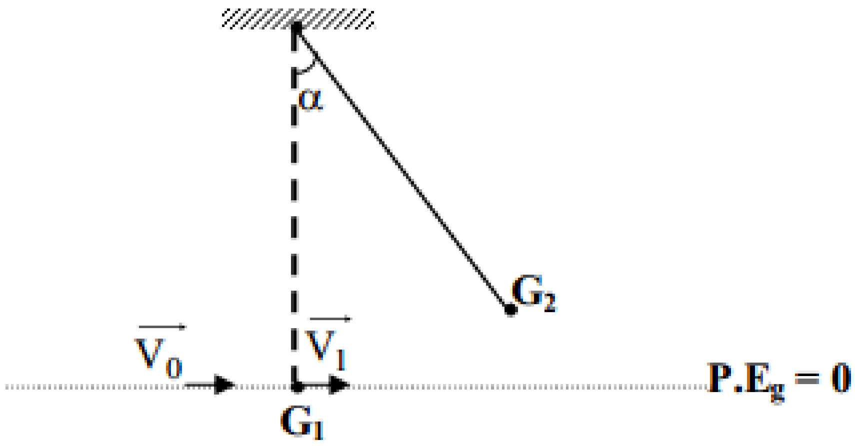


Figure 2

1. During a collision, which one of the two physical quantities,thelinearmomentumorthekinetic energy of the system does not remain always conserved ?
2. Determine the expression of the value of V_1 of the velocity $\vec{V_1}$ in terms of M, m and V_0.
3. **a)** Determine, just after impact, the mechanical energy of the system (pendulum, Earth) in terms of V_0, M, and m.
   b) Determine, in terms of M, m , g, ℓ and α, the mechanical energy of the system (pendulum, Earth) at point G_2.
   c) Deduce the value of V_0.
4. Verify the answer of question (1).

PHYSICS
LS 2016-2

Exercise 13:

Nature of a collision

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 (Fig.1).

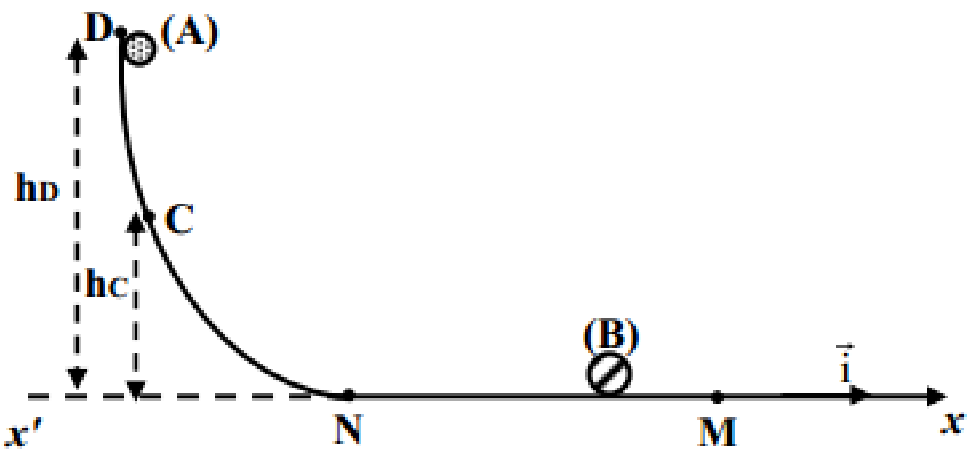


Fig. 1

The horizontal plane passing through MN is taken as the reference level of gravitational potential energy.

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 $\vec{P_S}$ 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 (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.

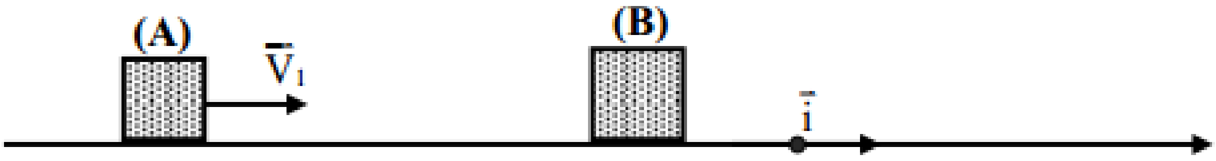
PHYSICS
LS 2015-1

Exercise 14 : **Collision and interaction**

In order to study the collision between two bodies, we consider a horizontal air table equipped with a launcher and two pucks (A) and (B) of respective masses $m_A = 0.4$ kg and $m_B = 0.6$ kg.

(A), launched with the velocity $\vec{V}_1 = 0.5\ \vec{i}$, collides with (B) initially at rest.

(A) rebounds with the velocity $\vec{V}_2 = -0.1\ \vec{i}$ and (B) moves with the velocity $\vec{V}_3 = 0.4\ \vec{i}$ (V_1 , V_2 and V_3 are expressed in m/s). Neglect all frictional forces.



A – Linear momentum

1) a) Determine the linear momentums:
   i) $\vec{P}_1$ and $\vec{P}_2$ of (A), before and after collision respectively;
   ii) $\vec{P}_3$ of (B) after collision.

   b) Deduce the linear momentums $\vec{P}$ and $\vec{P}'$ of the system [(A), (B)] before and after collision respectively.

   c) Compare $\vec{P}$ and $\vec{P}'$. Conclude.

2) a) Name the external forces acting on the system [(A), (B)].
   b) Give the value of the resultant of these forces.
   c) Is this resultant compatible with the conclusion in question (1- c)? Why?

B – Type of collision

1) Determine the kinetic energy of the system [(A), (B)] before and after collision.
2) Deduce the type of the collision.

C – Principle of interaction

The duration of collision is $\Delta t = 0.04$ s; we can consider that $\frac{\Delta\vec{P}}{\Delta t} \approx \frac{d\vec{P}}{dt}$.

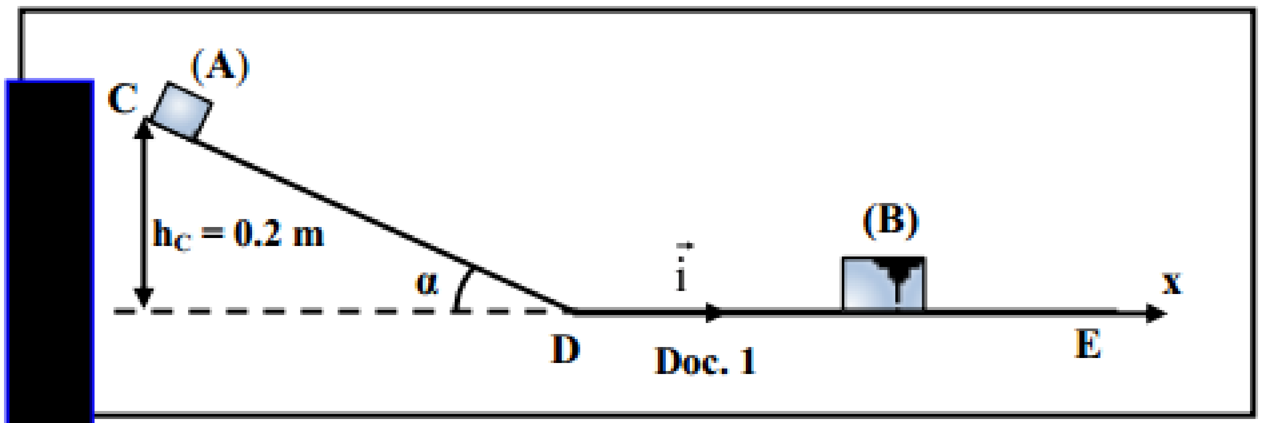
1) Determine during Δt:
   a) the variations $\Delta\vec{P}_A$ and $\Delta\vec{P}_B$ in the linear momentums of the pucks (A) and (B) respectively;
   b) the forces $\vec{F}_{A/B}$ exerted by (A) on (B) and $\vec{F}_{B/A}$ exerted by (B) on (A).
2) Deduce that the principle of interaction is verified.

PHYSICS
LS 2022-1

Exercise 15 : **Verification of the principle of interaction**

The aim of this exercise is to verify the principle of interaction between two blocks.
For this purpose, we consider two blocks (A) and (B) considered as particles of respective masses $m_A = 200$ g and $m_B = 800$ g.
(A) and (B) can move without friction on a track CDE lying in a vertical plane.
This track is formed of two parts: the first one CD is straight and inclined by an angle α with respect to the horizontal and the second one DE is straight and horizontal.
Block (A) is released without initial velocity from point C situated at a height $h_C = 0.2$ m above a horizontal x-axis, confounded with DE, of unit vector $\vec{i}$ (Doc. 1).

Take:
- the horizontal plane containing the x-axis as a reference level for gravitational potential energy;
- $g = 10\ m/s^2$.



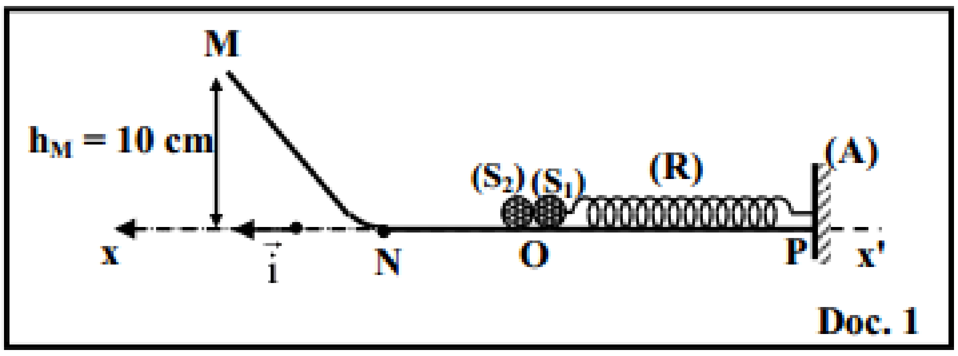
1) The mecha[redacted] energy of the system [(A), Track, Earth] is conserved between C and D. Why?
2) Deduce tha[redacted] speed of (A) at point D is $V_A = 2$ m/s.
3) (A) continu[redacted]s motion with a velocity $\vec{V_A} = 2\,\vec{i}$ (m/s) along track DE until it makes a head-on elastic collision w[redacted]) initially at rest.
Show that t[redacted]elocities of (A) and (B) right after the collision are $\vec{V'_A} = -1.2\,\vec{i}$ (m/s) and $\vec{V'_B} = 0.8\,\vec{i}$ (m/s) respectivel[redacted]
4) The durati[redacted] the collision is $\Delta t = 0.1$ s, so $\frac{\Delta \vec{P}}{\Delta t} \cong \frac{d\vec{P}}{dt}$.
Apply, du[redacted]Δt, Newton's second law:
4.1) on ([redacted] determine the force $\vec{F}_{A/B}$ exerted by (A) on (B);
4.2) on ([redacted] determine the force $\vec{F}_{B/A}$ exerted by (B) on (A).
5) Deduce th[redacted] principle of interaction is verified.

Exercise[redacted]

De termination of the stiffness of a spring

PHYSICS
LS 218-1

In order to d[redacted]nine the stiffness k of a massless spring (R), [redacted]nsider:



- a track [redacted]found in a vertical plane ;
- a massle[redacted]ring (R) of horizontal axis and stiffness[redacted]aving one end fixed to a support (A); the[redacted] end is connected to an object (S_1) consider[redacted] a particle of mass $m_1 = 0.2$ kg;
- an objec[redacted] considered as a particle of mass $m_2 = 0.3$[redacted]placed at the origin O of a horizontal x-axis of unit vector $\vec{i}$ (Doc. 1).

Neglect all [redacted]rces of friction.
Take:
- the horiz[redacted]l plane passing through NP as a reference level for gravitational potential energy;
- $g = 10$ [redacted]

1- Collision b[redacted]n (S_1) and (S_2)
At equilibri[redacted]S_1) coincides with O. (S_1) is shifted from O to the right by a certain distance and it is released fro[redacted]t. (S_1) reaches O with a velocity $\vec{V_1} = 2\,\vec{i}$ (m/s), and enters into a head-on collision with (S_2) in[redacted] at rest. Just after collision, (S_1) rebounds with a velocity $\vec{V'_1} = -0.4\,\vec{i}$ (m/s) and (S_2) moves to th[redacted] with a velocity $\vec{V'_2} = V'_2\,\vec{i}$.

1-1) Applyi[redacted] principle of conservation of linear momentum for the system $[(S_1), (S_2)]$, show that $V'_2 = 1.$[redacted].
1-2) Specify[redacted]ther this collision is elastic or not.

2- Motion of ([redacted]fter collision
Just after co[redacted]n, (S_2) moves along the horizontal track PN with the speed V'_2 and then continues its motion alon[redacted] inclined plane MN. (S_2) leaves the inclined plane at M with a speed V_M. The height of M above the[redacted]rence level is $h_M = 10$ cm. Determine the speed V_M of (S_2) at point M.

Exercise 17: Collisions and mechanical oscillator

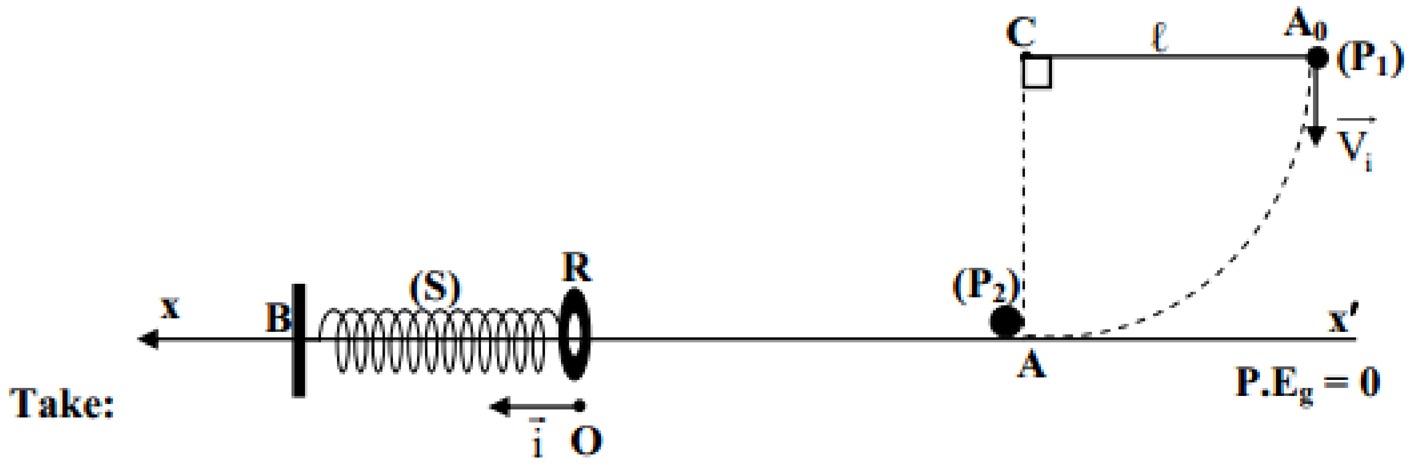
LS 2013-1

A – Collision

A pendulum is formed of a massless and inextensible string of length $\ell = 1.8$ m, having one of its ends C fixed to a support while the other end carries a particle (P_1) of mass $m_1 = 200$ g .

The pendulum is stretched horizontally. The particle (P_1) at A_0 is then launched vertically downward with a velocity $\vec{V}_i$ of magnitude $V_i = 8$ m/s.

At the lowest position A, (P_1) enters in a head-on perfectly elastic collision with another particle (P_2) of mass $m_2 = 300$ g initially at rest. Neglect all frictional forces.



Take:

- the horizontal plane passing through A as a gravitational potential energy reference;
- $g = 10$ m/s^2.

1) a) Calculate the mechanical energy of the system [pendulum, Earth] at the instant of launching (P_1) at A_0.

b) Determine the magnitude V_1 of the velocity $\vec{V}_1$ of (P_1) just before colliding with (P_2).

2) a) Name the physical quantities that are conserved during this collision.

b) Show that the magnitude V_2' of the velocity $\vec{V}_2'$ of (P_2), just after collision, is 8 m/s.

Exercise 18 : Determination of the mass of a block and stiffness of a spring

PHYSICS LS 2017-2

Consider two blocks, (A) of unknown mass m_A and (B) of mass $m_B = 0.8$ kg, and a spring (R) of negligible mass and of stiffness k. The aim of this exercise is to determine m_A and k.

Neglect all the forces of friction and take $g = 10$ m/s^2.

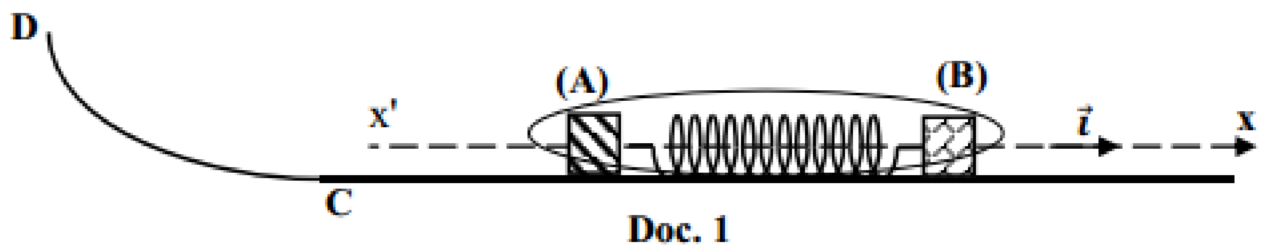
1- First experiment: Determination of m_A

The spring is placed on a horizontal track. The spring is compressed between (A) and (B) by means of a light string (Document 1).

The center of mass of (A) and that of (B) belong to the same horizontal plane which is taken as a reference level for gravitational potential energy.

The x-axis extends positively to the right.

We burn the string, (A) and (B) are ejected in opposite directions.



Doc. 1

1-1) Name the external forces acting on the system [(A), (B) and (R)].

1-2) Deduce that the linear momentum of the system [(A), (B) and (R)] is conserved during the motion of (A) and (B) on the horizontal track.

1-3) The velocity of the center of mass of block (B) just after ejection is $\vec{V}_B = 0.75\,\vec{i}$ (m/s).

1-3-1) Determine the linear momentum $\vec{P}_A$ of block (A).

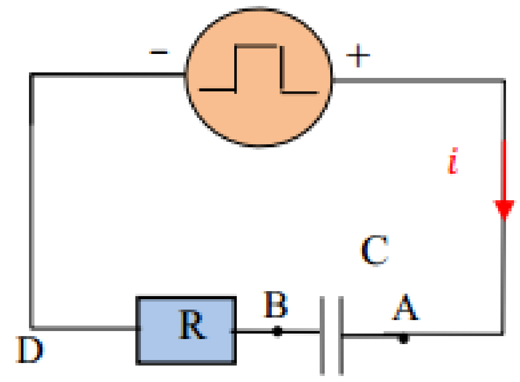
1-3-2) Deduce in terms of m_A the velocity $\vec{V}_A$ of the center of mass of (A) just after ejection.

1-4) Block (A) continues its motion and reaches a curvilinear path CD situated in the vertical plane (Document 1). The maximum height attained by the center of mass of (A) above the reference level is $h_{max} = 5$ cm.

1-4-1) Apply the principle of conservation of mechanical energy to the system [(A), Earth] to determine the magnitude V_A of $\vec{V}_A$.

1-4-2) Deduce the value of the mass m_A .

RC dipole in square signal



Application

Charging phase ①

$i = \frac{dq}{dt}$ and $q = C\,u_C$

We write then $i = C\frac{du_C}{dt}$

Discharging phase ②

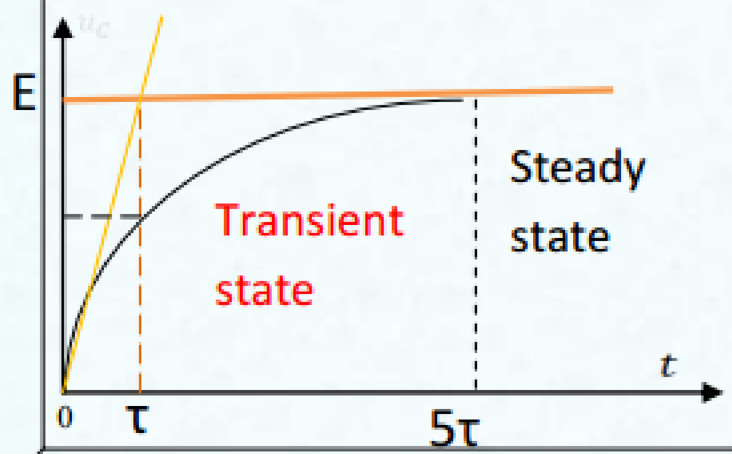
$q \searrow$ because the tension $u_C \searrow$

We write then

$i = -\frac{dq}{dt} > 0$

Proprieties

③



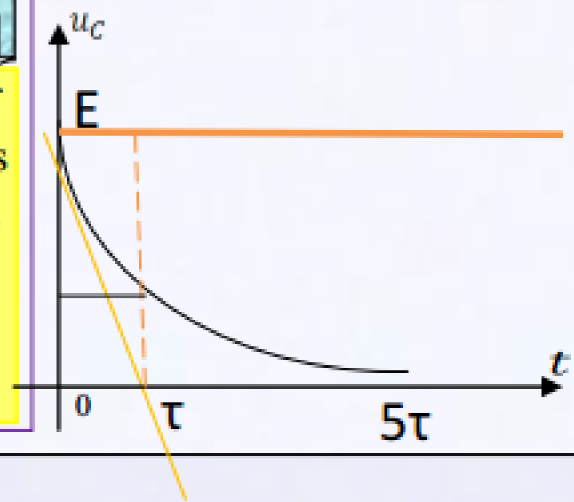
④

Constante of time

Is the time needed for the tension u_C reaches 63% of E during the charging phase, and 37% of E during the discharging phase.

$\tau = RC$

⑤



Derivative with respect to time of the function : Ae^{-bt}

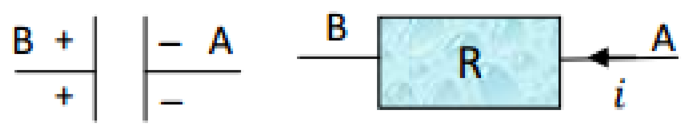
$$\frac{d}{dt}\left(Ae^{-bt}\right) = -Abe^{-bt}$$ ⑥

Energy stored in a capacitor ⑦

- It is an electric form.
- Its value is $W = \frac{1}{2}Cu_C^{\,2}$ at an instant t .
- Its maximum value is $W_0 = \frac{1}{2}CE^2$

(Unit : J in international system.)

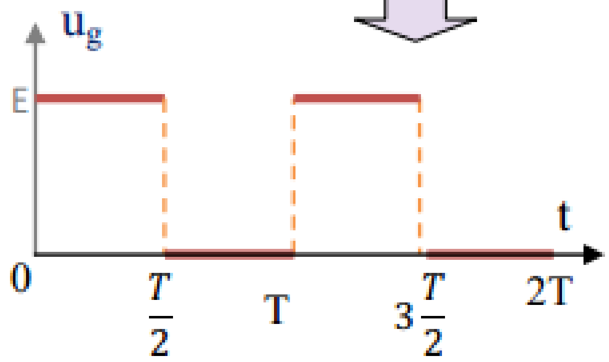
Remarks:



$u_{BA} = u_C$; $u_{AB} = Ri$

L.F.G.[redacted]ode: square signal

A L.F.[redacted]ow frequency generator) delivers in the ele[redacted]c circuit a **periodic** voltage (Mode: square signal).



Complete:[redacted]e voltage passes briefly from ug=E to a constant value u_g = [redacted].

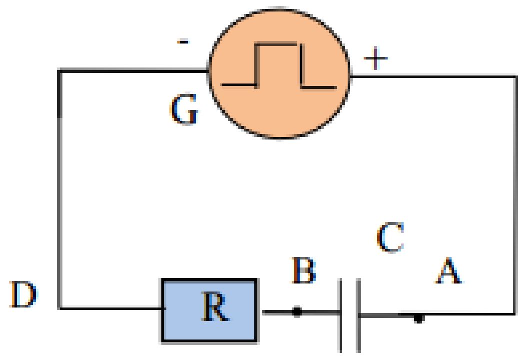
Then from [redacted]value **0**to the value u_g = ...(*Alternatively*) .

Question[redacted] for $0 < t < 2T$ [*see the above figure*]; what interval of time, the L.F.G is equivalent[redacted]n identical battery?

Question[redacted]for what is the L.F.G identical to, in the interval $\frac{T}{2} < t < T$?

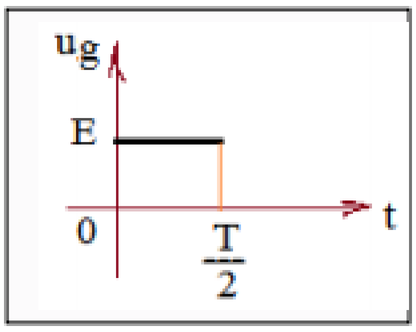
E[redacted]ctric phases of a capacitor

[redacted]rcuit

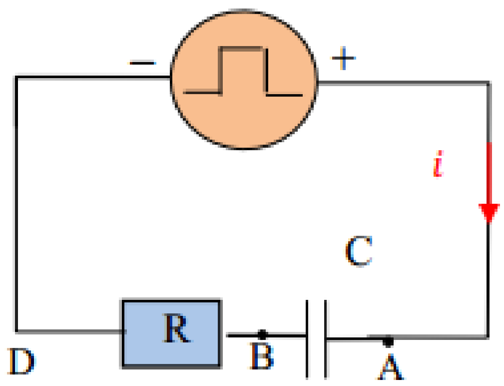


Charg[redacted]g pha[redacted]

Case when the value of u_g passes briefly from 0 to E



- **i.e. in the interval $0 < t < \frac{T}{2}$**



The voltage [redacted]ross the terminals of C was 0 at t = 0.

This voltage [redacted]creases ***progressively*** , during an interval of time called chargi[redacted]hase. $u_C \nearrow$ for $0 < t < \frac{T}{2}$.

During this i[redacted]al of time, the electric charge q of the armature A increases.

Then, the rel[redacted] between the electric current i and the charge q is written as: $i = \frac{dq}{dt}$.

Finally, **The[redacted] of addition of voltage,** applied across the terminal of the dipole RC, is written:

$u_{AB} + u_{BD}$ = [redacted](1) $\Rightarrow u_C + Ri = E$. by substituting $i = \frac{dq}{dt} = C\frac{du_C}{dt}$ in this equation, we can write now : [redacted]+ $RC\frac{du_C}{dt} = E$ (2)

*This is the [redacted]rential equation that governs the evolution of the voltage u_C across the termin[redacted]f the capacitor during **the charging phase**.*

Verify that: $u_C = E(1- e^{\frac{-t}{\tau}})$ is a solution of the equation (2) , with $\tau = RC$.

We should verify that u_C = E-E $e^{\frac{-t}{\tau}}$ is the solution of the differential equation (2).

then we find its derivative $\frac{du_C}{dt}$.

$\frac{du_C}{dt} = 0 - E(-\frac{1}{\tau}e^{\frac{-t}{\tau}}) = \frac{E}{\tau}e^{\frac{-t}{\tau}}$.

And we substitute in (2), we obtain

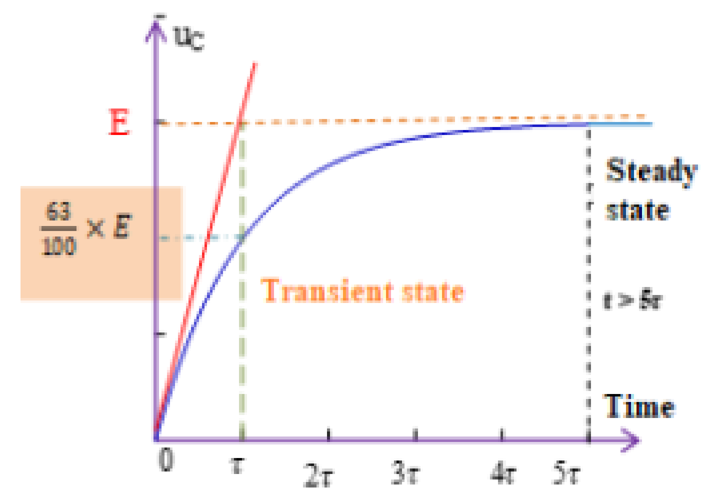
at : $E - E\,e^{\frac{-t}{\tau}} + RC\frac{E}{\tau}e^{\frac{-t}{\tau}} = E$;

$E\,e^{\frac{-t}{\tau}}(\frac{RC}{\tau} - 1) = 0 \Rightarrow \frac{RC}{\tau} - 1 = 0$

Generally ; $\tau = R_{éq}C$

with R'_{eq} :

is the equivalent resistance



Formulas

During the charging phase :

- The time constant : $\tau = R_{éq}C$
- $u_c = 0{,}63E$ for $t = \tau$

Definition:

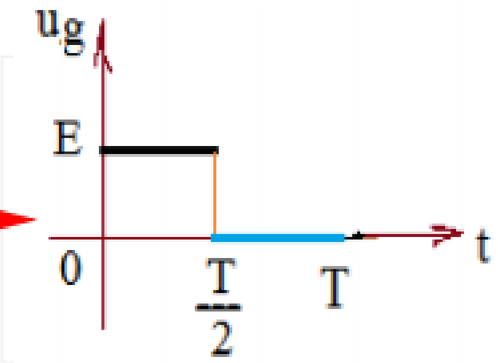
During the charging phase:

The time constant τ of an RC circuit is the time interval after which the voltage of the capacitor reaches 63% of the value of E.

And for $t \approx 5\tau$, u_C is approximately equal to E .

Discharging phase

Case when the value of u_g passes briefly from E to 0



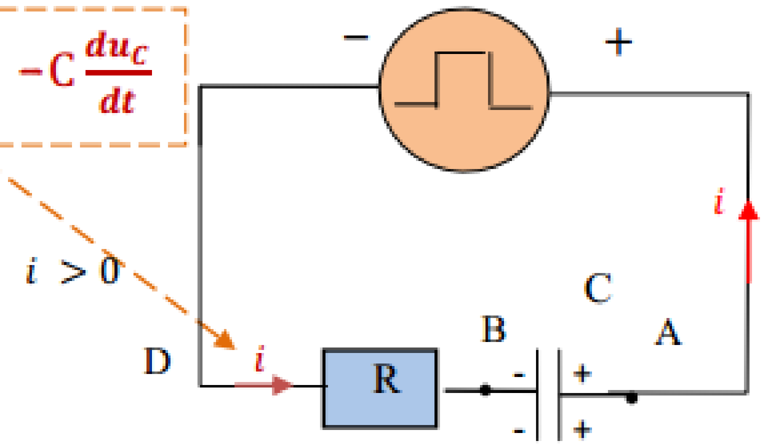
- **i.e. in the interval $\frac{T}{2} < t < T$**

The voltage u_C across the terminals of C was equal to E at the instant $t = \frac{T}{2}$.

Attention: We can use this instant as a new origin of time (t =0) at the beginning of this phase, called phase of discharging of the capacitor.

Even more, pay attention to the new direction of current i (real direction > 0) the electric current is now delivered from the capacitor to the circuit ; So, q ↘ , then $\frac{dq}{dt} < 0$.

In this case, we can write : $i = -\frac{dq}{dt} = -C\frac{du_C}{dt}$



The law of addition of voltage:

$u_{AD} = u_{AB} + u_{BD}$ (1)

with $u_{AD} = u_g = 0$.i.e.$0 = u_C - Ri$ with $u_C = u_{AB}$.

Finally: $0 = u_C + RC\frac{du_C}{dt}$ by replacing $i = -C\frac{du_C}{dt}$.

We obtain: (1) $\Rightarrow u_C + RC\frac{du_C}{dt} = 0$ (2) .

*This is the differential equation that governs the evolution of the voltage u_C across the terminals of the capacitor in **the discharging phase**.*

?

Verify that : $u_C = E\, e^{\frac{-t}{\tau}}$ is a **solution** of the equation (2) , with $\tau = RC$.

We need to[redacted]fy that $u_C = E\, e^{\frac{-t}{\tau}}$ [redacted] solution of the differential [redacted]ation (2).

Then we fi[redacted]e derivative $\frac{du_C}{dt}$.

$\frac{du_C}{dt} = E(-\frac{1}{\tau}$ [redacted] $= -\frac{E}{\tau}e^{\frac{-t}{\tau}}$.

And then su[redacted]ute in (2) ,

We find tha[redacted]

$-E\, e^{\frac{-t}{\tau}} + R$[redacted]$^{\frac{-t}{\tau}} = 0$;

$\Rightarrow$

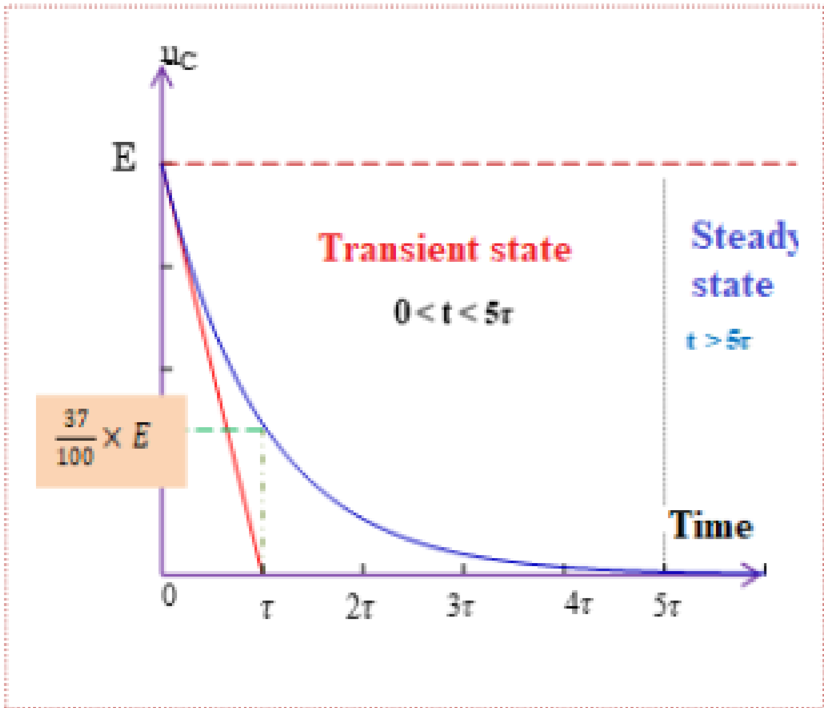
$E\, e^{\frac{-t}{\tau}}(\frac{RC}{\tau} - 1$[redacted]$0 \Rightarrow \frac{RC}{\tau} - 1 = 0$

Generally [redacted] $= R'_{éq}C$

with R'_{eq} [redacted]

is the equiv[redacted] resistance

Definition :



Formulas

During the discharging phase :

- The time constant: $\tau = R'_{eq}C$
- $u_c = 0,37E$ for $t = \tau$

During the discharging phase

- The time constant τ of an RC circuit is the duration after which the remaining voltage of the capacitor is 37 % of the value of E.

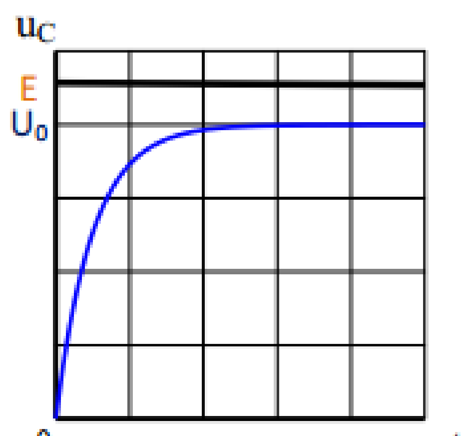
and; for $t \approx 5\tau$, u_C is approximatly $= 0$

RC dipole

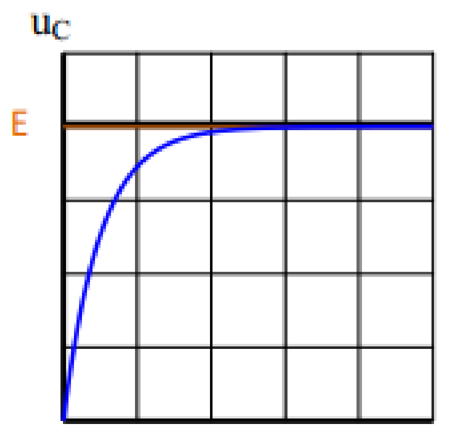
Exercises

Exercise 1 -a :

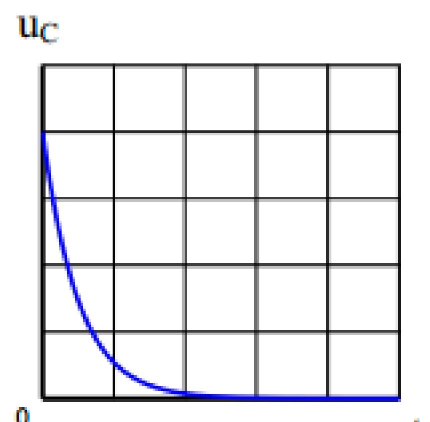
Consider the diagram of the adjacent circuit, with $R \neq 0$.
We close K; choose with justification the document corresponding to this situation.



Doc.1



Doc. 2



Doc.3

Exercise 2 -b :

During the charging phase of a capacitor, the differential equation of u_C during the time is:

$\frac{du_C}{dt}+\frac{1}{RC}u_C=\frac{E}{RC}$. The solution of this equation can be written as: $u_C= A(1-e^{\frac{-t}{\tau}})$.

Verify that A=E and τ =RC

Exercise 3-c :

During the charging phase of a capacitor, the differential equation of u_C during the time is:

$$\frac{du_C}{dt}+\frac{1}{RC}u_C=\frac{E}{RC}.$$

The solution of this equation can be written as: $u_C= A - B\, e^{\frac{-t}{\tau}}$.

Determine A, B and τ.

Exercise 4 -d :

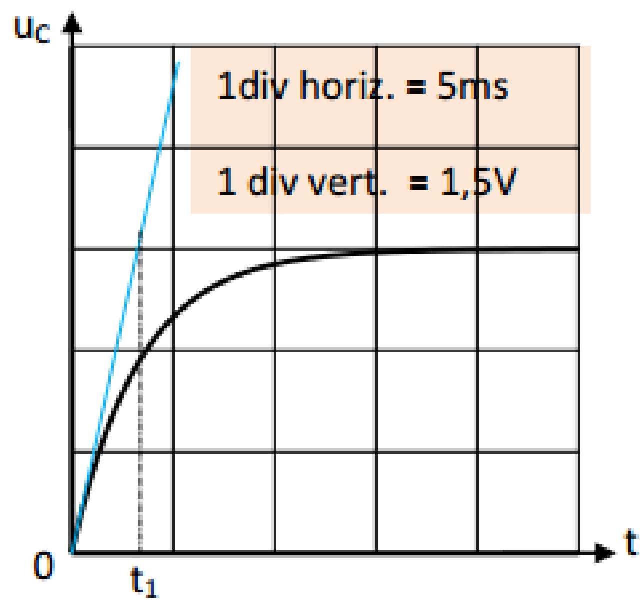
Given: $u_C=A+B\, e^{-\lambda t}$ is the solution of the differential equation $\frac{du_C}{dt}+\frac{1}{RC}u_C=\frac{E}{RC}$

Determine A,B and λ .

Exercise 5 -e :

During the phase of charging of the capacitor, the curve u_C has the shape given in the adjacent document.

1) Use the method of tangent at the origin to determine the time Constant of the dipole RC.
2) Knowing that the dry cell is ideal and characterized by emf = E
   2.1- Determine E.
   2.2- Calculate the voltage across the resistor R at the instant t

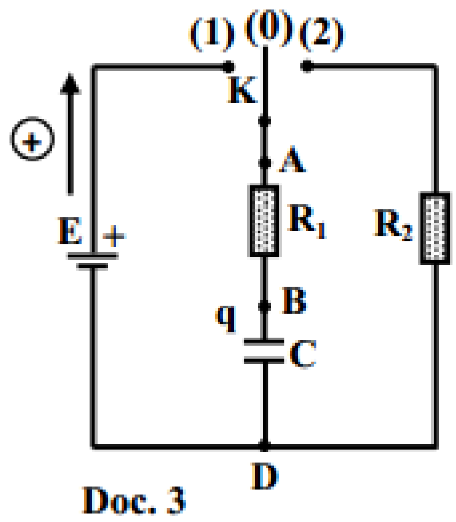


Exercise 2 **Charging and discharging a capacitor** **PHYSICS** LS 2021-1

The aim of this exercise is to study the charging and the discharging of a on capacitor.

For this purpose, we set up the circuit of document 3 that includes:

- an ideal battery of electromotive force E = 10 V;
- two resistors of resistances $R_1 = R_2 = 4\ k\Omega$;
- a capacitor of capacitance C;
- a switch K.



Doc. 3

1) Charging the capacitor

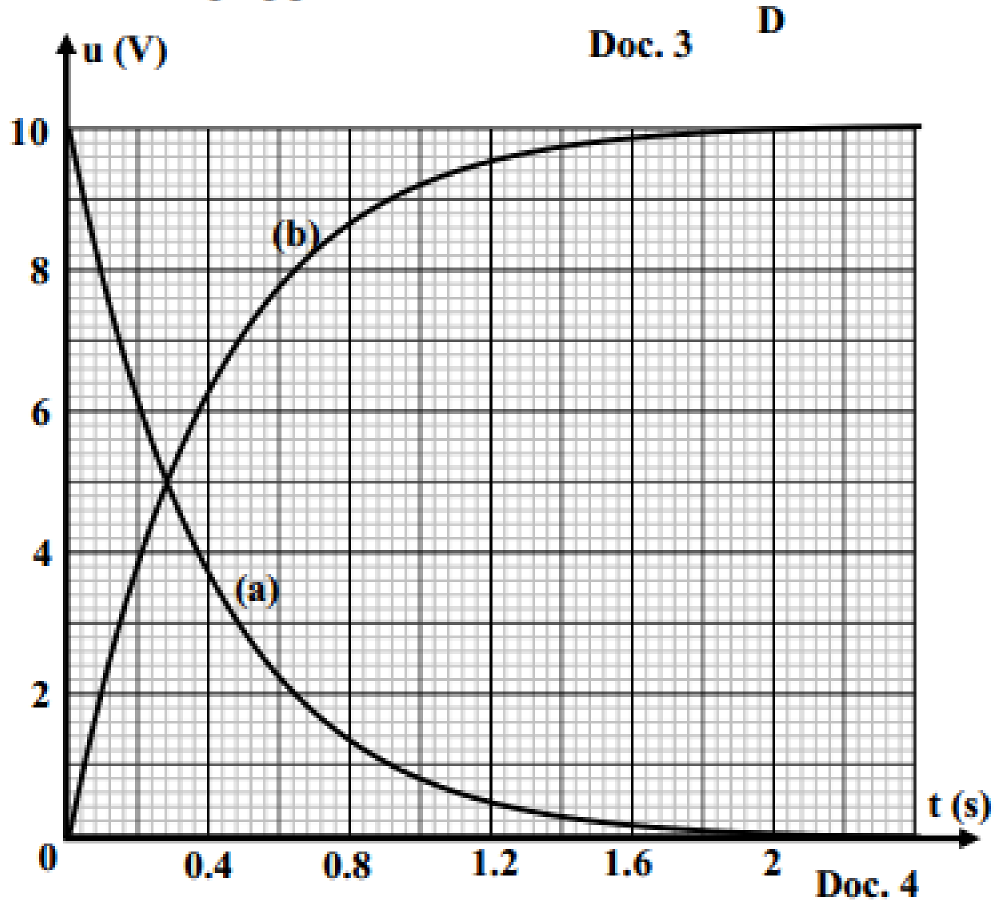
The switch K is initially at position (0) and the capacitor is uncharged.

At the instant $t_0 = 0$, K is turned to position (1) and the charging process of the capacitor starts.

At an instant t, plate B of the capacitor carries a charge q and the circuit carries a current i.

An appropriate device allows us to display the voltage $u_{AB} = u_{R_1}$ across the resistor and the voltage $u_{BD} = u_C$ across the capacitor.

Curves (a) and (b) of document 4 show these voltages as functions of time.



Doc. 4

1.1) Curve (a) represents u_{R_1} and curve (b) represents u_C. Justify.

1.2) The time constant of this circuit is given by $\tau_1 = R_1 C$.

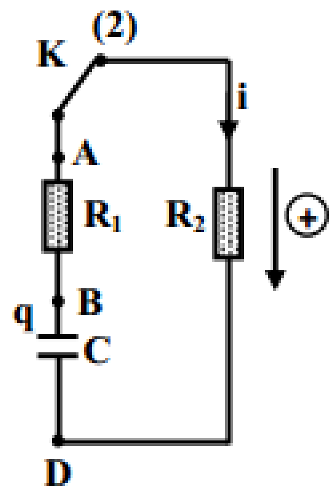
1.2.1) Using document 4, determine the value of τ_1.

1.2.2) Deduce the value of C.

1.3) Calculate the time « t_1 » needed by the capacitor to practically become completely charged.

2) Discharging the capacitor

The capacitor is completely charged. At an instant taken as a new initial time $t_0 = 0$, the switch K is turned to position (2), and the capacitor starts discharging through the resistors of resistances R_1 and R_2. At an instant t the circuit carries a current i (Doc. 5).



Doc. 5

2.1) Show, using the law of addition of voltages, that the differential equation which governs u_C is:

$$RC\frac{du_C}{dt} + u_C = 0 \quad \text{where } R = R_1 + R_2.$$

2.2) The solution of this differential equation is of the form: $u_C = E\, e^{\frac{-t}{\tau_2}}$ where τ_2 is the time constant of the circuit of document 5.

Determine the expression of τ_2 in terms of R and C.

2.3) Verify that the time needed by the capacitor to practically become completely discharged is $t_2 = 5\tau_2$.

3) Duration of charging and discharging the capacitor

Show, without calculation, that « t_2 » is greater than « t_1 ».

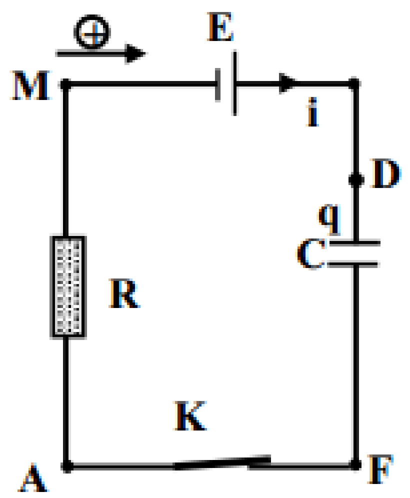
Exercise [redacted] **Charging of a capacitor**

PHYSICS
LS 2020*

The aim of [redacted]xercise is to determine the capacitance C of a capacitor.
For this aim [redacted] set-up the series circuit of document 3 that includes:

- an id[redacted]attery (G) of emf E;
- a res[redacted]of resistance $R = 1\ k\Omega$;
- a cap[redacted]r, initially uncharged, of capacitance C;
- a sw[redacted]K.

We close th[redacted]tch K at the instant $t_0 = 0$, and the charging process starts.
At an instan[redacted]ate D of the capacitor carries a charge q and the circuit carries a cur[redacted].
An oscillosc[redacted] conveniently connected, allows to display the voltage $u_{AM} = u_R$ ac[redacted]he resistor.



Doc. 3

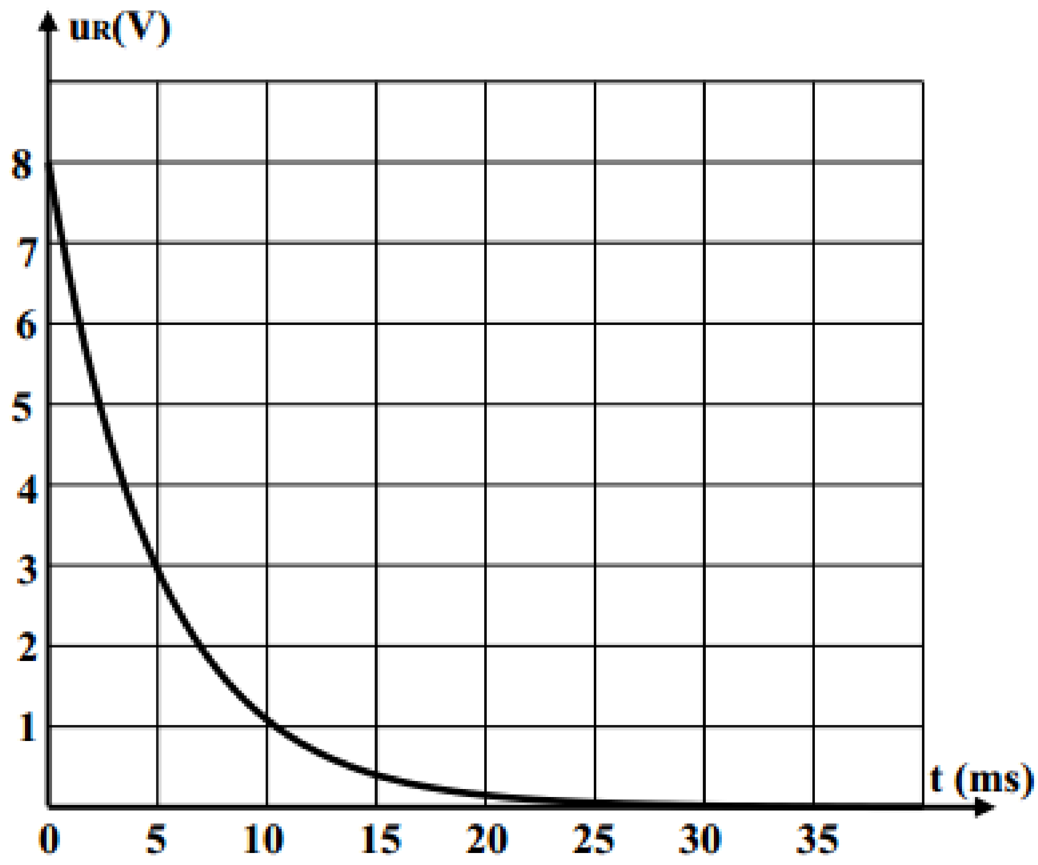
1) Redraw [redacted]ircuit of document 3 and show on it the connections of the oscilloscope.
2) Establis[redacted] differential equation that governs the variation of the voltage $u_{DF} = u_C$.
3) Show th[redacted]$= E\left(1 - e^{\frac{-t}{RC}}\right)$ is a solution of the established differential equation.
4) Deduce [redacted]xpression of u_R in terms of E, R, C and t.
5) Docume[redacted]shows u_R as a function of time.
   - 5-1) Sh[redacted]at the shape of the curve is i[redacted]eement with the ex[redacted]ion of u_R.
   - 5-2) Sp[redacted] the value of E.
6) The tim[redacted]stant τ of the (R-C) series ci[redacted]is given by $\tau = RC$. Choose, [redacted] the four statements below, t[redacted]atements that describe correctly[redacted]ring the charging phase of the ca[redacted]or. Justify your answer.

   Stateme[redacted] τ is the time during which th[redacted]tage across the resistor is 37% of [redacted]aximum value.

   Stateme[redacted] τ is the time during which th[redacted]tage across the resistor attains i[redacted]ximum value.

   Stateme[redacted] τ is a physical quantity that perm[redacted]o slow down the estab[redacted]nent of the steady state.

   Stateme[redacted] τ is the time during which the voltage across the capacitor will be equal to that across the resis[redacted]



Doc. 4

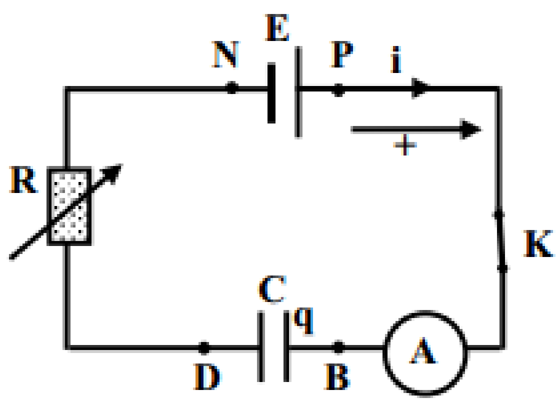
7) Using d[redacted]ent 4, determine the value of τ.
8) Deduce [redacted]alue of C.

Exercise [redacted] **Capacitance of a capacitor**

PHYSICS
LS 2019-1

The aim of th[redacted]ercise is to determine the capacitance C of a capacitor.
We set-up the[redacted]es circuit of document 4.
This circuit i[redacted]es:

- an idea[redacted]ery of electromotive force $E = 10$ V;
- a rheos[redacted]resistance R;
- a capac[redacted]f capacitance C;
- an amm[redacted] (A) of negligible resistance;
- a switch K.



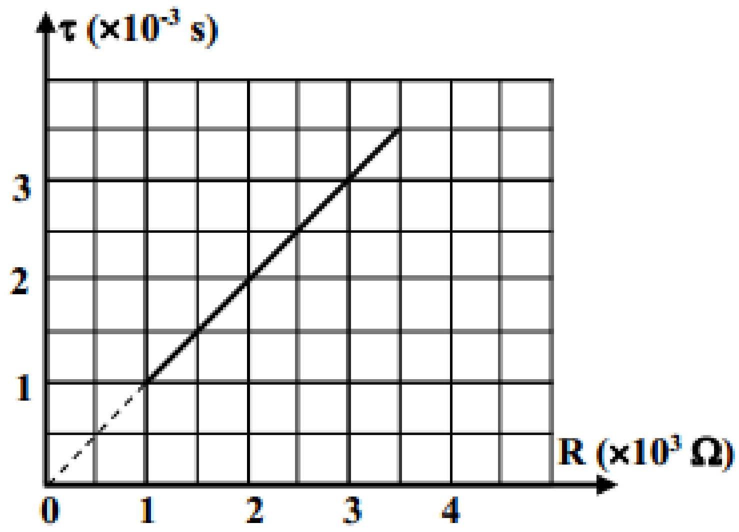
Doc.4

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.



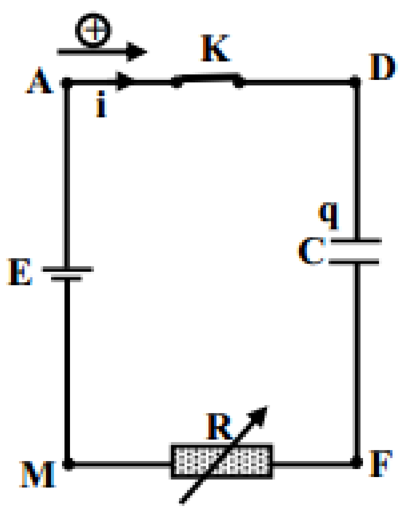
Doc. 5

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.

Exercise 5 : **Effect of the resistance on the charging of a capacitor**

PHYSICS
LS 2018-2

The aim of this exercise is to study the effect of the resistance of a resistor on the charging of a capacitor.



Doc. 2

For this aim, we set-up the circuit of document 2that includes:

- A capacitor, initially uncharged, of capacitance C = 4 μF;
- a resistor of adjustable resistance R;
- an ideal battery of voltage $u_{AM} = E$;
- a switch K.

We close the switch at $t_0 = 0$, and the charging process starts.

1. **Theoretical study**

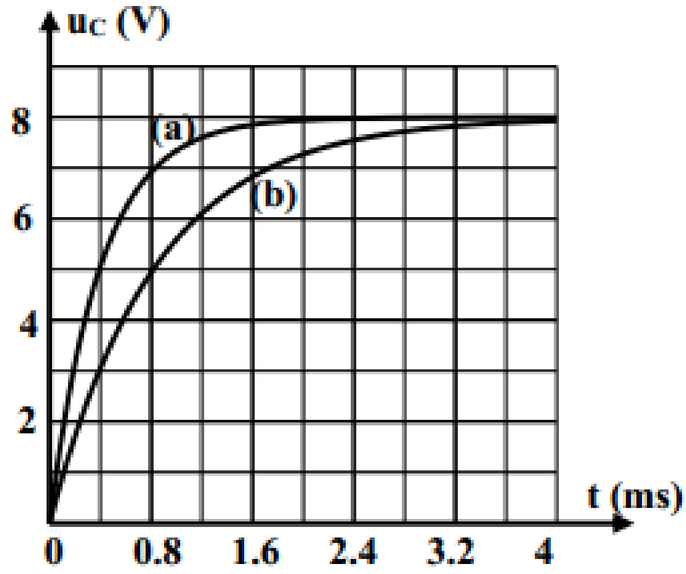
1.1) Derive the differential equation that describes the variation of the voltage$u_{DF} = u_C$ during the charging of the capacitor.

1.2) The solution of this differential equation has the form of: $u_C = A + B\,e^{Dt}$. Determine the constants A, B and D in terms of E, R and C.
1.3) Verify that the capacitor becomes practically fully charged at t = 5 RC.
1.4) Indicate the effect of the resistance of the resistor on the duration of the charging of the capacitor.

2. **Experimental study**

We adjust R to two different values R_1 and R_2; an appropriate device allows to trace, for each value of R, the voltage u_C as a function of time (Doc. 3).

- curve (a) corresponds to $R = R_1$.
- curve (b) corresponds to $R = R_2$.



Doc. 3

2.1) Using the curves of document 3:

2.1.1) specify the value of E;

2.1.2) specify, without calculation, whether the value of R_2 is: equal to, greater than, or less than the value of R_1;

2.1.3) determine the values of R_1 and R_2.

2.2) The capacitor is fully charged, the electric energy stored in the capacitor is W_C.

2.2.1) Is the value of W_C affected by the resistance of the resistor? Justify.

2.2.2) Deduce the value of W_C.

Exercise 6 : **Measurement of the speed of a bullet** PHYSICS LS 2006-1

In order to measure the speed of a bullet, a convenient setup is used. The principle of functioning of this setup is based on the charging of a capacitor.

A- Study of the charging of a capacitor

We are going to study the charging of a capacitor using a series circuit formed of a resistor of resistance R, a switch K and a capacitor of capacitance C initially neutral across the terminals of a generator of constant emf E and of negligible internal resistance (figure 1)

The switch K is closed at the instant $t_0 = 0$. The capacitor starts to charge. At the instant t , the circuit carries a current i and the armature A of the capacitor carries the charge q.

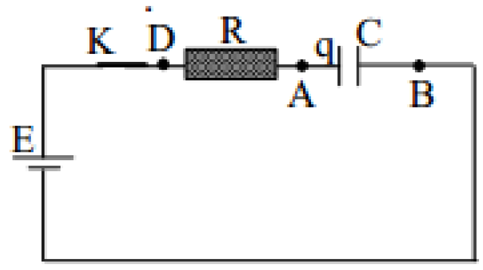


Figure 1

1) Applying the law of addition of voltages, determine the differential equation that describes the variation of the voltage $u_C = u_{AB}$ across the capacitor as a function of time.

2) a) Verify that $u_C = E\,(1 - e^{\frac{-t}{\tau}})$ is the solution of the differential equation where $\tau = RC$.

b) What does the time interval τ represent?

3) After what time would the steady state be practically attained?

B – Measurement of the speed of a bullet

The setup used to measure the speed V of a bullet is represented in figure 2. $E = 100$ V ; $R = 1000\ \Omega$; $C = 4\ \mu F$; $L = 1$ m.

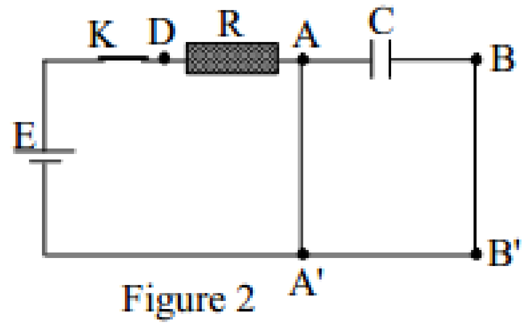


Figure 2

AA' and BB' are two thin parallel connecting wires lying in a vertical plane and are of negligible resistance . AA' and BB' are separated by a distance L.

The capacitor being neutral, the switch K is closed

1) **a)** The potential difference between A and A' is zero. Why?

b) The charging of the capacitor did not start. Why?

2) K being closed , we shoot the bullet normally at AA' and BB' with a speed V (fig.3).

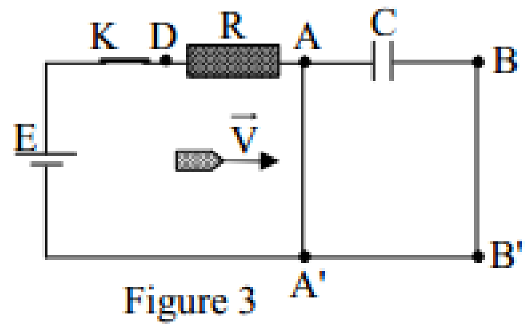


Figure 3

At the instant $t_0 = 0$, the bullet cuts the wire AA' and the capacitor starts to charge (fig.4).

The bullet continues its motion which is considered uniform rectilinear of the same [redacted] ed V.

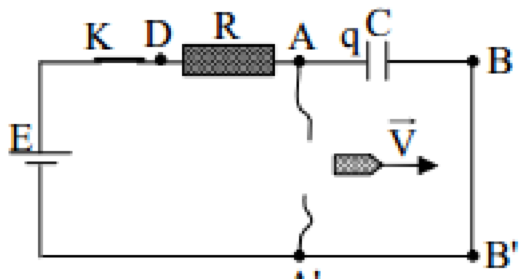


Figure 4

At the instan [redacted] he bullet cuts the wire BB' and the phenomenon of charging s [redacted] . The voltage across the capacitor is then 45.7 V

a) Taking i [redacted] onsideration the study in part A, determine the time interval [redacted] en by the bullet to cover the distance L.

b) Calculat [redacted]

3) In order to [redacted] sure precisely the value of V , the distance L between AA' and BB' must not excee [redacted] naximum value L_{max}. Determine the value of L_{max} .

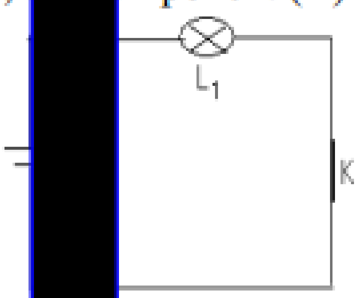
PHYSICS
LS 2008-1

Exercise [redacted] Role of a capacitor in a circuit

The object [redacted] s exercise is to study the role of a capacitor in an electric circuit in two different cases.(g = [redacted] s^2)

A- Variatio [redacted] the current in a circuit

We connect [redacted] wo circuits whose diagrams are represented in the diagram below; the two identical lamps L_1 an [redacted] are fed respectively with two identical generators G_1 and G_2 each of constant voltage E , [redacted] omponent (D) being a capacitor that is initially uncharged (Fig.1).



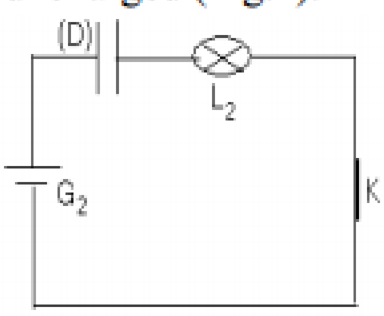


Figure 1

We close th [redacted] switches simultaneously at the instant $t_0 = 0$. We notice initially that L_1 and L_2 glow with t [redacted] me brightness, but the brightness of the lamp L_2 decreases progressively and finally its light goe [redacted] , L_1 keeping its same brightness.

a) What [redacted] e say about the voltage across each of the lamps at the instant $t_0 = 0$? Justify.

b) i) How [redacted] s the voltage across L_2 vary starting from the instant $t_0 = 0$?

ii) Ded [redacted] when the light of L_2 goes out, the value of the voltage across the capacitor.

iii) Ind [redacted] the role of the capacitor in the variation of the current in an RC circuit fed by a DC volt [redacted] during the charging phase.

***B-* Energy [redacted] ed in a capacitor**

1- Quali [redacted] e study

Conside [redacted] experiment whose diagram is represen [redacted] figure (3), where (M) is a motor to which a [redacted] y of mass m is suspended, a capacitor of large [redacted] itance, G an ideal generator of constant voltage [redacted] l K_1 and K_2 are two switches.

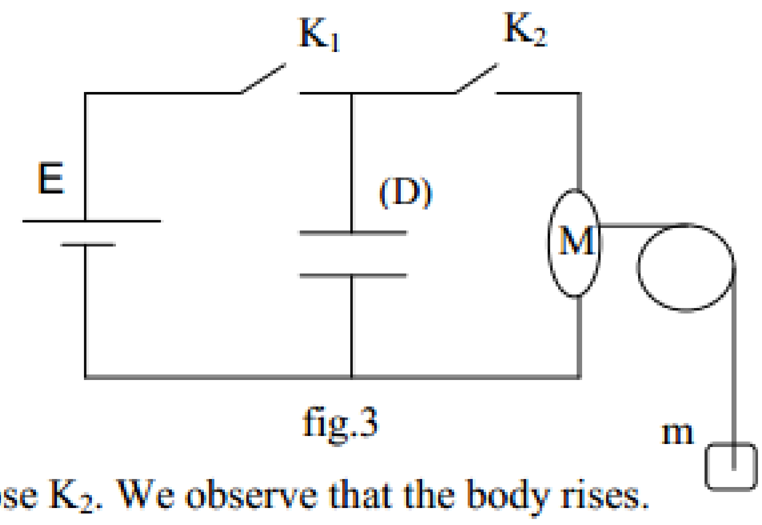


fig.3

In the fir [redacted] p of the experiment, we open K_2, and we close [redacted]

In the s [redacted] step of the experiment, we open K_1 and we close K_2. We observe that the body rises.

Explain [redacted] happens in each step of the experiment and tell why the body rises

2- Quanti [redacted] e study

The capac [redacted] as a capacitance C = 1 F , the body has a mass m = 500g and the e.m.f of the generator is E = 3 [redacted]

a- Calc [redacted] the energy initially stored in the capacitor.

b- Calc [redacted] the height rised by the body neglecting all energy losses.

c- What [redacted] of energy transfer did take place?

d- In fa [redacted] e body rises 83 cm. Why?

e- Dedu [redacted] e role of the capacitor in the previous circuit.

Exercise 8 : Brightness of a lamp

PHYSICS
LS 2022-1

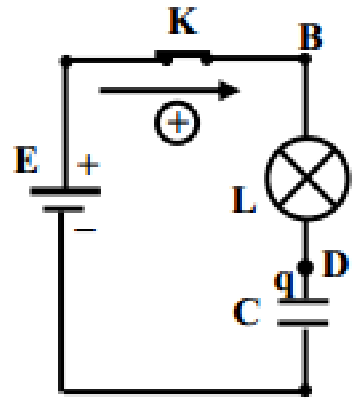
The aim of this exercise is to study the brightness of a lamp in two experiments.
For this purpose, consider:

- an ideal battery of electromotive force $E = 9$ V;
- a lamp L acting as a resistor of resistance $R = 10\ \Omega$;
- a capacitor of capacitance $C = 0.1$ F;
- a switch K.

Given that the brightness of the lamp increases with the increase of the current it carries and vice-versa.

1) First experiment: charging the capacitor

We connect the capacitor, initially uncharged, in series with the lamp and switch K across the battery (Doc. 4).
Switch K is closed at $t_0 = 0$, and the capacitor starts charging.



Doc. 4

1.1) Show that the differential equation that governs the variation of the voltage, $u_{DA} = u_C$, across the capacitor is: $E = RC\frac{du_C}{dt} + u_C$.

1.2) The solution of the obtained differential equation is of the form:

$u_C = E\,(1 - e^{\frac{-t}{\tau}})$, where τ is constant.

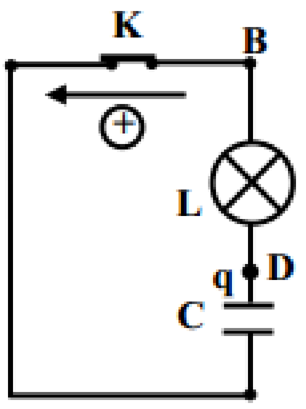
1.2.1) Determine the expression of τ in terms of R and C.

1.2.2) Calculate τ.

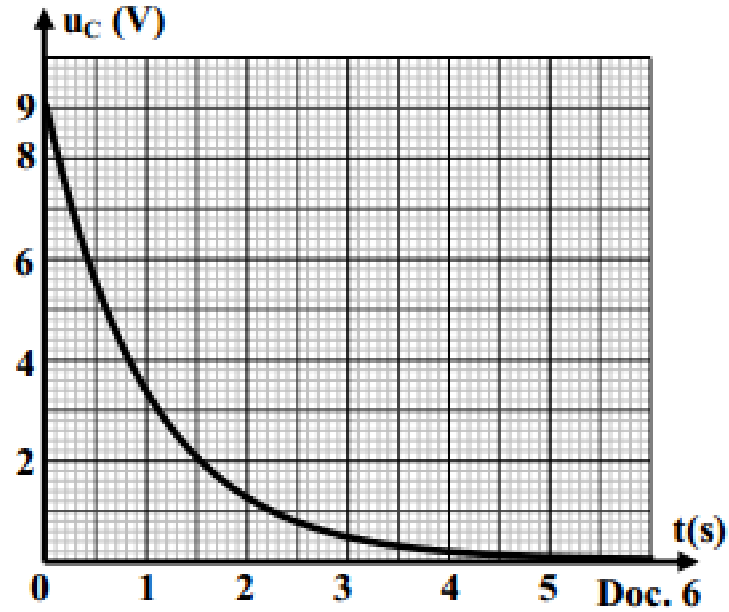
1.3) Deduce that the expression of the charge current is $i = 0.9\ e^{-t}$ (SI).

2) Second experiment: discharging the capacitor

The fully charged capacitor is connected in series with the lamp and switch K.
We close K at $t_0 = 0$ taken as a new initial time.
The capacitor discharges through the lamp (Doc. 5).
Document 6 shows the voltage $u_{DA} = u_C$ as a function of time.



Doc. 5



Doc. 6

2.1) Use document 6 to determine the value of the time constant τ' of this RC circuit.

2.2) Given that $u_C = E\ e^{\frac{-t}{\tau'}}$. Deduce the expression of the discharge current as a function of time.

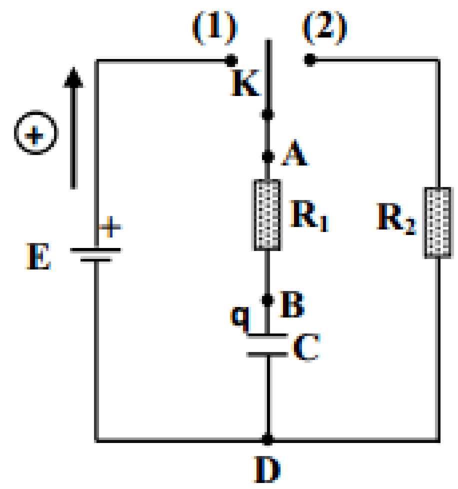
3) Conclusion

Using parts **(1.3)** and **(2.2)**, describe the brightness of the lamp in the first and the second experiments during the time interval [0 , 5 s]. Justify your answer.

Exercise 9 : Charging and discharging of a capacitor

PHYSICS
LS 2017-1

The aim of this exercise is to determine the capacitance of a capacitor by two different methods.
Consider the circuit represented in document 1. It is formed of an ideal generator that maintains across its terminals a constant voltage of value E, a capacitor of capacitance C, two resistors of resistances $R_1 = 10\ k\Omega$, $R_2 = 20\ k\Omega$ and a double switch K.



Doc. 1

1 – Charging the capacitor

The capacitor is initially neutral. At the instant $t_0 = 0$, we put K in position (1); the charging phenomenon of the capacitor starts.

1-1) Theoretical study

1-1-1) Show that the differential equation that describes the variation of the voltage $u_C = u_{BD}$ across the capacitor has the form: $E = R_1 C \dfrac{du_C}{dt} + u_C$.

1-1-2) The solution of this differential equation has the form: $u_C = A(1 - e^{\frac{-t}{\tau_1}})$.
Determine the expressions of the constants A and τ_1 in terms of E, R_1 and C.

1-1-3) Deduce that $u_C = E$ at the end of charging of the capacitor.

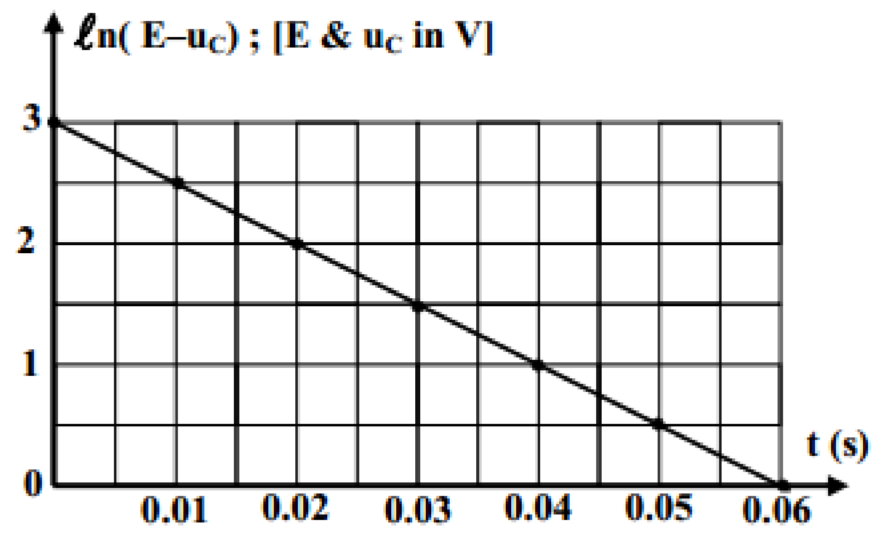
1-2) Experimental study

In order to determine the value of C, we use a convenient apparatus, which traces, during the charging of the capacitor, the curve representing $\ell n(E - u_C) = f(t)$ (Doc.2). [ℓn is the natural logarithm]

1-2-1) Determine, using the solution of the obtained differential equation, the expression of $\ell n\,(E - u_C)$ in terms of E, R_1, C and t.

1-2-2) Show that the shape of the curve in document 2 is in agreement with the obtained expression of $\ell n\,(E - u_C) = f(t)$.

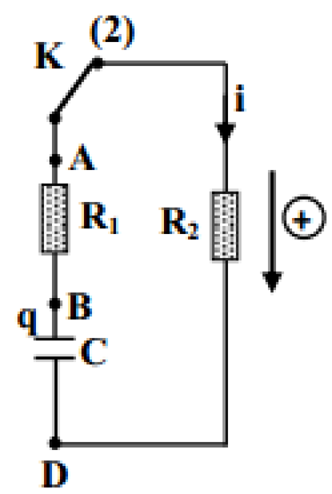
1-2-3) Using the curve of document 2, determine the values of E and C.



Doc. 2

2 – Discharging the capacitor

The capacitor being fully charged. At an instant taken as a new origin of time $t_0 = 0$, the switch K is placed at position (2); thus the phenomenon of discharging of the capacitor starts (Doc. 3).



Doc. 3

2-1) Theoretical study

2-1-1) Show that the differential equation in the voltage $u_C = u_{BD}$ across the capacitor has the form: $u_C + \alpha \dfrac{du_C}{dt} = 0$; where α is a constant to be determined in terms of R_1, R_2 and C.

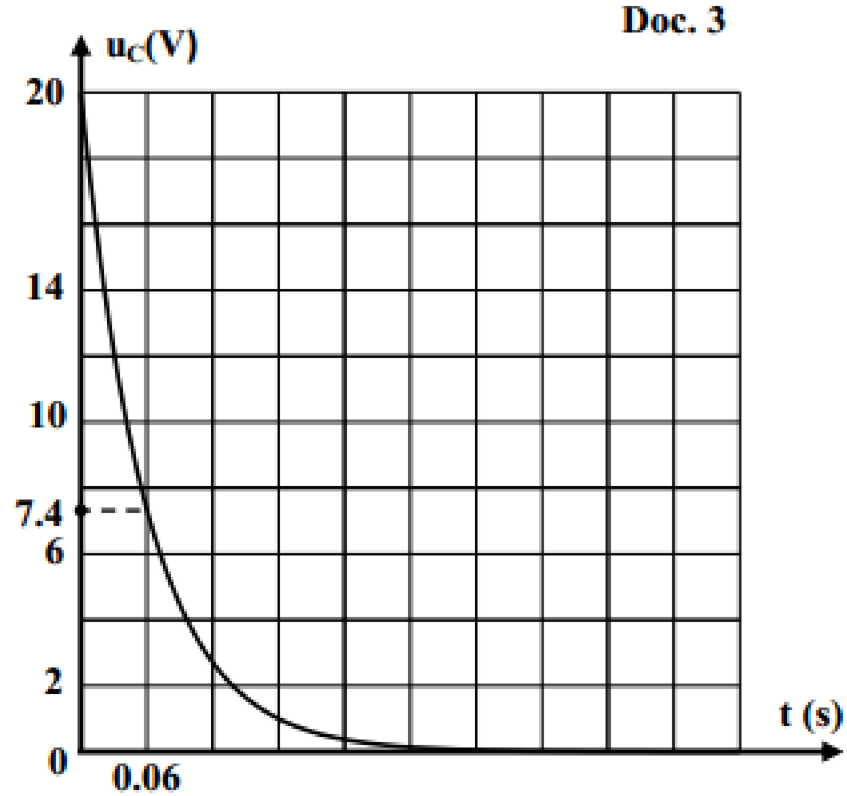
2-1-2) The solution of this differential equation has the form: $u_C = E\,e^{\frac{-t}{\tau_2}}$ where τ_2 is constant. Show that $\tau_2 = \alpha$.

2-2) Experimental study

The variation of the voltage u_C across the capacitor as a function of time is represented in document 4.

2-2-1) Determine, using document 4, the value of the time constant τ_2 of the discharging circuit.

2-2-2) Deduce the value of C.



Doc. 4

Exercise 10 :

Study of discharging a capacitor

PHYSICS
LS 2012-1

A capacitor of[redacted]citance C is initially charged under a voltage E.
At $t_0 = 0$, we c[redacted]ct across the terminals of the capacitor a resistor of resistance $R = 1\ k\Omega$ (Fig[redacted]
At an instant t[redacted]armature A carries the charge $q > 0$ and the circuit carries a current i.

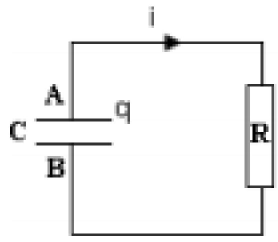


Fig.1

A – Theoreti[redacted]udy

1) Write [redacted]lation between i and q.
2) Show [redacted]he differential equation of the voltage $u_C = u_{AB}$ across the capacitor is $\frac{du_C}{dt} + \frac{1}{RC}u_C = 0$.
3) The so[redacted]n of this differential equation is $u_C = D e^{\frac{-t}{\tau}}$.
   Deter[redacted]the expressions of the constants D and τ in terms of E, R and C.
4) Show [redacted]after a time $t = \tau$, the voltage across the capacitor attains 37% of its maximum value E.

B – Determin[redacted] of the capacitance C

In order to det[redacted]he the value of C, we use a convenient apparatus, which traces, during the discharging of the capacitor, [redacted]urves representing $u_C = g(t)$ (Fig.2) and $\ell n(u_C) = f(t)$ (Fig.3)

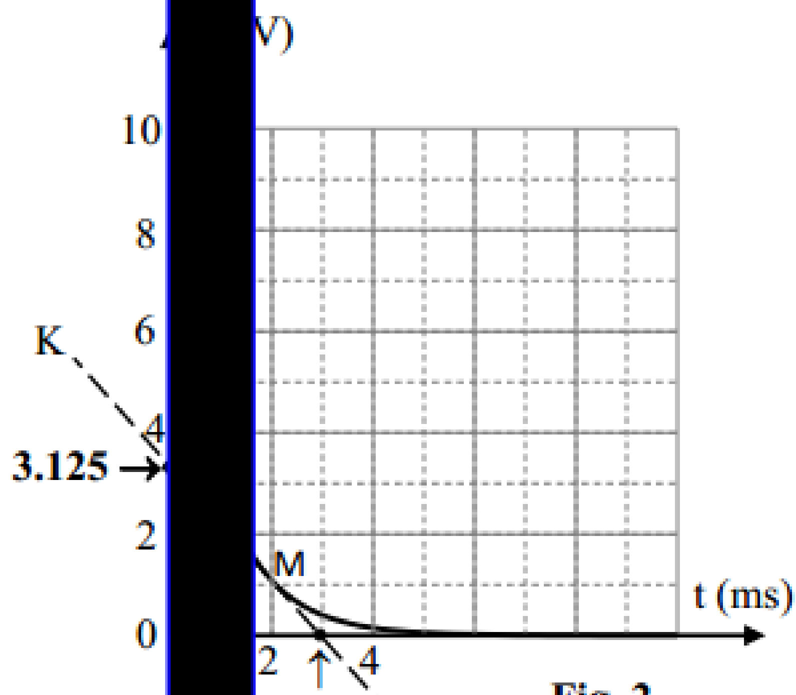


Fig. 2

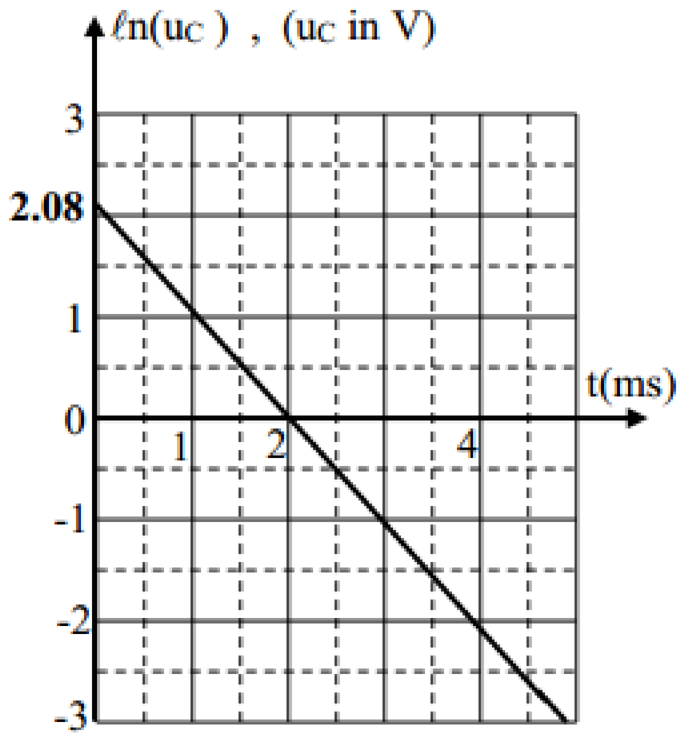


Fig.3

We proceed i[redacted]three following methods:

1) First meth[redacted]

Referring t[redacted]curve of figure 2:

a) give th[redacted]ue of E;
b) using [redacted]sult of part (A – 4) determine the value of τ and deduce the value of C.

2) Second me[redacted]

The figure 2 s[redacted] also the tangent KL to the curve at point M (2 ms, 1V).

a) Referr[redacted] this figure determine the slope of the tangent at point M.
b) Determ[redacted]he value of C.

3) Third met[redacted]

a) Determ[redacted]he expression of $\ell n(u_C)$ in terms of E, R, C and t.
b) Show [redacted]he shape of the curve in figure 3 is in agreement with the obtained expression of the functio[redacted]$(u_C) = f(t)$.
c) Referr[redacted] the curve of figure 3, determine again the values of E and C.

Exercise [redacted]

Charging and discharging of a capacitor

PHYSICS
LS 2013-2

The aim of t[redacted]xercise is to determine, by two different methods, the value of the capacita[redacted] of a capacitor. For this aim, we set-up the circuit of figure 1. This circuit [redacted]med of an ideal generator delivering a constant voltage of value $E = 10\ V$, a capacitor of capacitance C, two identical resistors of resistances $R_1 = R_2 = 10\ k\Omega$ and a double switch K.

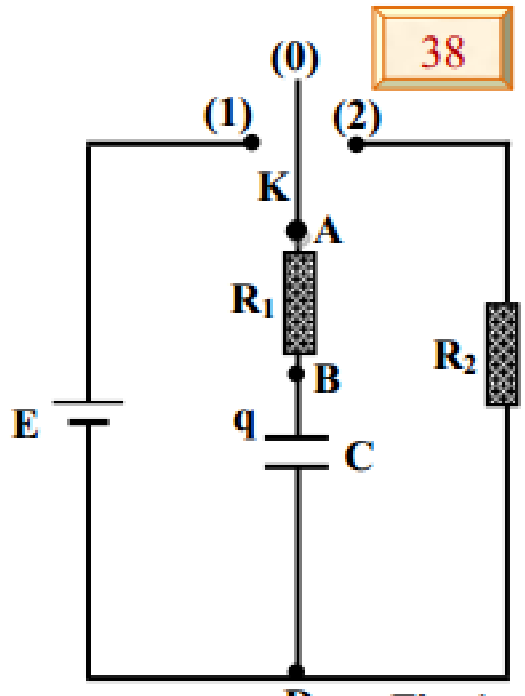


Fig. 1

A – Charging the capacitor

The switch K is in the position (0) and the capacitor is neutral. At the instant $t_0 = 0$, we turn K to position (1) and the charging of the capacitor starts.

1) Theoretical study

a) Applying the law of addition of voltages and taking the positive direction along the circuit as that of the current, show that the differential equation that describes the variation of the voltage $u_C = u_{BD}$ across the capacitor has the form: $E = R_1 C\dfrac{du_C}{dt} + u_C$.

b) The solution of this differential equation has the form: $u_C = A(1 - e^{\frac{-t}{\tau_1}})$ where A and τ_1 are constants. Show that $A = E$ and $\tau_1 = R_1C$.

c) Show that at the end of charging $u_C = E$.

d) Show that the expression $u_{AB} = u_{R_1} = E\,e^{\frac{-t}{R_1C}}$.

e) Establish the expression of the natural logarithm of u_{R_1} [$\ell n\,(u_{R_1})$] as a function of time.

2) Graphical study

The variation of $\ell n\,(u_{R_1})$ as a function of time is represented by figure 2.

a) Justify that the shape of the obtained graph agrees with the expression of $\ell n(u_{R_1})$ as a function of time.

b) Deduce, using the graph, the value of the capacitance C.

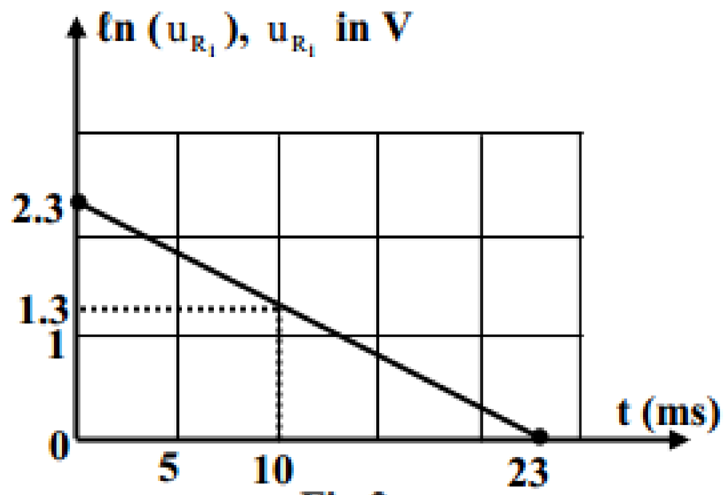


Fig.2

B – Discharging the capacitor

The capacitor being fully charged, we turn the switch K to position (2). At an instant $t_0 = 0$, taken as a new origin of time, the discharging of the capacitor starts.

1) During discharging, the current circulates from B to A in the resistor of resistance R_1. Justify.

2) Taking the positive direction along the circuit as that of the current, show that the differential equation in the voltage u_C across the capacitor has the form: $u_C + (R_1 + R_2)\,C\dfrac{du_C}{dt} = 0$.

3) The solution of the above differential equation has the form: $u_C = Ee^{\frac{-t}{\tau_2}}$ where τ_2 is the time constant of the circuit during discharging. Show that $\tau_2 = (R_1 + R_2)\,C$.

4) The variation of the voltage u_C across the capacitor and the tangent to the curve $u_C = f(t)$ at the instant $t_0 = 0$, are represented in figure 3. Deduce, from this figure, the value of the capacitance C.

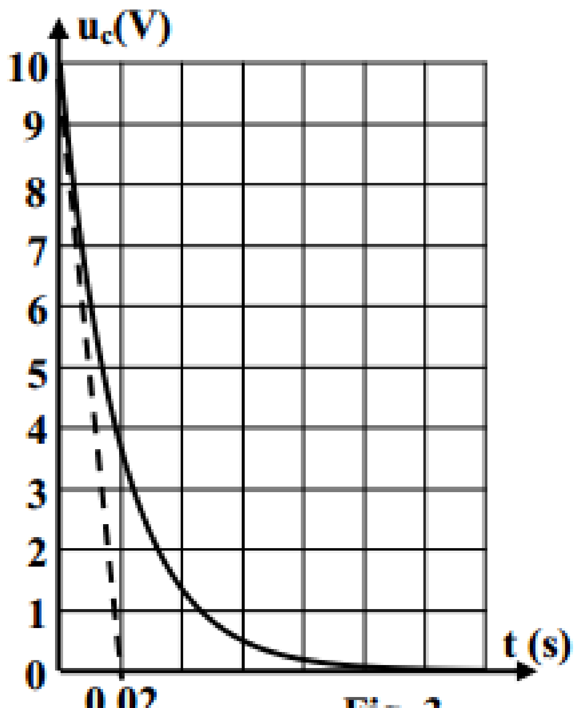


Fig. 3

Exercise 12 : Determination of the characteristics of an electric component

An electric [redacted]ponent (D), of unknown nature, which may be a resistor of resistanc[redacted]r a pure coil of inductance L or a capacitor of capacitance[redacted]

To determi[redacted] nature and the characteristic of (D) we consider the following:

- An i[redacted]generator G of constant electromotive force (e.m.f) E;
- Tw[redacted]stors of resistances $R_1 = 100\ \Omega$ and $R_2 = 150\ \Omega$;
- A d[redacted] switch K.

We set up t[redacted]rcuit of figure 1.

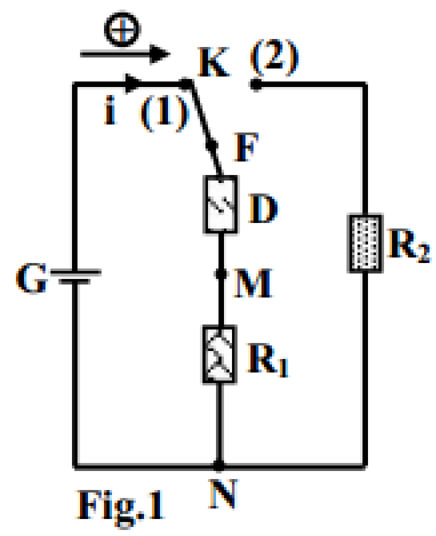


Fig.1

A – First E[redacted]ment

At an instan[redacted] 0 , the switch K is turned to position (1). Figure 2 sh[redacted]e variation of the voltage u_{FM} across the terminals of[redacted]as a function of time and the tangent to this curve at t_0 =[redacted]

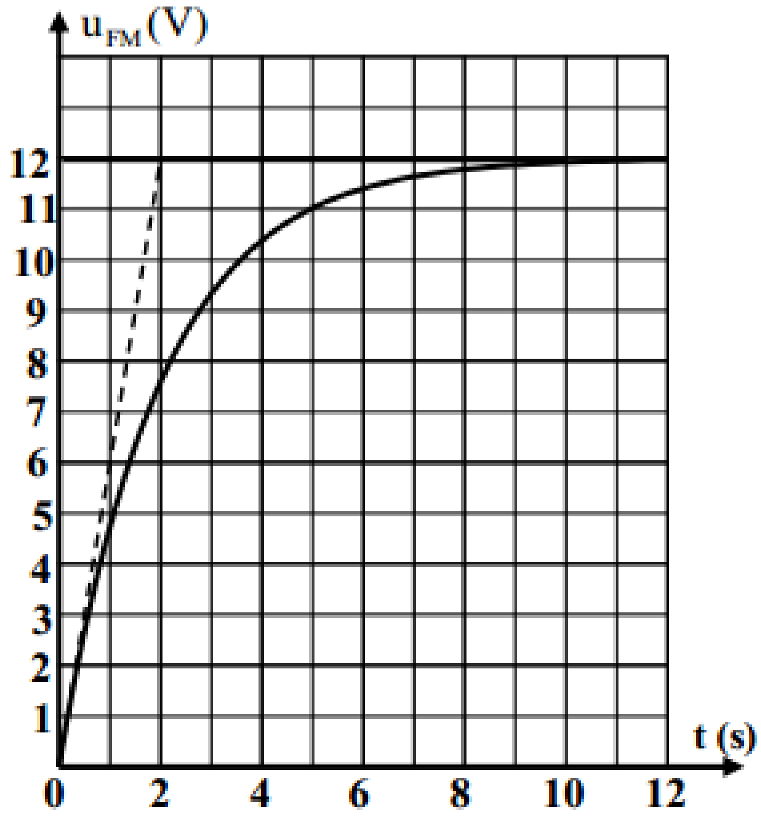


Fig. 2

1) The co[redacted]nt (D) is a capacitor. Justify.
2) Indicate[redacted]alue of the e.m.f E of the generator.
3) Calcula[redacted]$t_0 = 0$, the current carried by the circuit.
4) Derive t[redacted]fferential equation describing the variation of the volta[redacted]$_{FM} = u_C$.
5) The solu[redacted]of the differential equation has the form:

   $u_C = u_{FM}$[redacted] $+ B\ e^{-\frac{t}{\tau}}$.

   Determi[redacted]e expressions of the constants A, B and τ in terms of[redacted]C and E.
6) Determi[redacted]raphically, the value of the time constant τ .
7) Deduce [redacted]alue of C.

B – Second[redacted]eriment.

During the [redacted]ing of the capacitor and at an instant t_1, we turn the switch K to the position (2)[redacted]re 3).

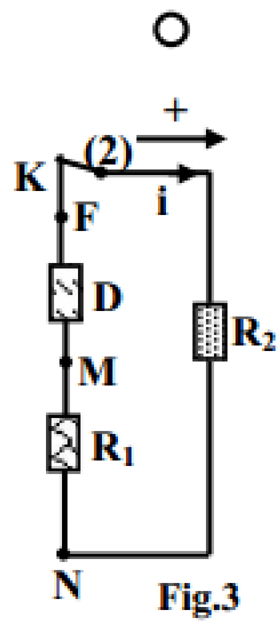


Fig.3

1) Name the [redacted]menon that takes place.
2) The resisto[redacted]can support a maximum power of $P_{max} = 0.24$ W.
   a) Calcul[redacted]e maximum value of the current which can pass through R_2 without damag[redacted](the thermal power is given by the relation: $p = R\ i^2$).
   b) Applyi[redacted]e law of addition of voltages, show that the maximum voltage across [redacted]rminals of the capacitor is $u_{FM} = 10$ V so that R_2 will not be damag[redacted]
   c) At the [redacted]t t_1 the current is maximum. Determine, graphically, the maximum duratio[redacted]= t_1 of the charging process of the capacitor so that the resistor R_2 will no[redacted]amaged.

Exercise 13

Determination of the resistance of a resistor

PHYSICS
LS 2010-1

We intend to determine the resistance R of a resistor (R). We thus connect up the circuit represented in figure (1) that is formed of an ideal generator of e.m.f $E = 5$ V, the resistor (R), an uncharged capacitor (C) of capacitance $C = 33\ \mu F$ and a double switch (K).

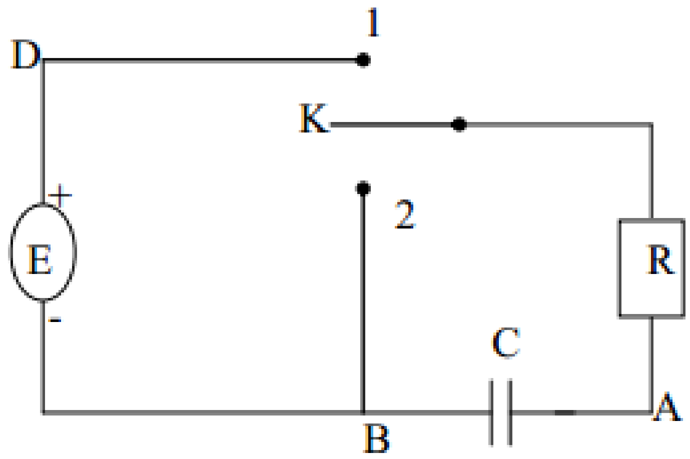


Fig. 1

A – Charging of the capacitor

1) We intend to charge the capacitor. To what position, 1 or 2, must then (K) be moved?
2) The circuit reaches a steady state after a certain time. Give then the value of the voltage u_{AB} across (C) and that of the voltage across (R).

B – Discharging of the capacitor

1) Draw a diagram of the circuit during the discharging of the capacitor and show on it the direction of the current it carries.
2) Derive the differential equation in $u_C = u_{AB}$ during the discharging.
3) The solution of this differential equation has the form :

$u_C = E\ e^{-\frac{t}{\tau}}$ (u_C in V , t in s)

where τ is a constant.

a) Determine the expression of τ in terms of R and C .

b) Determine the value of u_C at the instant $t_1 = \tau$.

c) Give, in terms of τ , the minimum duration needed at the end of which the capacitor is practically totally discharged.

d) Derive the expression of $\ell n\ u_C$, the natural logarithm of u_C , in terms of E , τ and t.

e) The diagram of figure 2 represents the variation of $\ell n\ u_C$ as a function of time .

Referring to the graph of figure 2, determine the value of R.

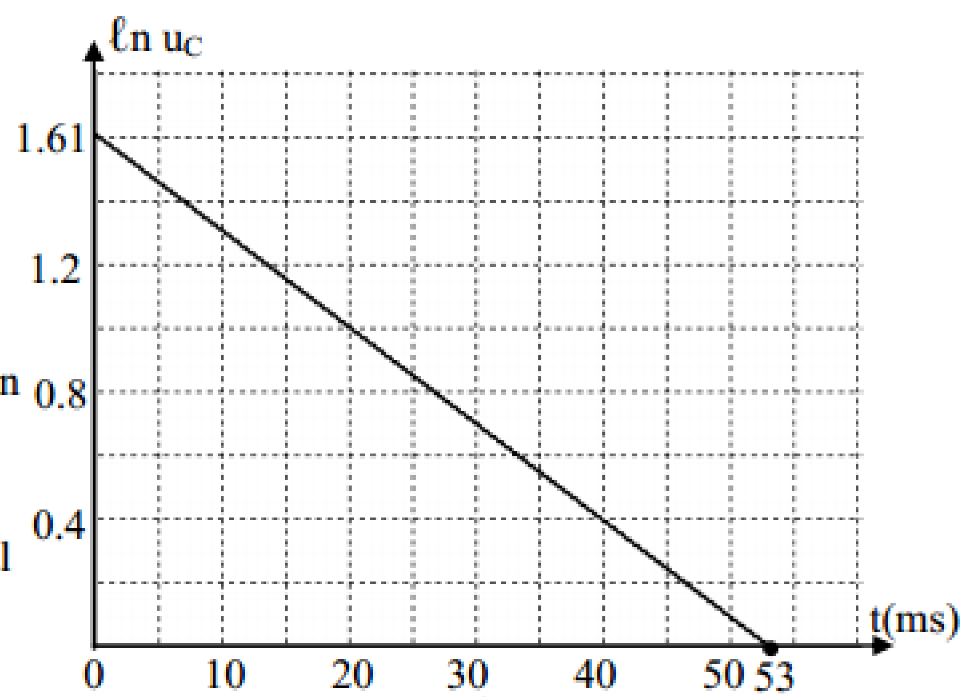


Fig. 2

Light : Diffraction

(Wave aspect)

Monochromatic light

This source of light emits radiation of same frequency .

Phenomenon of diffraction of light

When the light meets a sharp obstacle, or passes through a narrow hole or slit < 1mm it undergoes the diffraction.

Diffraction pattern

- **We observe different fringes, <u>bright</u> and <u>dark</u>,** situated on both sides of the central bright fringe<u>that is the brightest one</u>
- The fringes are **<u>collinear</u>** with a direction perpendicular to that of the slit.

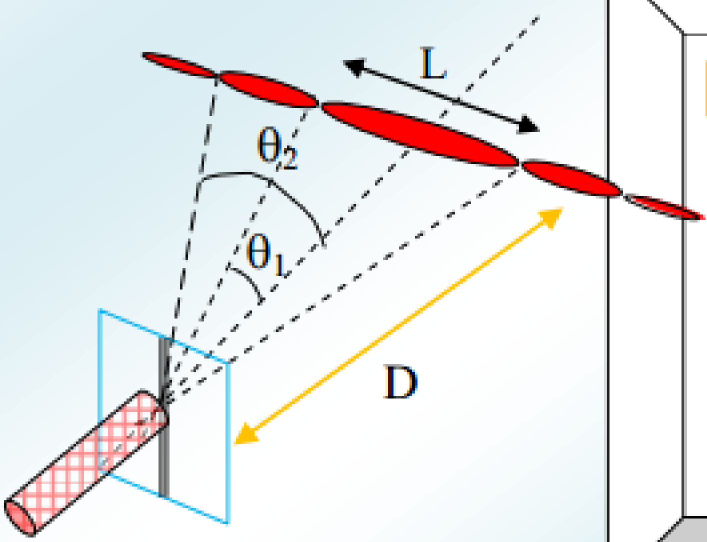
Formulas

Dark fringes Positions

$$\theta_n = n\frac{\lambda}{a} \quad \text{for}$$

θ_n **very small**

Case of a linear slit



Central fringe

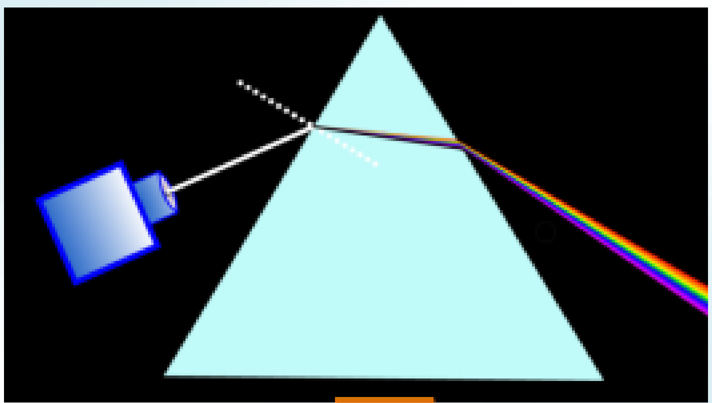
Angular width :

$$\alpha = 2\frac{\lambda}{a}$$

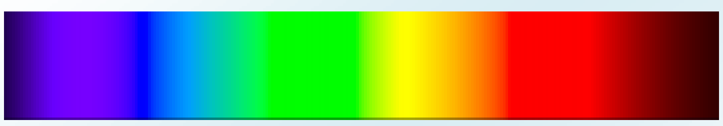
Linear width :

$$L = 2\frac{\lambda D}{a}$$

Scattering of poly-chromatic light by a prism



Continuous visible spectrum

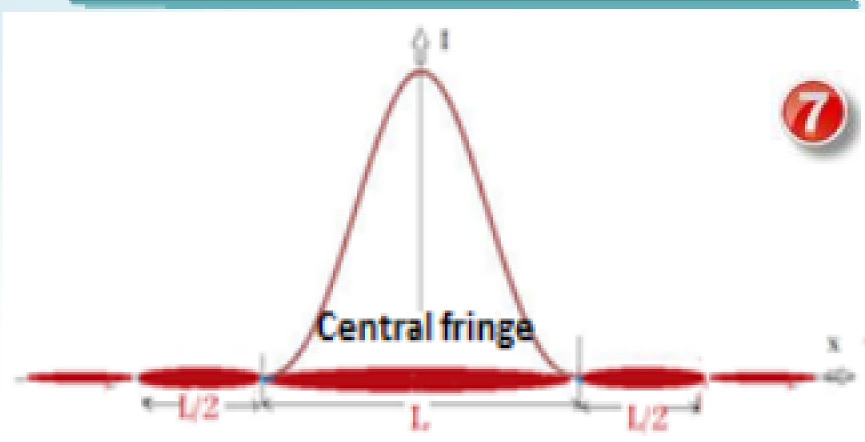


$3{,}75\ 10^{14} < f_{Hz} < 7{,}5\ .10^{14}$

or in Vacuum : $400 < \lambda_{nm} < 800$

violet red

Monochromatic Radiations of same frequencies

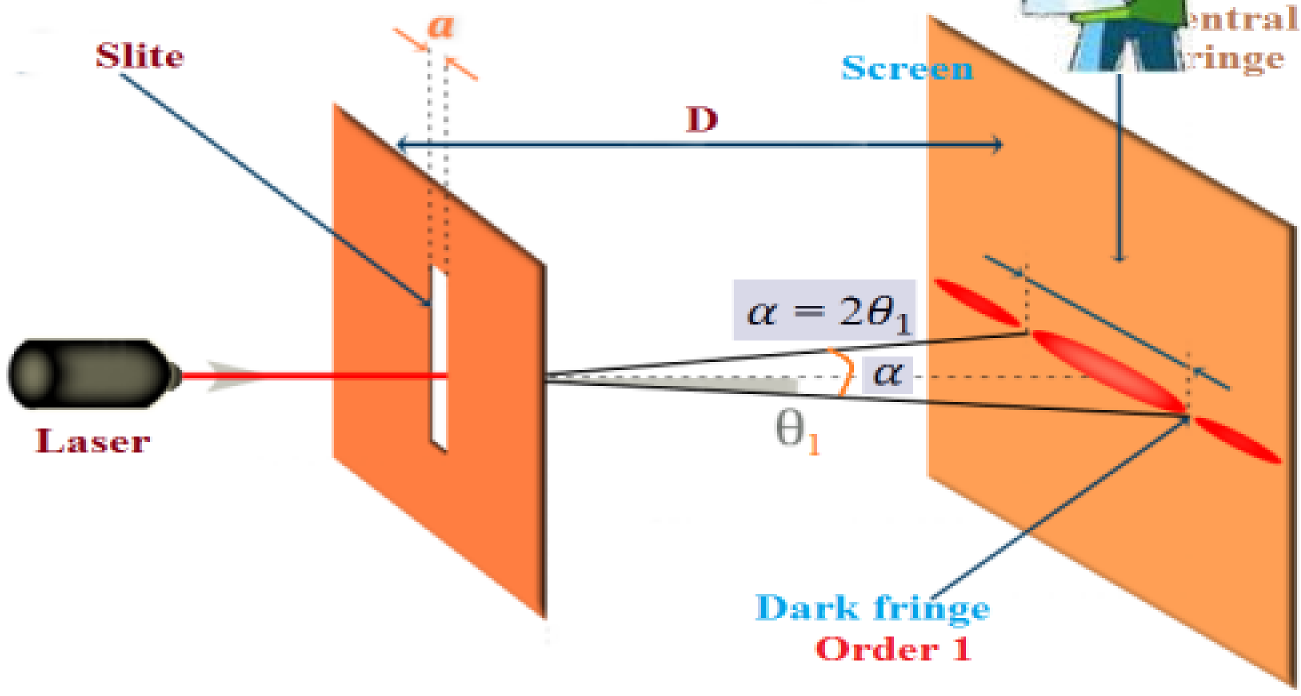


L is the linear width of the central fringe

Diffraction

Chap. 13

Exercises



Exercise 1 : **Determination of the wavelength of a laser light**

PHYSICS
GS-2001_1

The monochromatic light emitted by a laser source, of wavelength A, illuminates, under normal incidence, a very narrow slit F_1 of width $a_1 = 0.1$ mm cut in an opaque screen (E_1). The phenomenon of diffraction is observed on a screen (E_2) parallel to (E_1), found at a distance D = 4 m from it (fig. 1).

The central bright fringe on (E_2) has a linear width =5cm.

1) Describe the diffraction pattern observed on (E_2).
2) The phenomenon of diffraction shows evidence of a certain aspect of light. What is it?
3) Calculate the angular width of the central bright fringe.
4) Calculate the value of λ.

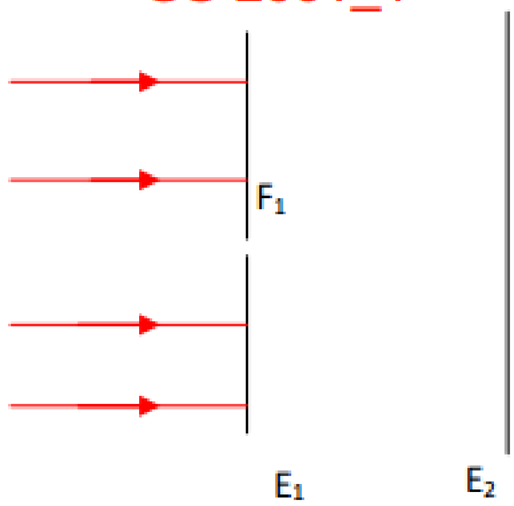


fig. 1

Exercise 2 : **Sources and interference**

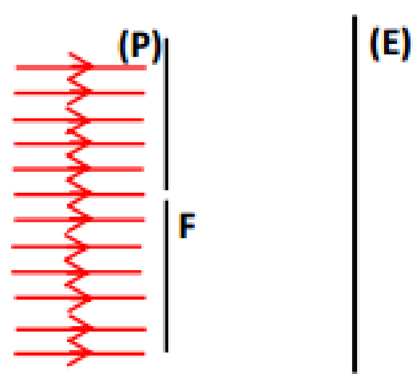
PHYSICS
GS-2007_2

A source of monochromatic radiation of wavelength λ in air illuminates under normal incidence a horizontal slit F of adjustable width a cut in an opaque screen (P). A screen of observation (E) is placed parallel to (P) at a distance D = 5 m (Fig.1).

1) For $\lambda = 0.5$ µm, show on a diagram the shape of the luminous beam emerging from the slit in each of the two following cases :

- width of the slit a = 2 cm.
- width of the slit a = 0.4 mm.

2) Which phenomenon will taking place when the value of a is in order of 1mm ?

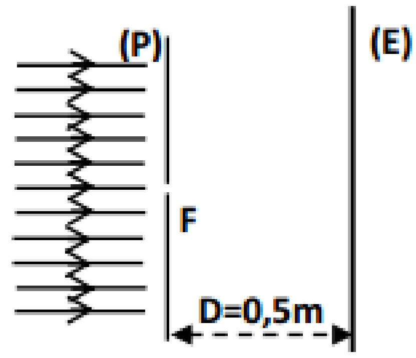


Exercise 3 [redacted] :

Central fringe

PHYSICS
GS-2007_2

The width of [redacted] lit is now kept at 0.4 mm and the radiation used belongs to the visible spectrum. (wavelength [redacted] visible spectrum : $0.4\ \mu m \le \lambda \le 0.8\ \mu m$)



1) Write , in [redacted] ase, the expression giving angular width of the central bright frin [redacted] terms of λ and a.

2) Show that [redacted] near width of this central fringe is given by : $L = \frac{2D\lambda}{a}$.

3) Calculat [redacted] linear widths L_{red} and L_{violet}, when us [redacted] uccessively a red radiation ($\lambda_{red} = 0.8\ \mu m$) and a vi [redacted] adiation ($\lambda_{violet} = 0.4\ \mu m$).

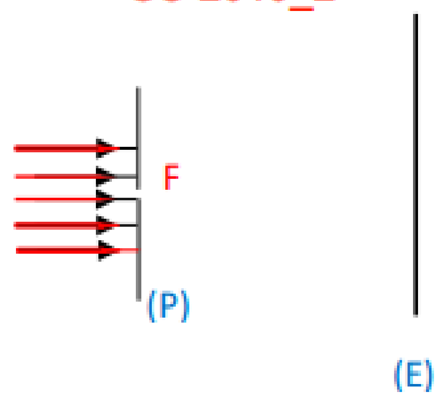
4) We illum [redacted] the slit with white light. We observe over the linear width L_{violet} white light. Justify.

Exercise [redacted]

Diffraction

PHYSICS
GS-2010_2

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



1) Describe [redacted] would be observed on (E) in the two following cases:

a) $a = a_1$ [redacted] m.

b) $a = a_2$ [redacted] mm.

2) It is imposs [redacted] to isolate a luminous ray by reducing the size of the slit. Why?

3) We use the [redacted] f width $a_2 = 0.5$ mm. The width of the central fringe of diffraction observed o [redacted] is 7.2 mm. Show that the wavelength of the light used is $\lambda = 600$ nm.

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

Exercise [redacted]

Aspect of light

PHYSICS
GS-2011-1

Consider a sou [redacted]) emitting a monochromatic luminous visible radiation of frequency $\nu = 6.163\times10^{14}$ Hz.

Given: c = 3× [redacted] m/s ; $h = 6.62\times10^{-34}$ J·s ; $1eV = 1.6\times10^{-19}$ J.

A – This sour [redacted] uminates a very thin slit that is at a distance of 10 m from a screen. A pattern, extending [redacted] a large width, is observed on the screen.

1) Due to wh [redacted] henomenon is the formation of this pattern?

2) Determin [redacted] width of the slit knowing that the linear width of the central fringe is 40cm.

B – The same [redacted] ce illuminates now the two slits of Young's double slit apparatus, these slits are vertical a [redacted] re separated by a distance a = 1 mm. A pattern is observed on a screen placed parallel to the pla [redacted] the slits at a distance D = 2 m from this plane. Describe [redacted] bserved pattern and calculate the interfringe distance i.

C – What asp [redacted] f light do the two preceding experiments show evidence of ?

Problems

Visit website physpro

Problem [redacted]

Diffraction

PHYSICS
GS-2012-2

A laser sou [redacted] mits a monochromatic cylindrical beam of light of wavelength $\lambda = 640$ nm in air. This beam falls normally on a vertical screen (P) having a horizontal slit F_1 of width a.

The phenomenon of diffraction is observed on a screen (E) parallel to (P) and situated at a distance D = 4 m from (P).

Consider on (E) a point M so that M coincides with the second dark fringe counted from O, the center of the central bright fringe. OIM = θ (θ is very small) is the angle of diffraction corresponding to the second dark fringe (Fig. 1).

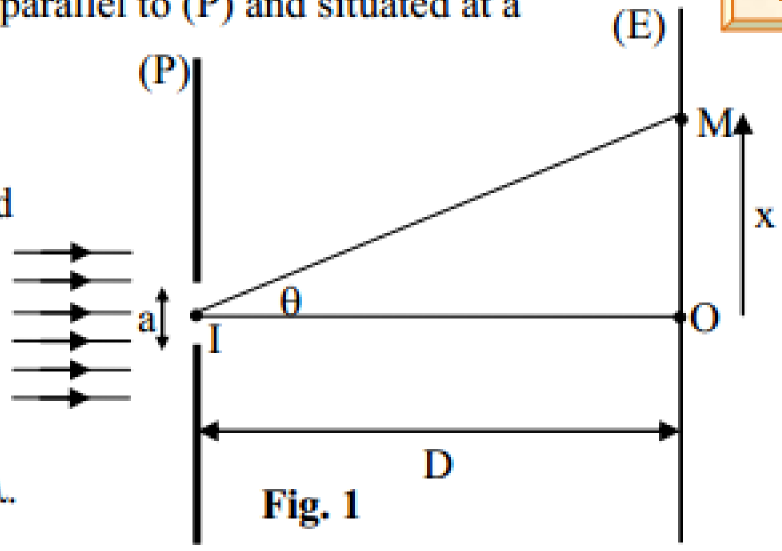


Fig. 1

1) Write the expression of θ in terms of a and λ.
2) Determine the expression of OM = x in terms of a, D and λ.
3) Determine the value of a if OM = 1.28 cm.
4) We replace the slit F_1 by another slit F_1' of width 100 times larger than that of F_1. What do we observe on the screen (E)?

Problem 2: **Applications of the diffraction of light**

PHYSICS
LS 2013-2

A – Measurement of the width of a slit

A laser beam of light, of wavelength in vacuum $\lambda = 632.8$ nm, falls normally on a vertical slit of width «a». The diffraction pattern is observed on a screen placed perpendicularly to the laser beam at a distance D = 1.5 m from the slit.

Let «L» be the linear width of the central fringe (Fig. 1).
The angle of diffraction θ corresponding to a dark fringe of order n is given by $\sin\theta = \frac{n\lambda}{a}$ where n = ±1, ±2, ±3…
For small angles, take tan θ ≈ sin θ ≈ θ in radian.

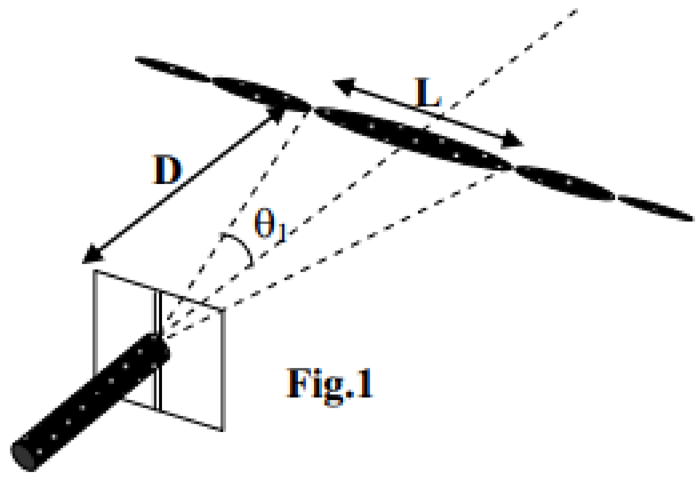


Fig.1

1) Describe the aspect of the diffraction pattern observed on the screen.
2) Write the relation among a, θ_1 and λ.
3) Establish the relation among a, λ , L and D.
4) Knowing that L = 6.3 mm, calculate the width «a» of the used slit.

B – Controlling the thickness of thin wire

A manufacturer of thin wires wishes to control the diameter of his product. He uses the same set-up mentioned in part (A) but he replaces the slit by a thin vertical wire. He observes on the screen the phenomenon of diffraction (figure 2).
For D = 2.60 m, he obtains a central fringe of constant linear width L_1 = 3.4 mm.

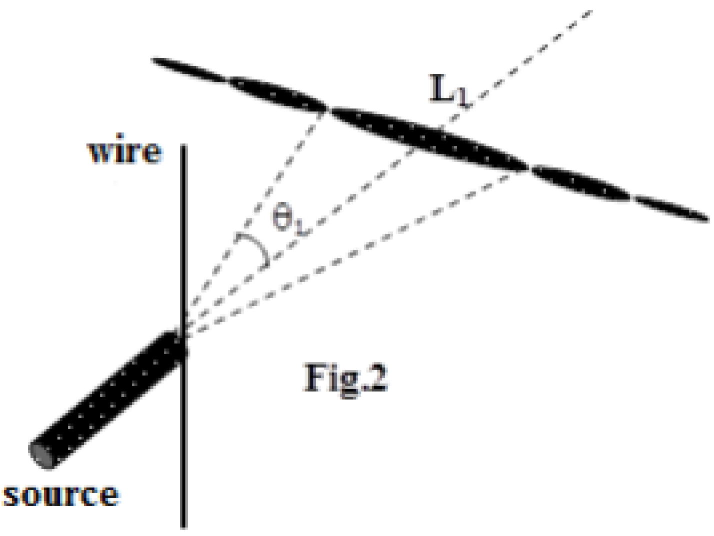


Fig.2

1) Calculate the value of the diameter «a_1» of the wire at the illuminated point.
2) The manufacturer illuminates the wire at different positions under the same precedent conditions. Specify the indicator that permits the manufacturer to check that the diameter of the wire is constant.

C – Measurement of the index of water

We place the whole set-up of part (A) in water of index of refraction n_{water}. We obtain a new diffraction pattern.

We find that for D = 1.5 m and a = 0.3 mm, the linear width of the central fringe is L_2 = 4.7 mm.
1) Calculate the wavelength λ' of the laser light in water.
2) a) Determine the relation among λ , λ' and n_{water}.
   b) Deduce the value of n_{water} .

Chap.16

Light : Photo-electric
(Corpuscular aspect)

Aspe[redacted]of light
(Corp[redacted]ular)

The light [redacted]ormed of tiny part[redacted]s called photons.T[redacted]e photons are of zero [redacted]s and zero [redacted]ges ①

Energy of the photon

$E_{pho} = h\nu = h\dfrac{c}{\lambda}$

with h : Planck's constant ②

Photoelectric effect

Definition :
It's the emission of electrons from the surface of a metal when illuminated by a suitable radiation . ③

Definitions

④ **Thr[redacted]hold wavel[redacted]th**

Def. : [redacted]is the **ma[redacted]m wavelen[redacted]** s (of the radiation[redacted]elow it, this rad[redacted]n can extract el[redacted]ns from the [redacted]ce

conditi[redacted]mission
λ < o[redacted]l to λ_s

⑤ **Threashold frequency ν_s**

Def. : This is the **minimum frequency ν_s** (of a radiation), above it, this radiation can extract electrons from the surface

condition of emission
ν > or equal to ν_s

⑥ **Work function W_0**

Def. : This is the minimum energy needed to extract an electron from the surface of a metal

$W_0 = h\dfrac{c}{\lambda_0}$

condition of emission
E_{photon} > or equal to W_0

KE$_{max}$ o[redacted]n extracted electron[redacted]om the metal

KE= [redacted]oton − W_0 ⑦

We face[redacted]ree cases :

1) E_{pho} < [redacted] KE= 0 *no emission*
2) E_{pho} = [redacted] KE = 0
3) E_{pho}> [redacted] KE = $E_{pho} - W_0$

Source of radiation and power

P = N.E_{photon} = N$h\nu$ ⑧
with N : nb of emitted pho/sec

Effective photons and efficiency

$r = \dfrac{N_{pho\ effictive}}{N_{pho\ received}}$

Note :
Always r < 1

Photoelectric effect

Chap. 16

Exercises

Problem 1: **The two aspects of light**

PHYSICS GS--2003_1

We cover a metallic plate by a thin layer of cesium whose threshold wavelength is $\lambda_o = 670$ nm.

Then we illuminate it with a monochromatic radiation of wavelength in vacuum $\lambda = 480$ nm.

A convenient apparatus is placed near the plate in order to detect the electrons emitted by the illuminated plate.

1- This emission of electrons by the plate shows evidence of an effect. What is that effect?
2- What does the term "threshold wavelength" represent?
3- Calculate, in J and eV, the extraction energy (work function) of the cesium layer.
4- What is the form of energy carried by an electron emitted by the plate? Give the maximum value of this energy.

Given: Planck's constant: $h = 6.6 \times 10^{-34}$ J.s; speed of light in vacuum: $c = 3 \times 10^{8}$ m/s; 1 eV= 1.6×10^{-19} J.

Problem 2: Photoelectric Effect

PHYSICS GS 2005 -1

The experiments on photoelectric emission performed by Millikan around the year 1915, intended to determine the kinetic energy K.E of the electrons emitted by metallic cylinders of potassium (K) and cesium (Cs) when these cylinders are illuminated by monochromatic radiation of adjustable frequency ν.

The object of this exercise is to determine, performing similar experiments, Planck's constant (h), as well as the threshold frequency ν_o of potassium and the extraction energy W_o of potassium and that of cesium.

I - ***1)*** What aspect of light does the phenomenon of photoelectric effect show evidence of ?

2) A monochromatic radiation is formed of photons. Give two characteristics of a photon.

3) For a given pure metal, the incident photons of a monochromatic radiation provoke photoelectric emission. Give the condition for this emission to take place.

II- In a first experiment using potassium, a convenient apparatus is used to measure the kinetic energy K.E the electrons corresponding to frequency ν of the incident radiation.

The obtained [redacted] lts are tabulated in the following table:

Given : 1eV [redacted] 0 $\times 10^{-19}$ J.

ν (Hz)	E_C (eV)
6×10^{14}	0,25
7×10^{14}	0,65
8×10^{14}	1,05
9×10^{14}	1,45
10×10^{14}	1,85

1- Using Eins [redacted] s relation about photoelectric effect,show that the kinetic ener [redacted] f an extracted electron may be written in the form :

$$K.E = a\nu + b.$$

2- ***a)*** Plot , o [redacted] graph paper, the curve represent [redacted] he variation of the kinetic energy K.E versus ν , using the [redacted] wing scale:

- on the [redacted] of abscissas: 1cm represents a frequency of 10^{14}Hz
- on the [redacted] of ordinates: 1 cm represents a kinetic energy of 0.5 eV.

b) Using [redacted] raph, determine:

i) the [redacted] e, in SI, of h , the Planck's constant.

ii) th [redacted] shold frequency ν_o of potassium.

3- Deduce t [redacted] lue of the extraction energy W_o of potassium.

III- In a seco [redacted] periment using cesium, we obtain the following values: K.E = 1 eV for $\nu = 7 \times 10^{14}$Hz.

1) Plot, with [redacted] fication ,on the preceding system of axes, the graph of the variation of K.E as a function o [redacted]
2) Deduce fr [redacted] is graph the extraction energy W'_o of cesium.

Problem 3 [redacted] Photoelectric effect

PHYSICS
GS_2007_2

A source of wa [redacted] ngth λ= 0.5 µm in air illuminates separately two metallic plates, one made of cesium and the other of zi [redacted]
The table belo [redacted] es, in eV, the values of the extraction energy W_0 (work function) for some metals.

M [redacted]	Cesium	Rubidium	Potassium	Sodium	Zinc
W [redacted])	1.89	2.13	2.15	2.27	4.31

Given : h = 6. [redacted] 10^{-34} J.s ; 1 eV = 1.6$\times 10^{-19}$J ; c = 3 $\times 10^{8}$ m/s.

1) Calcul [redacted] n J and in eV, the energy of an incident photon.

2) For wh [redacted] etal would photoelectric emission take place? Justify.

3) Calcul [redacted] eV the maximum kinetic energy of an emitted electron.

4) The ce [redacted] plate receives a monochromatic luminous beam of wavelength in air λ = 0.5 µm, of power [redacted] 3978$\times 10^{-4}$ W. The number of electrons emitted per second is then n = 10^{16}.

a) Ca [redacted] e the number N of photons received by the plate in one second.

b) Th [redacted] ntum efficiency r of the plate is the ratio of the number of the electrons emitted per sec [redacted] o the number of photons received by the plate during the same time. Calculate r.

Duality wa [redacted] rticle

The wave th [redacted] of light is used to interpret the phenomenon of diffraction. This theory is not able to interpret the [redacted] toelectric effect. Why?

Problem [redacted] Photoelectric Effect

PHYSICS
LS_2009_2

A) The photo [redacted] ric effect was discovered by Hertz on 1887. The experiment represented in figure 1 may show evid [redacted] of this effect. A zinc plate is fixed on the conducting rod of an electroscope.

The whole [redacted] p is charged negatively.

If we illun [redacted] e the plate by a lamp emitting white light rich with ultraviolet radiations (U.V), the leaves F and F' o [redacted] electroscope approach each other rapidly.

1) Due to [redacted] is the approaching of the leaves?

2) The ph [redacted] ectric effect shows evidence of an aspect of light. What is this aspect?

B) The experiments performed by Millikan towards 1915, intended to determine the maximum kinetic energy K.E of the electrons emitted by metallic plates when Zinc plate illuminated by monochromatic radiation of adjustable wavelength λ in vacuum.

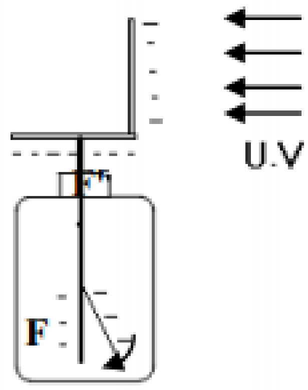


Fig.1

In an experiment using a plate of cesium, a convenient apparatus allows us to measure the maximum kinetic energy K.E of an emitted electron corresponding to the wavelength λ of the incident radiation.

The variation of K.E as a function of λ is represented in the graph of figure 2.

The aim of this part is to determine the value of Planck's constant h and that of the extraction energy W_0 of cesium.

1) Write down the expression of the energy E of an incident photon, of wavelength λ in vacuum, in terms of λ, h and c.

2) **a)** Applying Einstein's relation about photoelectric effect, show that the maximum kinetic energy K.E of an extracted electron may be written in the form

$K.E = \frac{a}{\lambda} + b$, where a and b are constants.

b) Deduce the expression of the threshold wavelength λ_0 of cesium in terms of W_0, h and c.

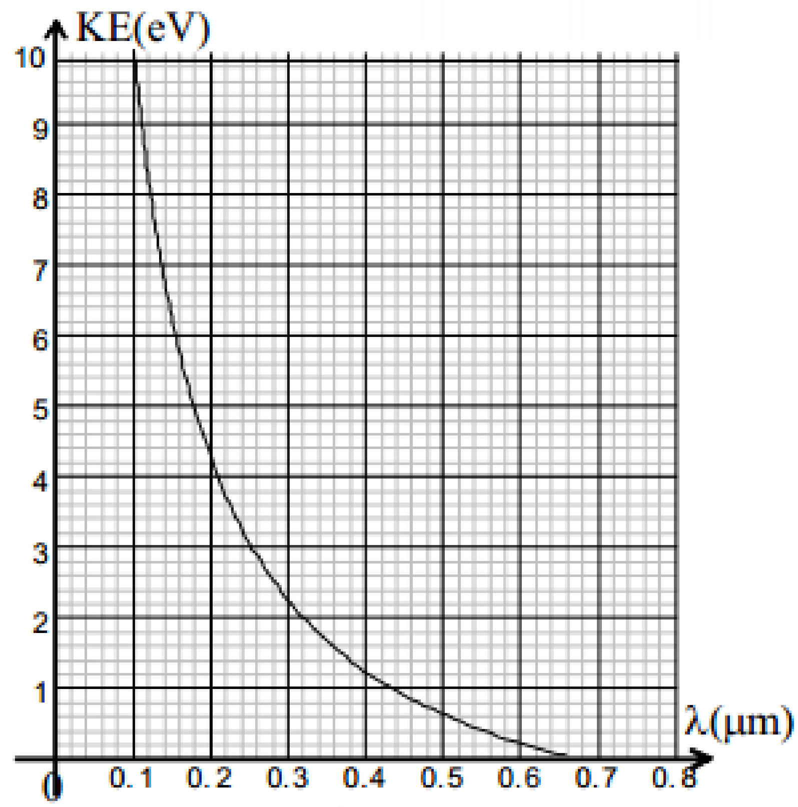


Fig.2

3) Referring to the graph:

a) Give the value of the threshold wavelength λ_0 of cesium;

b) Determine the value of W_0 and that of h.

Problem 5 : **Photoelectric effect**

PHYSICS
LS-2010-2

A metallic plate, covered with a layer of cesium, is illuminated with a monochromatic luminous beam of wavelength $\lambda = 0.45 \times 10^{-6}$ m in vacuum.
The work function (extraction energy) of cesium is $W_0 = 1.88$ eV.
A convenient apparatus (D) is used to detect the electrons emitted by the illuminated plate.

1) What aspect of light does the phenomenon of photoelectric effect show evidence of ?

2) Define the term "work function" of a metal.

3) The luminous beam illuminating the metallic plate is formed of photons.

a) ***i)*** Write down the expression of the energy E of a photon in terms of h, c and λ.

ii) Calculate, in eV, the energy of an incident photon.

b) (D) detects electrons emitted by the plate.

Why do we have an emission of electrons by the plate?

c) Calculate, in eV, the maximum kinetic energy of an emitted electron.

4) The luminous power P received by the plate is 10^{-3} W, and the emitted electrons form a current $I = 5$ μA.

a) Calculate the number n of photons received by the plate in one second.

b) Knowing that the current I is related to the number N of the electrons emitted per second and to the elementary charge e by the relation: $I = N \times e$. Calculate N .

c) ***i)*** Calculate the quantum efficiency $r = \frac{N}{n}$.

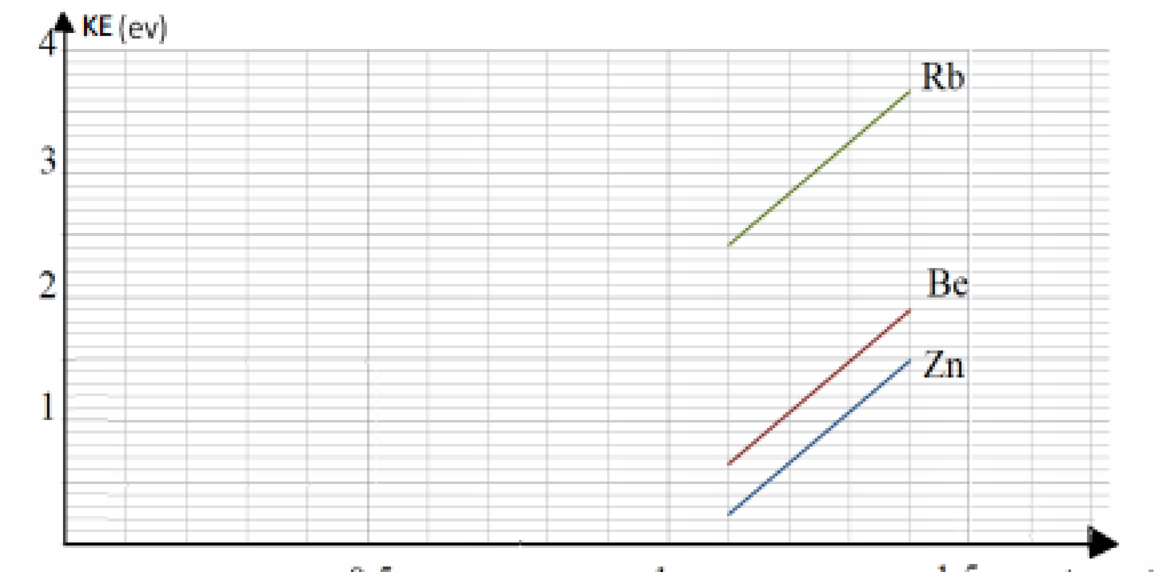
ii) Deduce that the number of effective photons in one second is relatively small.

Problem 6: Photoelectric effect

An experimenter uses a mono-energetic electromagnetic radiation source of adjustable frequency ν to illuminate, respectively, three metal plates, one in Zinc (Zn), another one in Beryllium (Be) and a third one in Rubidium (Rb). The experimenter varies the frequency ν of the incident radiation and records, for each value of ν, the value of the maximum kinetic energy of an electron emitted by each of the three plates in the table (Doc 6).
He obtains the graph giving KE = f(ν) for each of the three plates, these graphs being represented in (Doc 7).
Take: 1 eV = 1.60×10^{-19} J; c = 3×10^{8} m/s.

ν (10^{15} Hz)	KE (eV)		
	Zn	Be	Rb
1.10	0.241	0.651	2.421
1.15	0.448	0.858	2.628
1.20	0.655	1.065	2.835
1.25	0.862	1.272	3.042
1.30	1.069	1.479	3.249
1.35	1.276	1.686	3.456
1.40	1.483	1.893	3.663

(Doc 6)



(Doc 7)

1) We notice that the photoelectric effect does not occur for some visible and infrared incident radiation regardless of the intensity of radiation and the duration of exposure. Why does this result defy the wave theory of light?
2) Indicate the aspect of light that the photoelectric effect phenomenon shows in evidence.
3) Interpret, based on Einstein's hypothesis relative to the photoelectric effect, the fact that the three graphs are parallel line segments.
4) Calculate, referring to (Doc 6), the value of Planck's constant.
5) Determine, referring to the graphs in (Doc 7), the threshold frequency of each of the metal plates.
6) Deduce the value of the extraction energy corresponding to each of the metal plates.
7) The experimenter illuminates each plate with an incident radiation of wavelength, in vacuum, 333 nm.

7-1) Specify, for each plate, whether there is an emission of electrons or not.
7-2) Calculate, in case we have an emission of electrons, the maximum kinetic energy of an emitted electron.

d) We increase the luminous power P received by the plate without changing the wavelength λ.
Would the current increase or decrease? Why?

Problem 7: Photoelectric effect

PHYSICS
GS 2016 - 1

A hydrogen lamp of power P_S = 2W, emits uniformly radiation in all directions in a homogeneous and non - absorbing medium. This lamp illuminates a potassium cathode C of a photoelectric cell of work function W_0 = 2.20 eV and of a surface area s = 2cm^2 placed at a distance D = 1.25m from the lamp (figure1).

1) Calculate the threshold wavelength of the potassium cathode.
2) Among the rays of Balmer series, specify the radiation that can produce photoelectric emission.
3) Using a filter we illuminate the cell by a blue light H_β of wavelength λ = 486.13nm. The generator G is adjusted so that the anode (A) captures all the emitted electrons by the cathode of quantum efficiency r = 0.875%.
   a) Show that the received power of the radiation P_0 of the cell is 2.04×10^{-5}W.
   b) Determine the number N_0 of the incident photons received by the cathode C in one second.
   c) Determine the current in the circuit.

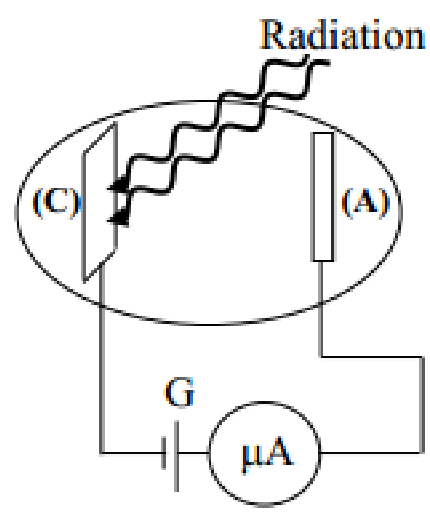


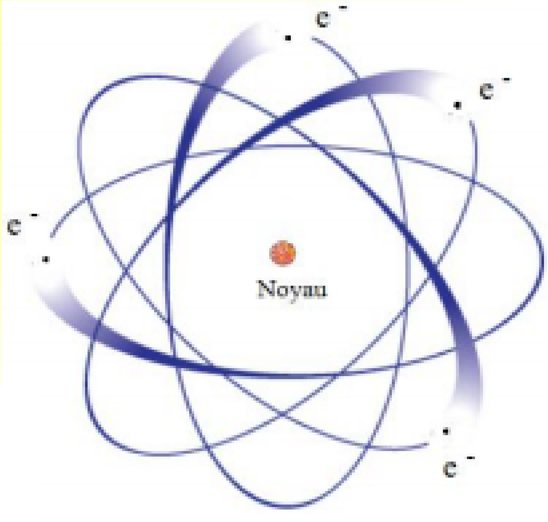
Figure 1

Atom

Bohr [redacted] model

The e [redacted] gy of the atom [redacted] quantified

The value [redacted] f energy are discret [redacted] at means disconti [redacted] us values. ①



Energy of the photon and the wavelength

During a transition from a level m to p

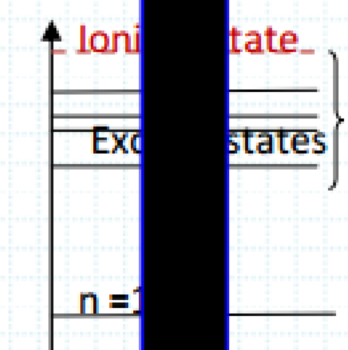
$E_{pho} = |E_m - E_p| = h\frac{c}{\lambda_{mp}}$

then $\lambda = hc/\Delta E$ ②

Hydrogen Atom

③

$E_n = -$ [redacted] 6 ev



Balmer series ④

Emission spectrum

Transition n > 2 → n=2

400nm ≤ λ ≤ 800nm in vacuum

These are the visible rays

$H_\alpha: 3 \rightarrow 2$;	$H_\beta: 4 \rightarrow 2$
$H_\gamma: 5 \rightarrow 2$;	$H_\delta: 6 \rightarrow 2$

⑤

Rydberg formula

$$\frac{1}{\lambda_{n,2}} = R_H\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

Transition:

n > 2 → n=2

light

Some [redacted] finitions : ⑥

a- Funda [redacted] ntal state

b- Ionize [redacted] ate

c- Ioniza [redacted] energy

[redacted] swers

a) Corresp [redacted] ng to the stable state, having [redacted] inimum energy.

b) This is [redacted] tate corresponding to the leve [redacted] ere the energy E=0 (ionized [redacted] m).

c) This is t [redacted] inimum energy needed [redacted] he atom, taken in its ground state to be ionized.

Another spectral series of the hydrogen atom H ⑦

- **Lyman** series: n > 1 to n = 1 {U.V} Ultraviolet : $\lambda < 400$nm.
- **Paschen** series: n > 3 to n =3 {I.R.} Infrared : $\lambda > 800$nm

Absorption spectrum ⑧

Black rays

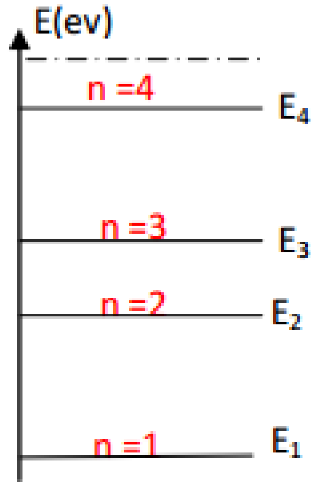
Atom

Exercises

Test Your Knowledge

Given : Plank's constant 6.63×10^{-34} J.s ; speed of light in vacuum 3×10^{8} m/s.

Correct the false statements and answer the questions.



Document 1

1) An atom, given in its <u>fundamental state</u>, absorbs a photon:

1. 1– The atom stays in its fundamental state.

1. 2– The fundamental state is associated to the level n = 2.

1. 3– The atom undergoes a deexcitation.

1. 4– The minimum value of the absorbed energy that can excite this atom is E_2-E_1.

1. 5– A photon of energy $E_{ph} < E_2 - E_1$ is absorbed by this atom.

1. 6– A photon of energy $E > E_2$-E_1 is nessecerily absorbed by this atom.

1. 7– The true answer of part 1.6 verify the quantization of energy of the atom.

1. 8– The energy of the atom in tha ionized state is E = 0.

1. 9– The ionization energy of an atom is E_1.

1. 10– The transition from n = 1 to n = 3 needs the absorption of a photon of energy E_3.

2) Knowing that the specific energies of <u>the H atom</u> are given by $E_n = -\frac{13,6}{n^2}$ in ev ; and the H atom is given in its fundamental state.

2. 1– The energy of the H atom in the 2nd excited state is -3,4 ev.

2. 2– This atom needs at least an energy of 10.2 eV to be excited.

2. 3– If the atom undergoes the transition from n = 4 to n = 1, we say that it is excited to the excited level n = 1.

2. 4– Absorbing an energy equal to $E_4 - E_1$, this atom will be excited to the third excited level.

2. 5– If the atom undergoes the transition from n = 4 to n = 1, we say that it will be excited to the level n = 1.

2. 6– The H atom, passing from level n = 4 to n = 1, absorbs a photon.

2. 7– The H atom undergoes the transition from n = 3 to n = 2. The emitted radiation has a wavelength λ_{32} = 120 nm.

2. 8– The H atom, when deexcited from level n = 3 to n = 2, emits a visible radiation.

2. 9– The H atom, given in its fundamental state, receives four photons of respective energies: 10 ev, 10.4 ev, 12.09 ev and 13.8 ev. Specify the energetic state of the atom after receiving each photon.

2. 10– An H atom, in its fundamental state, receives a particle (an electron for example) of kinetic energy 10.4 ev.

2.10.1- What will be the new state of the atom?

2.10.2- By comparing the result with the question 2.9, explain the difference between « **particle** » and « **photon** ».

3) The Rydberg formula is related to the hydrogen atoms only. It allows us to calculate the wavelength of the radiation that can be emitted or absorbed by the H atom.

3.1) Write the Rydberg formula corresponding to the transition from m to p with p > m.

3.2) Calculate the wavelength of the emitted radiation during the transition from n = 5 to n = 2.

3.3) Is the emitted radiation in the part 3.2 visible? What series is it associated to?

3. 1− Use the Rydberg formula to verify that the energy of the H atom at an energy level n is given by: $E_n = -\frac{13,6}{n^2}$.

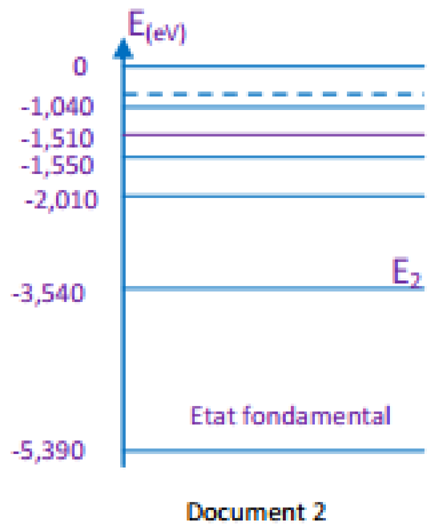
3. 2− What transitions correspond to the Balmer series? how can we specify these transitions corresponding to the H atom?

3. 3− What series does the transitions from n > 1 to n = 1 correspond to? What domain do these radiations belong to? (Visible; UV ou IR)?

3. 4− What transitions correspond to the Pashen series? What domain do these radiations belong to? (Visible; UV ou IR)?

3. 5− An atom is characterized by it energy diagram given in the document 2.
The atom is in the energy level E_2.
Can this atom absorb a photon of energy 1.99 ev?

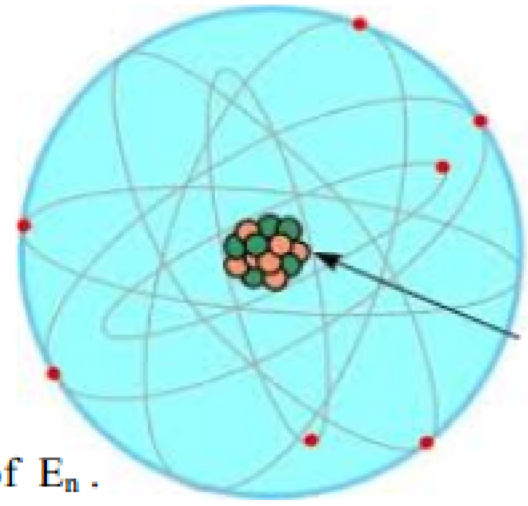
3. 6− The atom in the preceding question is deexcited from level n = 3 to a lower energy level. What are the possible deexcitation of this atom. Show them by an arrow.



Document 2

3. 7− Inversely, if the preceding atom undergoes an excitation from the fundamental state to the 3rd excited state. Show this transition by an arrow.

Exercise 1 : Atom and quantification of energy

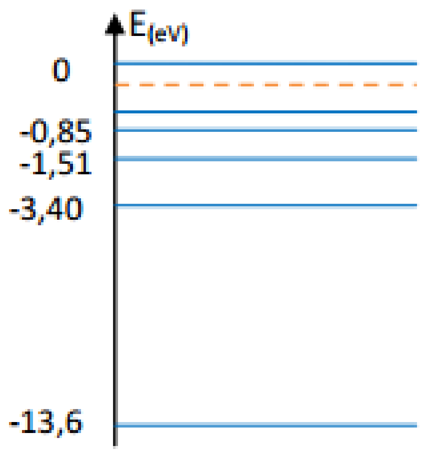


The energies of the different energy levels of the hydrogen atom are given by the relation: $E_n = -\frac{13.6}{n^2}$ (in eV)
where n is a positive whole number.

Planck's constant : $h = 6.63 \times 10^{-34}$ J.s ; $1\ eV = 1.60 \times 10^{-19}$ J ;
Speed of light in vacuum : $c = 3 \times 10^{8}$ m/s ; $1\ nm = 10^{-9}$ m.

1) The energies of the atom are quantized. Justify this using the expression of E_n.
2) Determine the energy of the hydrogen atom when it is:
   a) in the fundamental state .
   b) in the second excited state.
3) Give the name of the state for which the energy of the atom is zero.

Exercise 2 : Excitation of atom by radiations (photons)



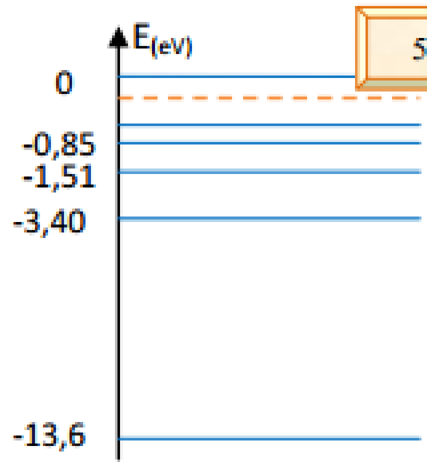
The hydrogen atom is in its fundamental state.

1) Calculate the minimum energy of a photon that is able to:
   a) excite this atom;
   b) ionize this atom.

2) The hydrogen atom receives, separately, three photons of respective energies:
   a) **11eV** b) **12,75 eV** c) **16 eV**

   Specify in each case the state of the atom. Justify.

Exercise 3 : Deexcitation of atom H



The hydrogen atom is found now in the energy level n = 3.

1) Specify all the possible transitions of the atom when it is dis-excited.
2) One of the emitted radiations is visible. Calculate its wavelength in vacuum.

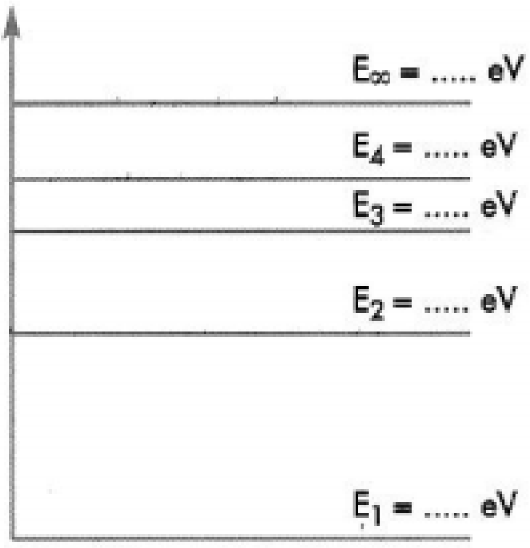
Exercise 4 : Quantized energy

The quantized energy levels of the hydrogen atom are given by the formula:

$E_n = \frac{E_o}{n^2}$ where $E_o = 13{,}6$ eV and n is a whole number ≥ 1.

1) Explain briefly what is meant by the term "quantized energy" and tell why the spectra (absorption or emission) of hydrogen are formed of lines.

2) Calculate the values of the energies corresponding to the energy levels n = 1, 2, 3, 4 and n = ∞. Redraw and complete the adjacent diagram.



Exercise 5 : Sodium atom

PHYSICS
GS 2017-1

Document 1 represents some of the energy levels of the sodium atom.

Given: $h = 6.6 \times 10^{-34}$ J.s ; $c = 3 \times 10^{8}$ m/s ;
$1 eV = 1.6 \times 10^{-19}$ J ; $1u = 931.5$ MeV/c^2.

The aim of this exercise is to study the excitation and the de-excitation of the sodium atom.

Excitation of the sodium atom

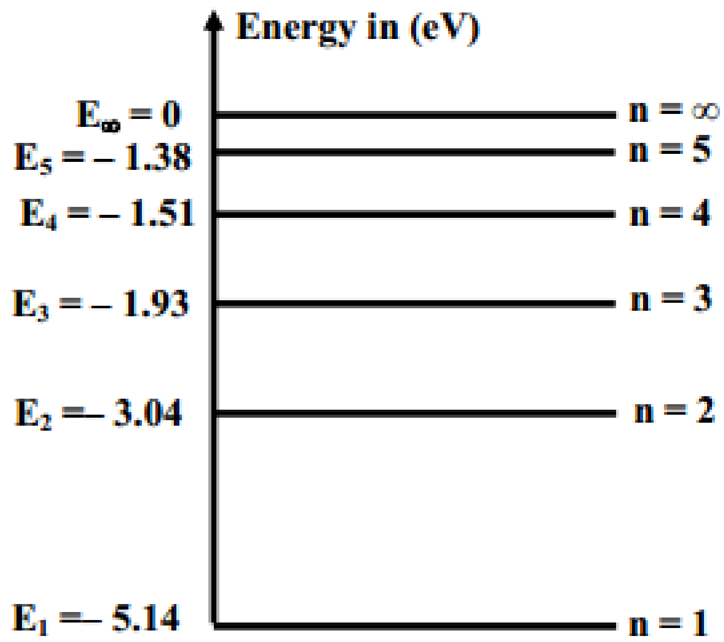
Consider a sample of sodium atoms, initially in the ground state. This sample is illuminated by white light that contains all the visible radiations: $0.4\ \mu m \leq \lambda_{visible} \leq 0.8\ \mu m$.

1-1) Using document 1, show that the energy of the sodium atom is quantized.

1-2) Determine, in eV, the maximum energy and the minimum energy of the photons in the white light.

1-3) Using document 1, show that white light is not capable to ionize the sodium atom.

1-4) Determine, in nm, the wavelength of the photon that excites the sodium atom to the first excited state.



Doc. 1

Problems

Visit website physprolb.com

Problem 1 : Spectrum of the hydrogen atom

PHYSICS

A - Emission spectrum

The Balmer's series of the hydrogen atom is the set of the radiations corresponding to the downward transitions to the level of n = 2.

The values of the wavelengths in vacuum of the visible radiations of this series are :

411 nm ; 435 nm ; 487 nm ; 658 nm.

a) Specify, with justification, the wavelength λ_1 of the visible radiation carrying the greatest energy.

b) Determine the initial level of the transition giving the radiation of wavelength λ_1 .

c) Deduce the three initial levels corresponding to the emission of the other visible radiations.

B - Absorption spectrum

A beam of S[redacted]ght crosses a gas formed mainly of hydrogen . The study of the absorption spectrum reveals the [redacted]nce of dark spectral lines.

Give , with [redacted]ication, the number of these lines and their corresponding wavelengths.

C - Interac[redacted] photon-hydrogen atom

1) We send o[redacted] hydrogen atom , being in the fundamental state, separately, two photons of respective energies 3.[redacted] and 10.2 eV .
   Specify, w[redacted]stification , the photon that is absorbed .
2) A hydroge[redacted]n found in its fundamental state absorbs a photon of energy 14.6 eV.The electron is thus ejected.
   a. Justify t[redacted]ction of the electron.
   b. Calculat[redacted]eV, the kinetic energy of the ejected electron.

Problem 2[redacted] **Ionization energy** PHYSICS GS- 2007-1

Given: 1 eV [redacted]$\times 10^{-19}$J ; Planck's constant h = 6.62 × 10^{-34} J.s; speed of light in vacuum c = 3×10^{8} m/s.

The object o[redacted]exercise is to compare the ionization energy of the hydrogen atom with that of the helium ion H[redacted]nd that of the lithium ion Li^{2+} <u>each having only one electron in the outermost shell</u>.

The quantize[redacted]rgy levels of each is given by the expression $E_n = -\frac{E_0}{n^2}$ where E_0 is the ionization energy and n[redacted]non-zero positive whole number.

I- Interpret[redacted] of the existence of spectral lines

1) Due to [redacted]s the presence of emission spectral lines of an atom or an ion?

2) Explain [redacted]ly the term "quantized energy levels".

3) Is a tran[redacted] from an energy level m to another energy level p (p < m) a result of an absorption or an emiss[redacted]f a photon? Why?

II- Atomic sp[redacted]m of hydrogen

For the hy[redacted]n atom $E_0 = 13.6$ eV.

1) A hydrog[redacted]om, found in its ground state, interacts with a photon of energy 14 eV.

a) Why?[redacted]

b) A part[redacted]s thus liberated. Give the name of this particle and calculate its kinetic energy.

2) a) Show [redacted]he expression of the wavelengths λ of the radiations emitted by the hydrogen atom is: $\frac{1}{\lambda} = R$[redacted]$-\frac{1}{m^2})$ where m and p are two positive whole numbers so that m > p and R_1 is a positi[redacted]nstant to be determined in terms of E_o, h and c. .

b) Verif[redacted] $R_1 = 1.096\times 10^{7}$ m^{-1}.

III- Atomic s[redacted]rum of the helium ion He^{+}

The spectru[redacted]he ion He^{+} is formed, in addition to others, of two lines whose corresponding reciprocal w[redacted]ngths $\frac{1}{\lambda}$ are: 3.292 $\times 10^{7}$ m^{-1} ; 3.901 × 10^{7} m^{-1} respectively. These lines correspond, respectively,[redacted]e transitions: (m = 2 $\rightarrow$ p = 1) and (m = 3 $\rightarrow$ p = 1).

1)a) Show [redacted]he values of $\frac{1}{\lambda}$ satisfy the relation $\frac{1}{\lambda} = R_2(\frac{1}{p^2} - \frac{1}{m^2})$ where R_2 is a positive constant.

b) Deduc[redacted] $R_2 = 4.389\times 10^{7}$ m^{-1}.

2) Find a r[redacted]n between R_2 and R_1.

Problem[redacted] **Interaction radiation-matter** PHYSICS LS 2005 2

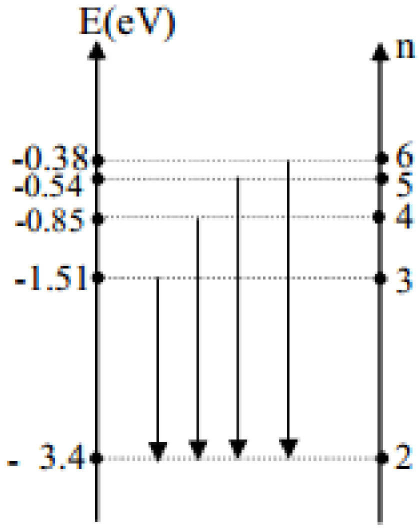
I- At the beg[redacted]g of the 1880's, Balmer identified, in the emission spectrum of hydrogen, the four visible ray[redacted]oted by H_α, H_β, H_γ and H_δ .

In 1913, B[redacted]elaborated a theory about the structure of the atom and showed that we can associate , to the hydrogen atom, energy levels given by the formula:

$E_n = -\frac{E_0}{n^2}$ where E_0 is a positive constant expressed in eV and n is a whole non-zero number .

According to Bohr, each of the rays of Balmer series is characterized by its wavelength λ in air and the corresponding downward transition :

H_α (λ_α = 658 nm ; transition from n = 3 to n = 2) ;
H_β (λ_β = 487 nm ; transition from n = 4 to n = 2) ;
H_γ (λ_γ = 435 nm ; transition from n = 5 to n = 2) ;
H_δ (λ_δ = 412 nm ; transition from n = 6 to n = 2).



The corresponding energy diagram of this series is represented in the adjacent figure.

1) Determine, using the diagram, the value of E_0 in eV.

2) **a - Emission spectrum**

i) Show , starting from the diagram, that the ray H_β corresponds to the emission of a photon of energy 2.55 eV.

ii) Verify that the value of the wavelength of the ray H_β is around 487 nm

b - Absorption spectrum

In order to obtain the absorption spectrum of the hydrogen atom, we illuminate hydrogen gas with white light What do we observe in the absorption spectrum?

3) The hydrogen atom , being in its first excited state (n = 2), collides with a photon of energy 2.26 eV. This photon is not absorbed. Why?

II-A hydrogen lamp illuminates now a photosensitive metallic surface of threshold wavelength λ_0 = 500 nm.

1) What are the visible radiations that may provoke photoelectric emission ? Why?

2) **a)** Determine the radiation that is able to extract an electron having the highest possible kinetic energy KE.

b) Calculate then KE .

III- The atomic line spectra and the phenomenon of photoelectric effect show evidence of a characteristic concerning the energy of an electromagnetic wave and the energetic exchange between matter and electromagnetic waves. Specify this characteristic.

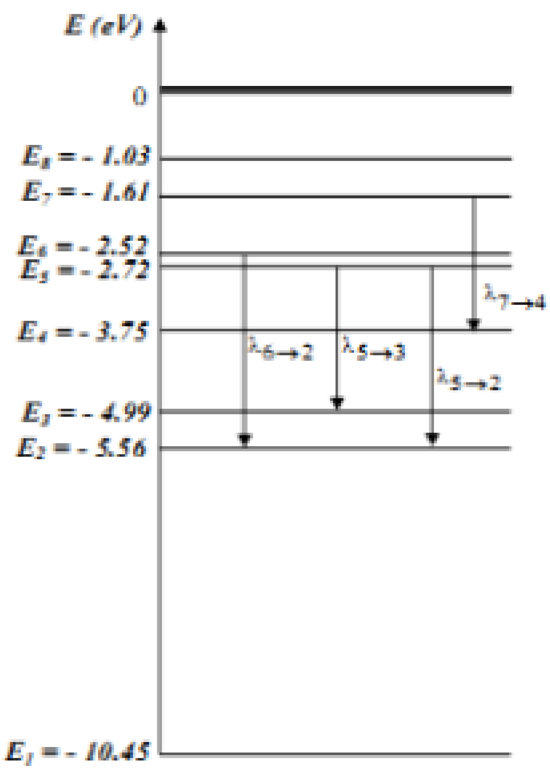
Given: - speed of light in vacuum $c = 3\times10^8$ m/s ;
- Planck's constant $h = 6.63\times10^{-34}$ J.s ;
- 1 eV = 1.6×10^{-19} J ;
- 1 nm = 10^{-9} m .

Problem 4 : *Emission spectrum of a mercury vapor lamp*

PHYSICS
LS 2006- 2

The object of this exercise is to determine the visible emission spectrum of a mercury vapor lamp.

The adjacent diagram gives, in a simplified way, the energy level of the ground state , those of the excited states E_2, E_3, E_4, E_5, E_6, E_7 , E_8 and the ionization energy level E = 0 of the mercury atom.



Given:

Planck's constant $h = 6.62\times10^{-34}$ J.s; speed of light in vacuum :
1 eV= 1.6×10^{-19}J; $c = 3\times10^8$ m /s;

I- Quantization of the energy of the atom

1) The energy of the mercury atom is quantized.
What is meant by "quantized energy"?

2) a) What is meant by « ionizing » an atom ?

b) Calculate, in eV, the ionization energy of a mercury atom taken in the ground state.

***3)* Interaction photon-atom.**

A photon cannot cause the transition of an atom from an energy level E_P to a higher energy level E_n unless its energy is exactly the same as the difference of the energies (E_n - E_P) of the atom.

The mercury atom being in the ground state.

a) Determine the maximum wavelength of the wave associated to a photon capable of exciting this atom.

b) The mercury atom is hit with a photon of wavelength $\lambda_1 = 2.062 \times 10^{-7}$ m.

i) Show that this photon cannot be absorbed.

ii) What is then the state of this atom?

c) The atom receives now a photon of wavelength λ_2. The atom is thus ionized and the extracted electron is at rest. Calculate λ_2.

II- Emission by a mercury vapor lamp

For an electron to cause a transition of an atom from an energy level E_P to a higher energy level E_n, its energy must be at least equal to the difference of the energies (E_n- E_P) of the atom.

During one electron-atom collision, the atom absorbs, from the electron, an amount of energy enough to ensure a transition. The rest of the energy is carried by the electron as kinetic energy.

When the mercury vapor lamp is under a convenient voltage, an electric discharge takes place.

Some electrons, each of kinetic energy 9 eV, moving in the vapor of mercury between the electrodes of the lamp, hit the gaseous atoms giving them energy. For that lamp, the atoms are initially in the ground state.

1) Verify that an atom may not overpass the energy level E_7.

2) The visible emission spectrum due to the downward transition of the mercury atom, is formed of four rays of wavelengths: $\lambda_{7\to4}$; $\lambda_{6\to2}$; $\lambda_{5\to2}$; $\lambda_{5\to3}$ ***(refer to the diagram).***

Determine the wavelengths of the limits of the visible spectrum of the mercury vapor lamp.

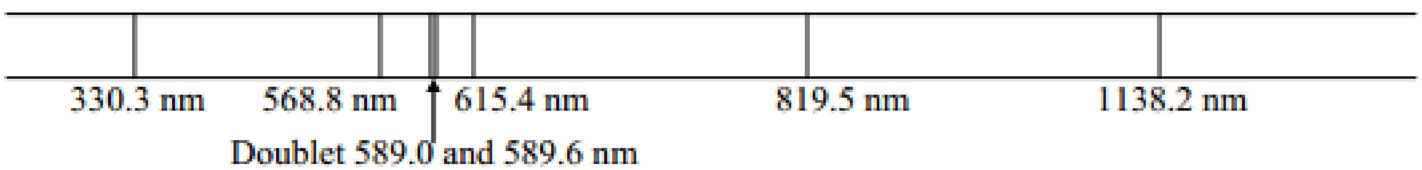
Problem 5 : Sodium vapor lamp

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

<u>**Given**</u>: $h = 6.62\times10^{-34}$ 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 below represents some of the lines of this spectrum.



a) The yellow doublet of wavelengths, in vacuum, λ_1= 589.0 nm and λ_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?

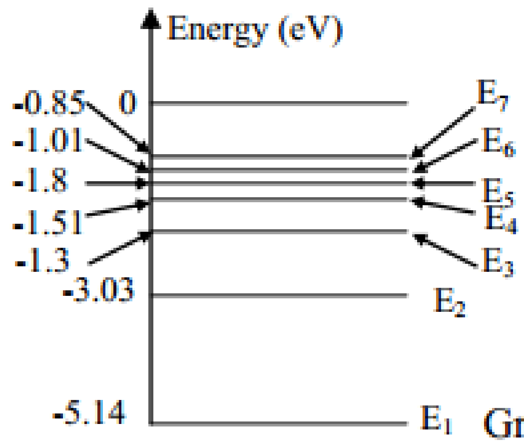
ii) The sodium vapor lamps are characterized by the emission of yellow light. Why?

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 adjacent figure:

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.

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 .

Atomic Nucleus $^A_Z X$

Const[redacted]ants (nucl[redacted]ns) ❶

Protons of positive charges.	[redacted]eutrons [redacted]d not [redacted]ve any [redacted]arge .

Mass defect ❷

Mass of nucleus < Σ (masses of nucleons)

$$\Delta m = \{ Zm_p + (A-Z)m_n \} - m_X$$

Number of nucleons ← A

Number of protons ← Z

$^A_Z X$

Isotopes ? ❸

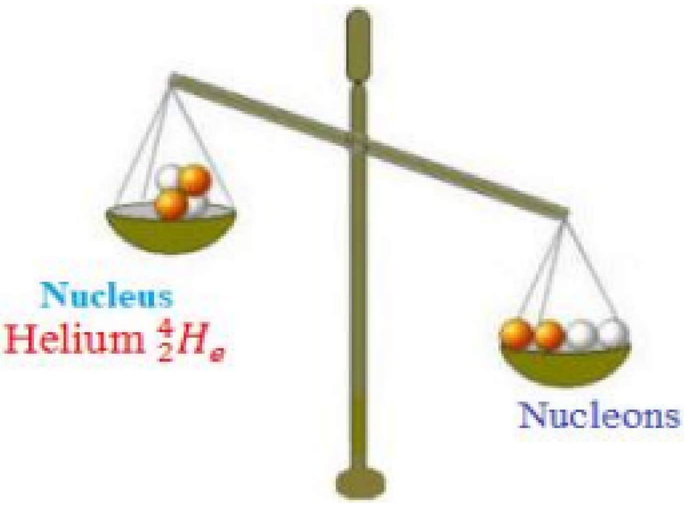
Are nuclei of the same element having the same charge number Z, but the number of nucleons A is different.

Properties

❹ Defi[redacted]ion

Bindin[redacted]nergy

This is [redacted] minim[redacted] energy neede[redacted] break up the [redacted]leus and se[redacted]te all the nu[redacted]ns



❺ Definition

Binding energy per nucleon

This is the needed energy to extract a nucleon from the nucleus of an atom.

Stability of a nucleus ❼

$$\frac{E_b}{A} \gtrapprox 8 \text{ MeV}$$

Bindi[redacted] Energy ❻

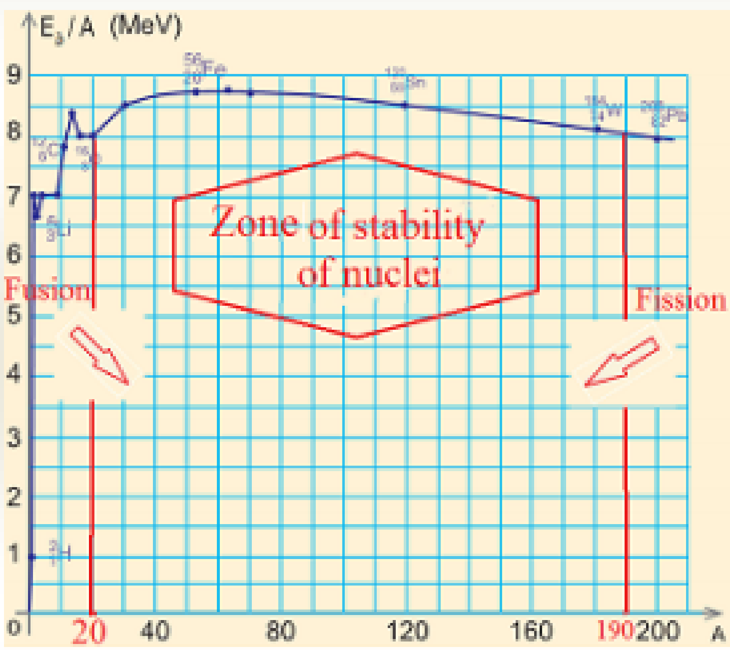
$$E_b = [redacted]n \times c^2$$

with

$$\Delta m = [redacted]m_p + (A-Z)m_n\} - m_X$$

$1u = 9$[redacted] MeV/c^2

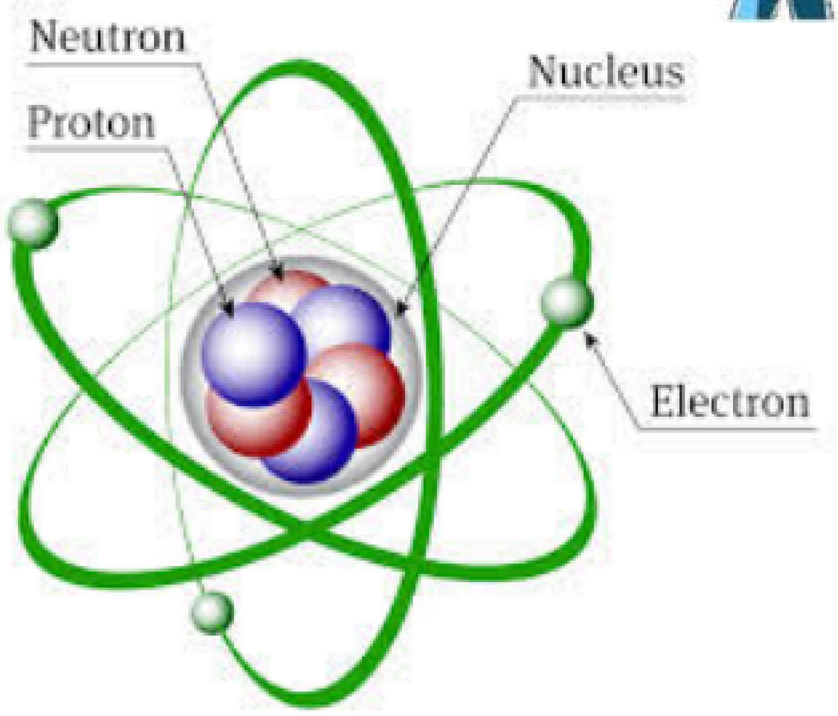
❽



Nucleus

Exercises

Chap. 18



Exercise 1 : **Studying the radionuclide $^{198}_{79}Au$**

PHYSICS
GS -2016-1

Given:

molar mass of $^{198}_{79}Au$: 198 g ;
mass of the electron: 5.50×10^{-4} u;
1 u = 931.5 MeV / c^2 = 1.66×10^{-27}kg ;
mass of the gold nucleus Au : 197.925 u ;
mass of the proton m_p = 1.00728 u ;

Avogadro's number : 6.022×10^{23} mol^{-1};
speed of light in vacuum c = 3×10^{8}m/s;
1 eV = 1.6×10^{-19}J;
mass of the mercury nucleus Hg : 197.923 u;
mass of the neutron m_n= 1.00866 u.

A- Comparison between the density of the gold nucleus and that of the gold atom

1) a) Calculate the mass of the gold atom $^{198}_{79}Au$.

b) Compare the mass of the gold atom $^{198}_{79}Au$ with that of its nucleus.

2) The average radius of the gold atom is r =16×10^{-11} m. The average radius of a nucleon is r_o = 12×10^{-16} m. Compare the density of the gold atom with that of its nucleus. Give a conclusion about the distribution of mass in the atom.

B- Stability of the gold nucleus

1. a) Give the constituents of the nucleus $^{198}_{79}Au$.

b) If the gold nucleus $^{198}_{79}Au$ is broken into its constituting nucleons, show that the sum of the masses of the nucleons taken separately at rest is greater than the mass of the nucleus taken at rest.
Due to what is this increase in the mass?

2. Knowing that a nucleus is considered stable when its binding energy per nucleon is larger or equal to 8 MeV, give a conclusion about the stability of the nucleus $^{198}_{79}Au$.

Exercise 2 : Stability of atomic nuclei

Consider the table below that shows some physical quantities associated with certain nuclei.

Nucleus	${}^{2}_{1}H$	${}^{3}_{1}H$	${}^{4}_{2}He$	${}^{14}_{6}C$	${}^{14}_{7}N$	${}^{94}_{38}Sr$	${}^{140}_{54}Xe$	${}^{235}_{92}U$
Mass (u)	2.0136	3.0155	4.0015	14.0065	14.0031	93.8945	139.892	234.9935
Binding energy E_b (MeV)	2.23	8.57	28.41	99.54	101.44	810.50	1164.75	
Binding energy per nucleon $\frac{E_b}{A}$ (MeV/nucleon)	1.11		7.10		7.25	8.62		

Numerical data:
Mass of a neutron: $m_n = 1.0087$ u ; mass of a proton : $m_p = 1.0073$ u ;
mass of an electron : $m_e = 0.00055$ u ; 1 u = 931.5 MeV /c^2.

1) ***a)*** Define the binding energy of a nucleus.

b) Write the expression of the binding energy E_b of a nucleus ${}^{A}_{Z}X$ as a function of Z, A, m_p, m_n, m_X (the mass of the nucleus ${}^{A}_{Z}X$) and the speed of light in vacuum c.

c) Calculate , in MeV, the binding energy of the uranium 235 nucleus.

d) Complete the table by calculating the missing values of $\frac{E_b}{A}$.

e) Give the name of the most stable nucleus in the above table. Justify your answer.

2) Each of the considered nuclei in the table belongs to one of the three groups given by:
A < 20 ; 20 < A < 190 ; A > 190.

Referring to the completed table, trace the shape of the curve representing the variation of $\frac{E_b}{A}$ as a function of A . Specify on the figure the three mentioned groups.

Nuclear Reactions

Spontaneous — Without any external intervention

The Radioactivity / What does this mean ? (1)

Answer: This is a spontaneous disintegration of a non-stable nucleus into another more stable nucleus .

$${}^{A}_{Z}X \dashrightarrow {}^{A1}_{Z1}Y + {}^{A-A1}_{Z-Z1}W + \dots$$

Parent Nucleus → Daughter nucleus + Particles + …

The daughter nucleus resulting from this disintegration is more stable than the parent

Types of disintegration

(2) α

Identification :

This is the helium nucleus ${}^{4}_{2}He$

$${}^{A}_{Z}X \longrightarrow {}^{A'}_{Z'}Y + {}^{4}_{2}He$$

- **This type of disintegration is the characteristic of heavy nuclei having A > 200 .**
- This particle is positively charged, the symbol of this particle is the helium ion: He^{2+}
- These particles are emitted with large speed $v \approx 2.10^{7}$ m /s.
- Their penetrating power in matter is very weak
- They can hardly penetrate a sheet of paper.

(3) β^-

Identification :

This is an electron ${}^{0}_{-1}e$.

$${}^{A}_{Z}X \longrightarrow {}^{A'}_{Z'}Y + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$$

- **This type of disintegration is the characteristic of nuclei rich in neutrons.**
- The particles β^- (betta -) are emitted with large speed $v \approx 2.7\times10^{8}$ m / s.
- They are less ionizing than α particles but 100 times more penetrating.

(4) β^+

Identification :

This is a positron ${}^{0}_{+1}e$.

$${}^{A}_{Z}X \longrightarrow {}^{A'}_{Z'}Y + {}^{0}_{1}e + {}^{0}_{0}\nu$$

- **This type of disintegration is characteristic of nuclei rich in protons.**
- The particles β^+ (betta) are emitted with large speed $v \approx 2.7\times10^{8}$ m / s.
- They are less ionizing than α particles but 100 times more penetrating.

Proprietes

(5) Radiations γ

- It's an electromagnetic wave.
- It's emitted by the daughter nucleus
- It has no mass and no charge.

Neutrino ${}^{0}_{0}\nu$ (6)

- Particle accompanied with the emission of β^- . **(no charge)**

$${}^{1}_{0}n \longrightarrow {}^{0}_{1}p + {}^{0}_{-1}e .$$

Antineutrino ${}^{0}_{0}\bar{\nu}$ (7)

- Particle accompanied with the emission of β^+ **(no charge)**

$${}^{1}_{1}p \longrightarrow {}^{0}_{1}e + {}^{1}_{0}n + {}^{0}_{0}\nu .$$

Soddy's laws (8)

conservation of mass number

$$\sum A^{Before} = \sum A^{After}$$

conservation of atomic number

$$\sum Z^{Before} = \sum Z^{After}$$

Liberated energy (9)

$$E_l = \Delta mc^2$$

with $\Delta m = m^{bef} - m^{af}$ mass deffect.

Conservation of enrgy $E^{before}_{total} = E^{after}_{total}$

$$\sum(mc^2 + Ec)^{before} = \sum(m'c^2 + E'c)^{After} + E_\gamma$$ (10)

Num[redacted]er of nuclei in a sample

Consider a [redacted]le containing a certain mass m of a radioactive element ^A_ZX at an instant t.

We can fin[redacted] number of nuclei in this sample using the relation: $N=\frac{m}{M}N_A$ (11)
with : M ([redacted]ar mass) and N_A (Avogadro's number).
We can als[redacted] this formula : $N=\frac{m}{m_X}$ (12)
with : m_X : [redacted]s of nuclei .

Question [redacted] sample of radioactive Bismuth $^{212}_{83}Bi$, has a mass m=50mg .
given: the m[redacted] mass of $^{212}_{83}B_i$ is 212g and Avogadro's number is N_A=6.022×[redacted]mole^{-1}.
Calculate th[redacted]mber of nuclei of $^{212}_{83}Bi$ in this sample.

Answer: Th[redacted]mber of nuclei in the sample is: $N=\frac{m}{M}N_A = \frac{0,05}{212}6.022\times10^{23} = 1.42\times10^{20}$ nuclei.

Radi[redacted]ctivity half -life (Period) (13)

Definition : [redacted]t is the half-life T of a radioactive sample?
The half life [redacted]od) T of a radioactive substance, is the duration in which the activity is reduced by one half.

The half life [redacted]od) $t_{1/2}$ is a characteristic of each nucleus.

$$N_0 \xrightarrow{T} \frac{N_0}{2} \xrightarrow{T} \frac{N_0}{4} \xrightarrow{nT} \ldots\ldots \to N = \frac{N_0}{2^n}$$

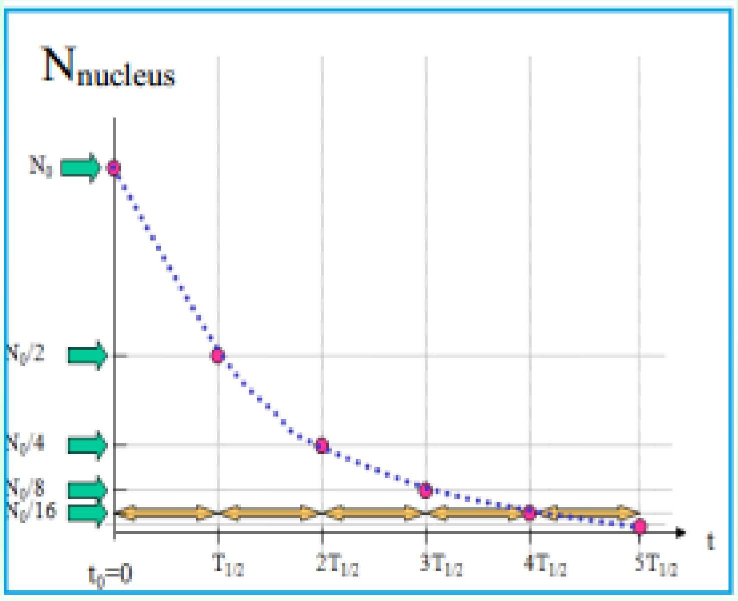
Remaining nuclei after t = nT
Disintegrated nuclei : $N - N_0$

$t_{1/2} = T \Rightarrow N=\frac{N_0}{2}$

The period d[redacted]ls only on the radioactive constant λ . then we obtain : $\lambda = \frac{ln2}{T}$ $T=\frac{ln2}{\lambda}$

Law[redacted]decay : (14)

$N = N_0$[redacted] with $\lambda=\frac{ln2}{T}$



Activity[redacted] a sample (15)

The acti[redacted]A of a radioactive substance is the numb[redacted]f disintegrations per unit of time.
A : is exp[redacted]ed in Becquerel's (Bq) ;
1 Bq = 1[redacted] sec.

$A = \lambda N$ at an instant t.

$A=-\frac{dN}{dt}$ [redacted] The – sign is obtained since dN < 0 to obtain A > 0 ; then $A = A_0e^{-\lambda t}$ (17)

Radioactivity

Exercises

Chap. 19

Exercise 1 : **Formation of carbon 14**

In the high atmosphere the carbon isotope $^{14}_{7}N$ is obtained by the impact of a nitrogen $^{14}_{6}C$ with a neutron.

1. The nuclides $^{12}_{6}C$ and $^{14}_{6}C$ are two isotopes. Why?
2. Write the equation of the formation of $^{14}_{6}C$.
3. Identify the emitted particle.

Exercise 2 : **Studying the disintegration of the gold nucleus $^{198}_{79}Au$**

When the gold nucleus $^{198}_{79}Au$, at rest, disintegrates it gives a daughter nucleus (mercury nucleus $^{A}_{Z}Hg$) of negligible speed. We were able to detect the emission of a γ photon of energy 0.412 MeV and a β^- particle of kinetic energy 0.824 MeV.

1. Write the equation of this disintegration reaction and, specifying the laws used ,determine *A* and *Z*.

2. a) Specify the physical nature of the γ radiation.

b) Due to what is the emission of this γ radiation ?

3. a) Show , by applying the law of conservation of total energy, the existence of a new particle accompanying the emission of β^-.

b) Give the name of this particle.

c) Deduce its energy in MeV.

Exercise 3 : **The radio-isotope polonium $^{210}_{84}Po$**

Given: $1u = 1.66 \times 10^{-27}$ kg $= 931.5$ MeV/c^2 ; 1 MeV $= 1.6\times10^{-13}$ J ;

Mass of some nuclei : m(Po) = 209.9829 u ; m(Pb) = 205.9745 u ; m(α) = 4.0026 u ;

In general, the decay of $^{210}_{84}Po$ is accompanied by the emission of γ radiation.

a) Due to what is the emission of γ radiation?

b) The emitted γ radiation has the wavelength $\lambda = 1.35\times10^{-12}$ m in vacuum.

c) Using the conservation of total energy, determine the kinetic energy of the emitted α particle.

Exercise 4 : **Decay of polonium 210**

The polonium $^{210}_{84}Po$ is an α emitter. The daughter nucleus produced by this decay is the lead $^{206}_{82}Pb$.

Given : 1 MeV $= 1.6\times10^{-13}$ J ;

The liberated energy by this decay is E = 5,4Mev , and the the nucleus $^{210}_{84}Po$ is initially at rest.

We suppose that the daughter nucleus $^{206}_{82}Pb$ is obtained at rest and in the fundamental state.

Deduce the kinetic energy of the emitted α particle

Exercise 5 : The radionuclide Potassium 40

The isotope of potassium $^{40}_{19}K$, is radioactive and is β^+ emitter; it decays to give the daughter nucleus argon $^{40}_{18}Ar$.

The object of this exercise is to study the decay of potassium 40.

a) Write down the equation of the decay of one potassium 40 nucleus and determine Z and A.

b) The value of E, liberated energy by the decay , is 0,47Mev ; and the daughter nucleus is supposed to be at rest . The energy carried by β^+ is, in general, smaller than E . Why?

Exercise 6 : Radioactivity of Cobalt

Cobalt $^{60}_{27}Co$ is a β^- radioactive. The daughter nucleus $^{A}_{Z}Ni$ undergoes a downward transition to the ground state. The energy due to this downward transition is $E(\gamma) = 2.5060$ MeV.

The β^- particle is emitted with a kinetic energy $K.E(\beta^-) = 0.0010$ MeV.

Numerical data: mass of the $^{60}_{27}Co$ nucleus: 59.91901 u ; mass of the $^{A}_{Z}Ni$ nucleus : 59.91544 u ;
mass of an electron : 5.486×10^{-4} u ; 1 u = 931.5 MeV/c^2 ; 1 MeV = 1.6×10^{-13} J .

1) Determine A and Z.
2) Calculate, in u, the mass defect Δm during this disintegration.
3) Deduce, in MeV, the energy E liberated by this disintegration.
4) During this disintegration, the daughter nucleus is practically obtained at rest.
In what form of energy does E appear?

Exercise 7 : Detection of a new paticle

When the gold nucleus $^{198}_{79}Au$, at rest, disintegrates it gives a daughter nucleus (mercury nucleus $_{80}Hg$) of negligible speed. We were able to detect the emission of a γ photon of energy 0.412 MeV and a β^- particle of kinetic energy 0.824 MeV.

a) When the liberated energy by the decay is 1,351Mev , show applying the the law of conservation of total energy, the existence of a new particle accompanying the emission of β^-.

b) Give the name of this particle.

c) Deduce its energy in MeV.

Exercise 8 : Detection of a new paticle

Cobalt $^{60}_{27}Co$ is a β^- radioactive. The daughter nucleus $^{A}_{Z}Ni$ undergoes a downward transition to the ground state. The energy due to this downward transition is $E(\gamma) = 2.5060$ MeV.

The β^- particle is emitted with a kinetic energy $K.E(\beta^-) = 0.0010$ MeV.

a- Deduce, from what preceded , that the electron, emitted by the considered disintegration, is accompanied by a certain particle. We have E = 2,8144Mev ,the liberated energy by the decay.
b- Give the name of this particle.
c- Give the charge number and the mass number of this particle.
d- Deduce in MeV, the energy of this particle.
e- Write down the global equation of this disintegration.

Exercise 9 : The use of Cobalt

In medicine, we use a source of radioactive cobalt $^{60}_{27}Co$ of activity A = 6×10^{19} Bq.

The emitted β^- particles are absorbed by the living organism.
1) The energy of the particle mentioned in the question (d) is not absorbed by the living organism. Why?
2) Calculate, in watt, the power transferred to the organism.
3) This large power is used in radiotherapy .What is its effect?

Problems

Visit website physprolb.com

Problem [redacted]

Energy liberated by the disintegration of thecobalt

PHYSICS
LS 2001 - 1

${}^{A}_{Z}X$	${}^{60}_{27}Co$	${}^{60}_{28}Ni$	${}^{0}_{-1}e$
Masse (en u)	59,9190	59,9154	0,00055

- 1 u = 931,[redacted]V/c^2. - Speed of light in vacuum: c = 3 x 10^8 ms^{-1}
- Planck's c[redacted]nt: h = 6.63 x 10^{-34} J.s - Avogadro's constant: 6.02 x 10^{23} mol^{-1}.
- Molar ma[redacted] cobalt: 60 $g.mol^{-1}$.

1) Determi[redacted] remaining number of ${}^{60}_{27}Co$ nuclei and the activity of this sample at the end of 10.6 years.

2) One of th[redacted]integrations of ${}^{60}_{27}Co$ gives rise to the nickel isotope ${}^{60}_{28}Ni$.

a) Write, [redacted]justification, the equation of the disintegration of one cobalt nucleus ${}^{60}_{27}Co$

Identify[redacted]mitted particle.

b) Calcula[redacted]MeV, the energy liberated by this disintegration.

c) Determi[redacted]e energy liberated by the disintegration of 1 g of cobalt ${}^{60}_{27}Co$.

d) Knowing[redacted]the energy liberated from the complete combustion of 1 g of coal is 30 kJ, find the mass o[redacted] that would liberate the same amount of energy calculated in part c).

Problem [redacted]

Radioactivity

PHYSICS
GS 2002 - 1

Given the ma[redacted]of the nuclei: m(${}^{131}_{53}I$) = 130. 87697 u; m(${}^{A}_{Z}Xe$) = 130.87538 u;
mass of an el[redacted]n = 5,5 x 10^{-4} u;
1 u = 931.5 [redacted]/c^2; 1 MeV = 1.6 x 10^{-13} J; h = 6,63 x 10^{-34} J.s et c = 3x10^8m/s

In order to d[redacted] a trouble in the functioning of the thyroid, we inject it with a sample of an iodine radionuclide[redacted]This radionuclide has a period (half-life) of 8 days and it is a β^- emitter. The disintegration of the nuclide[redacted] gives rise to a daughter nucleus ${}^{A}_{Z}Xe$ supposed at rest.

1) a) The dis[redacted]ration of a nucleus of ${}^{131}_{53}I$ is accompanied by the emission of a γ radiation. Due to what i[redacted] emission?

b) Write t[redacted]uation of the disintegration of ${}^{131}_{53}I$ nucleus.

c) Calculate[redacted]ecay constant of the radionuclide. Deduce the number of the nuclei of the sample at the instant of[redacted]tion, knowing that the activity of the sample, at that instant, is 1.5 x 10^5 Bq.

d) Calculate[redacted]umber of the disintegrated nuclei at the end of 24 days.

2) a) Calculate[redacted]nergy liberated by the disintegration of one nucleus of ${}^{131}_{53}I$.

b) Calculat[redacted]energy of a γ photon knowing that the associated wavelength is 3.55 x 10^{-12}m.

c) The ene[redacted]f an antineutrino being 0.07 MeV, calculate the average kinetic energy of an emitted electron.

d) During [redacted]isintegration of the ${}^{131}_{53}I$ nuclei, the thyroid, of mass 40 g, absorbs only the average kinetic energy o[redacted]emitted electrons and that of γ photons. Knowing that the dose absorbed by a body is the energy a[redacted]bed by a unit mass of this body, calculate, in J/Kg, the absorbed dose by that thyroid during 2[redacted]s.

Problem 3: **Radioactivity of polonium 210** PHYSICS GS 2003 - 1

In order to study the radioactivity of polonium $^{210}_{84}Po$ which is an α emitter, we take a sample of polonium 210 containing N_o nuclei at the instant $t_o = 0$.

A- Determination of the half-life (period)

We measure, at successive instants, the number N of the remaining nuclei. We calculate the ratio N/N_o and the result is tabulated as in the following table:

t (in days)	0	50	100	150	200	250	300
N / N_o	1	0.78	0.61	0.47	0.37	0.29	0.22
$-\ln (N / N_o)$	0	0.25				1.24	

1- Draw again the above table and complete it by calculating at each instant $-\ln (N/N_o)$.

2- Trace the curve representing the variation of $f(t) = -\ln (N/N_o)$, as a function of time, using the scale: 1 cm on the abscissa represents 25 days; 1 cm on the ordinate represents 0.1.

3- a- Knowing that $Ln(N/N_o) = -\lambda t$, determine graphically the value of the radioactive constant λ of polonium 210.

b- Deduce the half-life of polonium 210.

B- Activity of polonium 210

1- Define the activity of a radioactive sample.

2- Give the expression of the activity A_o of the sample at the instant $t_o = 0$, in terms of λ and N_o. Calculate its value for $N_o = 5 \times 10^{18}$.

3- Give the expression, in terms of t, of the activity A of the sample.

4- Calculate the activity A:

a- at the instant t = 90 days.

b- When t increases indefinitely.

C- Energy liberated by the disintegration of polonium 210

1- The disintegration of a nucleus of polonium produces a daughter nucleus which is an isotope of lead $^{A}_{Z}Pb$. Determine A and Z.

2- Calculate, in MeV, the energy liberated by the disintegration of one nucleus of polonium 210.

3- The disintegration of a polonium nucleus may take place with or without the emission of a photon. The energy of an emitted photon is 2.20 MeV. Knowing that the daughter nucleus has a negligible velocity, determine in each case the kinetic energy of the emitted α particle.

4- The sample is put in an aluminum container. Thus, the α particles are stopped by the container whereas the photons are not.

Knowing that half of the disintegrations are accompanied by a γ emission, determine the power transferred to the aluminum container at the instant t = 90 days.

Numerical data:

Mass of a polonium 210 nucleus: 209.9828 u   Mass of lead (Pb) nucleus: 205.9745 u

Mass of an α particle: 4.0015 u $1\ u = 1.66 \times 10^{-27}\ kg = 931.5\ MeV/c^2$.

Problem 4 : **The carbon 14** PHYSICS LS 2005-1

The object of this exercice is to show evidence of some characteristic properties of the radio element $^{14}_{6}C$ and to show the preocedure followed to know the age of a wooden fossil.

__Given :__

mass of a proton : $m_p = 1{,}00728$ u ;   mass of a neutron : $m_n = 1{,}00866$ u ;

mass of a nucleus $^{14}_{6}C = 14{,}0065$ u ;   mass of a nucleus $^{14}_{7}N = 14{,}0031$ u ;

Avogadro's number : $\mathcal{N} = 6{,}02 \times 10^{23}\ mol^{-1}$.   Molar mass of $^{14}_{6}C = 14\ g \times mol^{-1}$;

A - Formation of carbon 14

In the high atmosphere the carbon isotope $^{14}_{7}N$ is obtained by the impact of a nitrogen $^{14}_{6}C$ with a neutron.

1. The nuclides $^{12}_{6}C$ and $^{14}_{6}C$ are two isotopes. Why?
2. Write the equation of the formation of $^{14}_{6}C$.
3. Identify the emitted particle.

B – Disintegration of carbon 14

Carbon14 is radioactive β^- emitter. It disintegrates to give nitrogen $^{14}_{7}N$.

1. The emission of a β^- particle is due to the disintegration of a nucleon inside the nucleus.
2. Calculate the binding energy per nucleon of each of the nuclei $^{14}_{6}C$ and $^{14}_{7}N$.

3. In fact, a radioactive decay leads to a more stable state. Justify this statement taking into account the preceding results.

4. The activity of a substance containing carbon 14 is determined using a counter of β^- particles. A sample of wood containing 0.05g of carbon 14 of radioactive period T = 5570 years is exposed to the counter.
   Determine:
   a) The radioactive constant λ of carbon 14.
   b) The number of carbon 14 nucle contained in this sample at the instant of exposure.
   c) The activity of the sample at the considered instant.

C- Age of a wood fossil

We intend to determine the age of a piece of wood fossil. We expose this piece to the counter of β^- particles; it indicates 100 disintegration in 5 minutes. Knowing that a piece of the same wood, freshly cut, gives 1000 disintegrations in 5 minutes, determine the age of the wood fossil.

Problem 5: The technetium 99

PHYSICS
GS 2005-2

A - A bit of history...

In 1937, Pierrier and Sêgre obtained, for the first time, an isotope of technetium $^{99}_{43}Tc$ by bombarding the nuclei of molybdenum $^{98}_{42}Mo$ with an isotope of hydrogen $^{A}_{Z}H$ according to the following reaction :

$$^{98}_{42}Mo + {}^{A}_{Z}H \longrightarrow {}^{99}_{43}Tc + {}^{1}_{0}n$$

Determine Z and A specifying the laws used.

B- Production of technetium 99 at the present time and its characteristic

The isotope $^{99}_{43}Tc$ is actually obtained in a generator molybdenum/technetium, starting from the isotope $^{99}_{42}Mo$ of molybdenum. This molubdenum is a β^- emitter.

1) Write the equation corresponding to the decay of $^{99}_{42}Mo$.
2) Determine, in MeV, the energy liberated by this decay.
3) Most of the technetium nuclei obtained are in an exited state [$^{99}_{43}Tc^*$]

a- i) Complete the equation of the following downward transition: $^{99}_{43}Tc^* \longrightarrow {}^{99}_{43}Tc + \ldots\ldots$

ii) Specify the nature of the emitted radiation.

b- The energy liberated by this transition, of value 0.14 MeV, is totally carried by the emitted radiation; the nuclei [$^{99}_{43}Tc^*$] and $^{99}_{43}Tc$ are supposed to be at rest.

i) Determine, in u, the mass of the $^{99}_{43}Tc^*$ nucleus.

ii) Calculate the wavelength of the emitted radiation.

C- Using technetium 99 in medicine

The isotope $^{99}_{43}Tc$ is actually often used in medical imaging. The generator molybdenum/technetium is known, in medicine, by the name “ technetium cow”. Also, the daily preparation of the medically needed technetium 99, of half-life T_1 = 6 hours, starting from its “parent” the molybdenum of half-life T_2 = 67 hours, allows a weekly supply.

1) Why is it preferable, in medical service that requires the use of technetium 99, to keep a reserve of molybdenum 99 and not a reserve of technetium 99 ?
2) Determine the number of technetium 99 nuclei obtained from a mass of 1g of molybdenum 99 at the end of 24 hours. Deduce the mass of these technetium nuclei.

Given : Masses of nuclei and particles: $^{99}_{42}Mo = 98{,}88437$ u; $^{99}_{43}Tc = 98{,}88235$ u; $^{0}_{-1}e = 55\times10^{-5}u$.
1u [redacted]1,5 MeV/c² $= 1{,}66 \times10^{-27}$ kg ;
Pl[redacted]'s constant: h = $6{,}63 \times10^{-34}$ J.s ; 1eV = $1{,}6\ 10^{-19}$ J ; c = 3×10^{8} m/s .

Problem 6[redacted] Radioactivity

PHYSICS
GS-2006-2

The object of t[redacted]xercise is to show evidence of some characteristics of a thorium nucleus 230 and its role in dating.

Given : spee[redacted]ght in vacuum : $c = 3 \times 10^{8}$ ms^{-1}; 1eV = $1{,}6\times 10^{-19}$ J;
Av[redacted]o's number : $N = 6{,}02\times10^{23}$ mol^{-1};
Pla[redacted] cpnstant :h = $6{,}63\times10^{-34}$ J.s; 1u = 931,5 MeV/c^2 ;
ma[redacted]f the nuclei : $m\left(^{A}_{88}Ra\right) = 225{,}9770$ u; $m\left(^{230}_{Z}Th\right) = 229{,}9836$ u; $m(\alpha) = 4{,}0015$u.

A- Decay of [redacted]rium nucleus 230

The thor[redacted]nucleus ($^{230}_{Z}Th$) is radioactive and is an α emitter . The daughter nucleus is the isotope of the radi[redacted]Ra) .

1- **a)** Wri[redacted] equation of this decay and determine the values of A and Z.
b) Det[redacted]he the energy liberated by the decay of a thorium nucleus 230.

2- A decay[redacted]thorium nucleus 230 at rest, ttakes place without the emission of γ radiation. The daughte[redacted]eus ($^{230}{}_{z}$th) obtained has a speed almost zero. Determine the value of the kinetic energy K.E$_1$ of [redacted]mmitted α particle.

3- Another[redacted]y of a thorium nucleus 230 is accompanied with the emission of a γ radiation of wavelen[redacted]$\times 1^{0\text{-}12}$ m in vacuum.
a) Ca[redacted]e the energy of this radiation.
b) De[redacted] the value of the kinetic energy K.E$_2$ of the emitted α particle.

4- A sample [redacted] of thorium nucleus 230of activity A$_0$= $7{,}2\times10^{8}$ decays/s is placed near a sheet of aluminum at[redacted]nstant $t_0 = 0$. The α particles are stopped by the aluminum sheet whereas the photons are not absor[redacted]

a) Determi[redacted] J, the energy W transfered to the aluminum sheet during the first second knowing that 50%[redacted]he decays are accompanied with γ emission, and that the activity A$_o$ remains practical[redacted]nstant within this second.
b) Calcula[redacted] number of nuclei present in 1g of thorium 230. Deduce, in year^{-1}, the value of the radioac[redacted]onstant λ of thorium 230.

Problem 7[redacted] Measurement of the age of Earth

PHYSICS
LS-2006-1

One of the qu[redacted]ns that preoccupied man long ago since he started to explore the universe was the age [redacted]th. As from 1905, Rutherford proposed a measurement of the age of minerals thro[redacted]adioactivity.
In 1956, Clai[redacted]rson used the method (uranium - lead) to measure the age of a meteorite assuming tha[redacted]iginates from a planet that is formed approximately at the same time as that of Earth.

I – A radioac[redacted]family of uranium $^{238}_{92}U$

Uranium 238[redacted]adioactive period T= 4.5×10^{9} y (year) is at the origin of a radioactive family leading finally[redacted]he stable lead isotope $^{206}_{82}Pb$.

Each of these[redacted]cessive disintegrations is accompanied with the emission of an α particle or a β$^-$ particl[redacted]
The diagram [redacted]) gives all the radioactive nuclei originating from the uranium $^{238}_{92}U$ leading to the stable [redacted]pe $^{206}_{82}Pb$. (**page 4**)

The tables (**page 4**) give the radioactive period of each nuclide.

1) In the first disintegration, a uranium nucleus $^{238}_{92}U$ gives thorium nucleus $^{234}_{90}Th$ and a particle denoted by $^{A_1}_{Z_1}X$.

a) Write the equation of this disintegration and calculate the values of A_1 and Z_1.

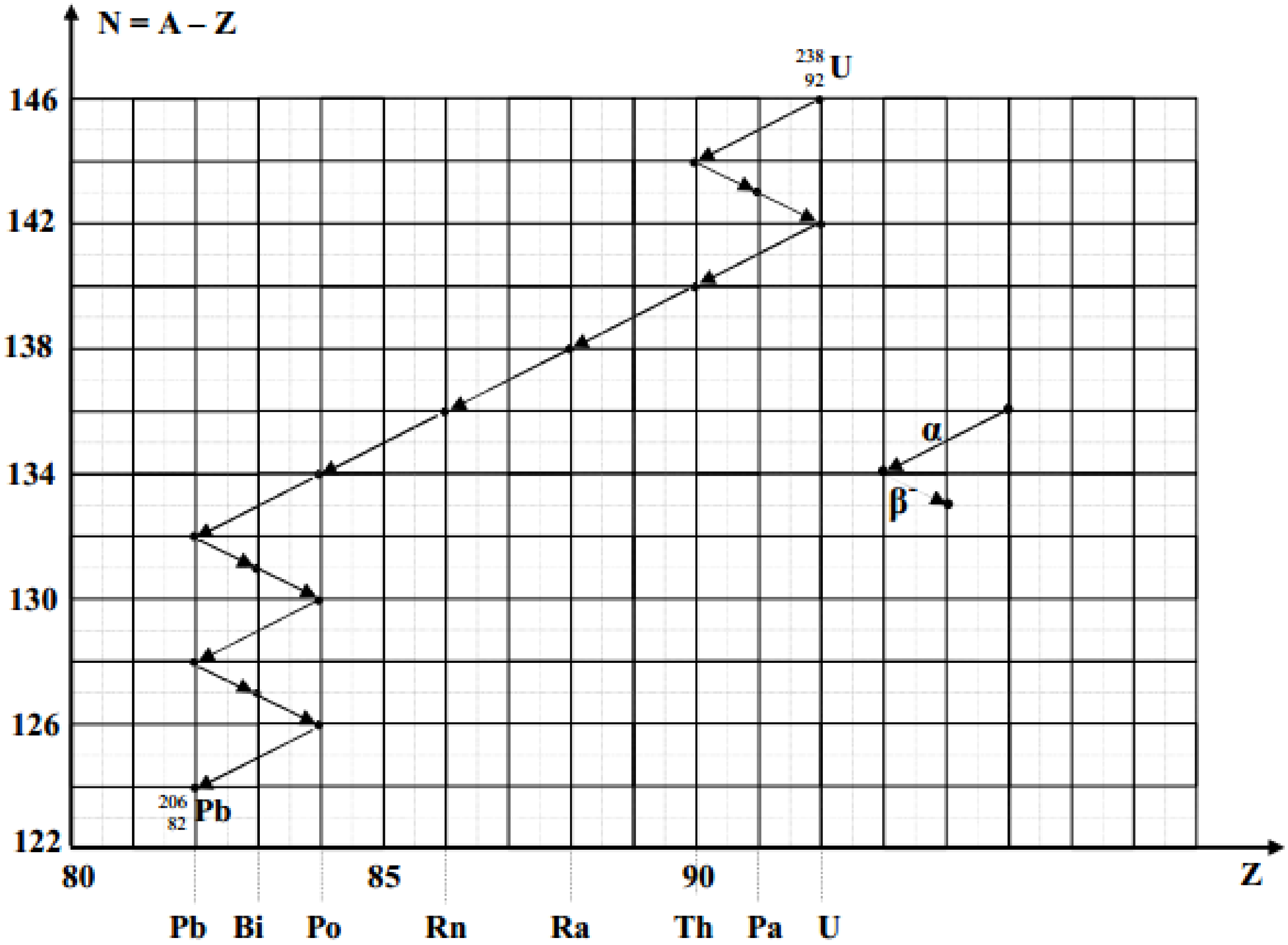
b) Specify the type of radioactivity corresponding to this transformation.

2) In the second disintegration, the thorium nucleus $^{234}_{90}Th$ undergoes a β^- decay. The daughter nucleus is the protactinium $^{A_2}_{Z_2}Pa$. Calculate A_2 and Z_2.

3) a) Referring to the diagram, tell how many α particles and how many β^- particles are emitted when the uranium nucleus $^{238}_{92}U$ is transformed into lead nucleus $^{206}_{82}Pb$.

b) Write the overall nuclear equation of the decay of uranium 238 into lead 206.

4) Using the diagram (Z,N) of the figure and the tables, tell why after few billions of years we can neglect the presence of the intermediary nuclei among the products of the disintegration uranium-lead.



Nucleus	$^{238}_{92}U$	$^{234}_{90}Th$	$^{234}_{91}Pa$	$^{234}_{92}U$	$^{230}_{90}Th$	$^{226}_{88}Ra$	$^{222}_{86}Rn$
Radioactive period	4.5×10^9 y	24 d	6.7 h	2.5×10^5 y	7.5×10^3 y	1.6×10^3 y	3.8 d

Nucleus	$^{218}_{84}Po$	$^{214}_{82}Pb$	$^{214}_{83}Bi$	$^{214}_{84}Po$	$^{210}_{82}Pb$	$^{210}_{83}Bi$	$^{210}_{84}Po$
Radioactive period	3.1 min	27 min	20 min	1.6×10^{-4}s	22 y	5d	138 d

II- The age of Earth

We have studied a sample of a meteorite whose age is equal to that of Earth. At the instant t, the sample studied contains 1g of uranium 238 and 0.88g of lead 206.
We suppose that at the instant of its formation $t_0 = 0$, the meteorite does not contain any atom of lead.

Numerical data: molar mass of uranium: 238 g/mol; molar mass of lead: 206 g/mol; Avogadro's number: $N_A = 6.02 \times 10^{23}$ /mol.

1) Calculate, at the instant t :

a) the number of uranium 238 nuclei, denoted by $N_U(t)$, present now in the sample;
b) the number of lead 206 nuclei, denoted by $N_{Pb}(t)$, present now in the sample.

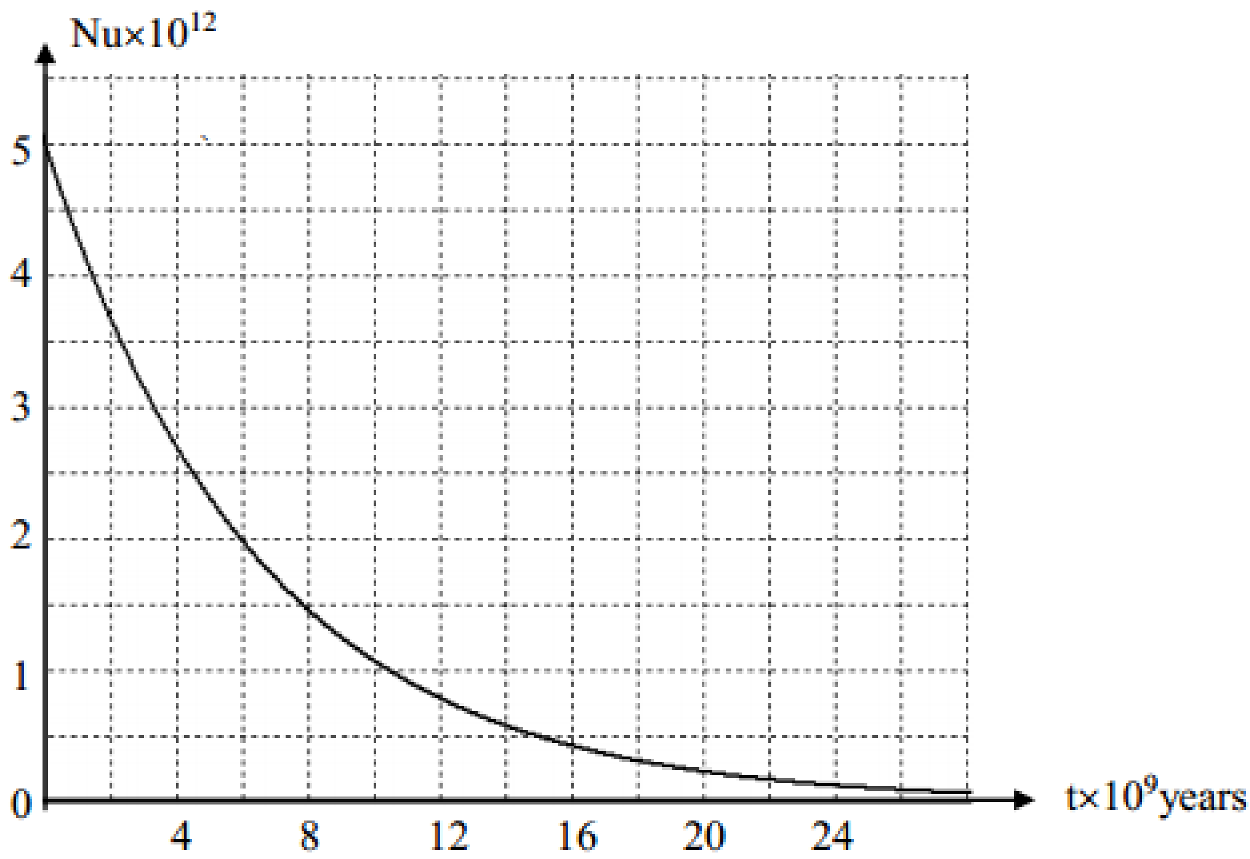
2) Deduce the number of uranium 238 nuclei $N_U(0)$, present in the sample at the instant $t_0 = 0$.

3) Give the expression of $N_U(t)$ as a function of $N_U(0)$, t, and T.

4) Deduce the age of Earth at the instant t.

Problem 8: **Determination of the age of the Earth** **PHYSICS** **LS-2008-1**

The object of this exercise is to determine the age of the Earth using the disintegration of a uranium 238 nucleus $\left({}^{238}_{92}U\right)$ into a lead 206 nucleus $\left({}^{206}_{82}\text{Pb}\right)$.



When we determine the number of lead 206 nuclei in a sample taken out from a rock that did not contain lead when it was formed, we can then determine its age that is the same as that of the Earth. The above figure represents the curve of the variation of the number N_u of uranium 238 nuclei as a function of time.

1 division on the axis of ordinates corresponds to 10^{12} nuclei.
1 division on the axis of abscissa corresponds to 10^9 years.

The equation of the disintegration of Uranium 238 into lead 206 is:

$$ {}^{238}_{92}\text{U} \rightarrow {}^{206}_{82}\text{Pb} + x\beta^- + y\alpha $$

1 .Determine, specifying the laws used, the values of x and y.
2. Referring to the curve, indicate the number N_{0u} of uranium 238 nuclei existing in the sample at the date of its birth $t_o = 0$.
3. Referring to the curve , determine the period (half-life) of uranium 238.Deduce the value of the radioactive constant λ of uranium 238.

4. ***a)*** Give, in terms of N_{0u}, λ and t, the expression of the number N_u of uranium 238 nuclei remain[redacted] the sample at instant t.

b) Calcul[redacted]he number of uranium 238 nuclei remaining in the sample at instant $t_1 = 2 \times$ [redacted]ears:

c) Verify[redacted]result graphically:

5. The numb[redacted]lead 206 nuclei existing in the sample at the instant of measurement (age of the Earth) is [redacted] 2.5×10^{12} nuclei.

a) Give th[redacted]tion among N_u, N_{0u} and N_{pb}.

b) Calcula[redacted] number N_u of uranium nuclei remaining in the sample at the date of measurement.

c) Determ[redacted]e age of the Earth.

Problem 9[redacted] The radionuclide Potassium 40

PHYSICS
GS-2008-2

The isotope[redacted]tassium $^{40}_{19}K$, is radioactive and is β^+ emitter; it decays to give the daughter nucleus argon $^{A}_{Z}Ar$. [redacted]bject of this exercise is to study the decay of potassium 40.

masses of n[redacted] m ($^{40}_{19}K$) = 39.95355 u ; m($^{A}_{Z}Ar$) = 39.95250 u ;

masses of pa[redacted]s: m ($^{0}_{1}e$) = 5.5×10^{-4} u; m (neutrino) ≈ 0 ;

Avogadro's [redacted]er: N = 6.02×10^{23} mol^{-1}; 1 u = 931.5 MeV/c^2 ;

Radioactive [redacted]d of $^{40}_{19}K$: T = 1.5×10^9 years; molar mass of $^{40}_{19}K$ = 40 g mol^{-1}.   1 MeV = 1.6×10^{-13} J.

A – Energet[redacted]dy of the decay of potassium 40

1) **Energ[redacted]erated by one decay**

   a) [redacted]e down the equation of the decay of one potassium 40 nucleus and determine Z and A.

   b) [redacted]ulate, in MeV, the energy E_1 liberated by this decay.

   c) [redacted]daughter nucleus is supposed to be at rest. The energy carried by β^+ is, in general, smaller [redacted] E_1. Why?

2) **Energ[redacted]eived by a person**

   The ma[redacted]f potassium 40 at an instant t, in the body of an adult is, on the average, equal to 2.6[redacted]% of its mass.

   An adul[redacted]on has a mass M = 80 kg.

   a) i) C[redacted]te the mass m of potassium 40 contained in the body of that person at the instant t.

   ii) D[redacted] the number of potassium 40 nuclei in the mass m at the instant t.

   b) i) C[redacted]te the radioactive constant λ of potassium 40.

   ii) D[redacted]e the value of the activity A of the mass m at the instant t.

   c) Dedu[redacted] J, the energy E liberated by the mass m per second.

B – Dating [redacted]tassium 40

Certain volc[redacted]ocks contain potassium and part of it, is potassium 40. At the instant of its formation ($t_0 = 0$), the [redacted]er of nuclei of potassium 40 is N_0 in the volcanic rock and that of argon is zero. At the instant t, the [redacted] contains respectively N_K and N_{Ar} nuclei of potassium 40 and of argon 40.

1) **a)** Writ[redacted]n the expression of N_K , that explains the law of radioactive decay, as a function of ti[redacted]

   b) Dedu[redacted]e expression of N_{Ar} as a function of time.

2) A geolo[redacted]analyzes a volcanic rock. He notices that the number of argon 40 nuclei is twice less than the num[redacted]of potassium 40 nuclei in this rock. Determine the age of this rock.

Problem 1[redacted] Determination of the half-life of Polonium 210

PHYSICS
GS-2009-2

Polonium 210 [redacted]eus ($^{210}_{84}Po$) is an α emitter, and it is the only polonium isotope that exists in nature; it was found by [redacted] Curie in 1898 in an ore. It is also obtained from the decay of a bismuth 210 nucleus ($^{210}_{83}Bi$). Mass[redacted] the nuclei: m (Bi) = 209.938445 u ; m(Po) = 209.936648 u

mass of the electron : m_e = 0.00055 u

$1\ u = 931.5\ MeV / c^2 = 1.66 \quad 10^{-27}$ kg.

Here is a part of the periodic table of elements: ${}_{81}Th$; ${}_{82}Pb$; ${}_{83}Bi$; ${}_{84}Po$; ${}_{85}At$; ${}_{86}Rn$.

A –The polonium 210

1) **a)** Write down the equation of the decay of bismuth 210.
   b) Identify the emitted particle and specify the type of this decay.
2) Calculate the energy liberated by this decay.
3) The decay of the bismuth 210 nucleus is accompanied with the emission of a γ photon of energy $E(\gamma) = 0.96$ MeV and an antineutrino of energy 0.02 MeV. Knowing that the daughter nucleus is practically at rest, calculate the kinetic energy of the emitted particle.

B – Half-life of polonium 210

1) **a)** Write down the equation of the decay of polonium 210.
   b) Identify the daughter nucleus.
2) In order to determine the radioactive period T (half-life) of ${}^{210}_{84}Po$, we consider a sample of this isotope containing N_o nuclei at the instant $t_o = 0$. Let N be the number of the non-decayed nuclei at an instant t.
   a) Write down the expression of the law of radioactive decay.
   b) Determine the expression of $-\ell n\left(\frac{N}{N_0}\right)$ as a function of t .
3) A counter allows to obtain the measurements that are tabulated in the following table :

t (days)	0	40	80	120	160	200	240
$\frac{N}{N_0}$	1	0.82	0.67	0.55	0.45	0.37	0.30
$-\ell n\left(\frac{N}{N_0}\right)$	0		0.4		0.8		1.2

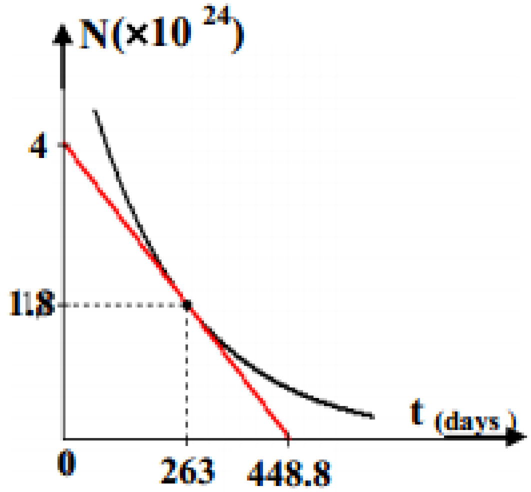
   a) Complete the table.
   b) Trace, on the graph paper, the curve giving the variation of $-\ell n\left(\frac{N}{N_0}\right)$ as a function of time.

   Scale: 1 cm on the abscissa axis corresponds to 40 days.
   1 cm on the ordinate axis corresponds to 0.2.

   c) Is this curve in agreement with the expression found in the question (B – **2**, b) ? Justify.
   d) **i)** Calculate the slope of the traced curve.
   ii) What does this slope represent for the polonium 210 nucleus?
   iii) Deduce the value of T.

Problem 11: **Radioactive period of polonium 210** PHYSICS LS-2010 -1

The adjacent figure shows the curve representing the variations with time t of the number N of the nuclei present in the radioactive sample ${}^{210}_{84}Po$, this number being called N_0 at the instant $t_0 = 0$. The same figure shows also the tangent to that curve at the instant $t_1 = 263$ days.



1) Write down the expression of N as a function of t and specify what does each term represent.

2) The activity of the radioactive sample is given by: $A = -\frac{dN}{dt}$.
   a) Define the activity A.
   b) Using the given on the figure above, determine the activity A of the sample at the instant $t_1 = 263$ days.

3) Deduce the value of the radioactive constant and the value of the half-life (period) of polonium 210.

Problem 12 Nuclear reactions and dating

PHYSICS LS-2011-1

$m(\alpha) = 4.00$[redacted]u; $m({}^{1}_{0}n) = 1.00866$ u; $m({}^{1}_{1}p) = 1.00728$ u; $m({}^{14}_{7}N) = 13.99924$ u;
$m({}^{14}_{6}C) = 1$[redacted]95 u; $m({}^{17}_{8}O) = 16.99473$ u; $1\ u = 931.5\ MeV/c^2$.

A – Artifici[redacted]action

The first pro[redacted]d artificial reaction was performed in 1919 by Ernest Rutherford at Cambridge. He bombarded [redacted]en nuclei (${}^{14}_{7}N$) with α particles (${}^{4}_{2}He$) having great kinetic energies. Oxygen nuclei (${}^{17}_{8}O$) and p[redacted]s (${}^{1}_{1}p$) are obtained. The equation corresponding to the reaction relative to one nitrogen nucleus is w[redacted] as: ${}^{4}_{2}He + {}^{14}_{7}N \longrightarrow {}^{17}_{8}O + x\,{}^{1}_{1}p$

1) Show tha[redacted]cifying the used law, x = 1.
2) a) Calcul[redacted]e "mass before" and the "mass after" in this nuclear reaction.
   b) Deduc[redacted] this reaction needs an amount of energy to be performed.
3) We negle[redacted] kinetic energy of the proton and those of nitrogen and oxygen nuclei. Show that, by applying [redacted]rinciple of conservation of the total energy, the kinetic energy of the α particle is equal to 1.183[redacted]

B – Natural [redacted]ion

A provoked r[redacted]n of nitrogen 14 occurs naturally. Indeed, when, in the upper atmosphere, a neutron of the cosmic ra[redacted]n hits a nitrogen nucleus (${}^{14}_{7}N$), a reaction takes place and produces a carbon nucleus (${}^{14}_{6}C$), that is [redacted]ioactive isotope of the stable carbon nucleus (${}^{12}_{6}C$). The equation corresponding to this reaction is w[redacted]as: ${}^{1}_{0}n + {}^{14}_{7}N \longrightarrow {}^{14}_{6}C + {}^{1}_{1}p$

1) Calculate[redacted]mass before" and the "mass after" in this nuclear reaction.
2) Deduce t[redacted]is reaction liberates energy.

C – Carbon d[redacted]g

The plants [redacted]b carbon dioxide from the atmosphere formed of both carbon 14 and carbon 12. The ratio o[redacted]e two isotopes is the same in plants and in atmosphere.
When the p[redacted]lies, it stops absorbing carbon dioxide. The carbon 14 existing in this plant disintegrates then withou[redacted]ng compensated. The period (half-life) of carbon 14 is T = 5730 years.

1) Calculate[redacted]ear^{-1}, the radioactive constant λ of carbon 14.
2) An analy[redacted] a sample of wood (dead plant), found in an Egyptian tomb, shows that its activity is 750 disin[redacted]tions per minute whereas the activity of a plant of the same nature and of the same mass freshly c[redacted]320 disintegrations per minute.
   Determi[redacted] age of the sample of wood found in the Egyptian tomb.

Problem [redacted] Iodine 131

PHYSICS LS-2012-1

The aim of t[redacted]xercise is to show evidence of some characteristics of iodine 131.
Iodine 131 ([redacted] is radioactive and is a β^- emitter. Its radioactive period (half-life) is 8 days.
Given: Ma[redacted]an electron: $m_e = 5.5\times10^{-4}$ u; 1 MeV = 1.6×10^{-13} J; 1 u = 931.5 MeV/c².

[redacted]lement	Iodine (${}^{131}_{53}I$)	Cesium(${}^{137}_{55}Cs$)	Xenon(${}^{131}_{54}Xe$)
[redacted]ass of nucleus	130.8770 u	136.8773 u	130.8754 u

A – Disinteg[redacted]n of iodine 131

1) Writ[redacted]n the equation of the disintegration of iodine 131 and identify the daughter nucleus.
2) The [redacted]egration of iodine 131 nucleus, is often, accompanied with the emission of γ rays. Due to what[redacted]s emission?
3) Calc[redacted]the radioactive constant λ of iodine 131 in day^{-1} and in s^{-1} .
4) Show [redacted] the energy liberated by the disintegration of one nucleus of iodine 131 is $E_{lib.} = 1.56\times10^{-13}$ J.

B – Application in medicine

During a medical examination of a thyroid gland of a patient, we inject this gland with a solution of iodine 131. The thyroid of this patient captures from this solution a number $N = 10^{11}$ of iodine nuclei.

1) Calculate, in Bq, the activity A corresponding to these N nuclei knowing that $A = \lambda N$.
2) Calculate, in J, the energy liberated by the disintegration of these N nuclei.
3) Deduce, in J/kg, the value of the dose absorbed by the thyroid gland knowing that its mass is 25 g.

C – Contamination

On the 26th of April 1986, an accident took place in the nuclear power plant of Chernobyl that provoked an explosion in one of the reactors. One of the many radioactive elements that were ejected to the atmosphere is the iodine 131. This element spread on the ground, absorbed by cows and contaminated their milk and then captured by the thyroid gland of consumers.

Every morning, a person drank a certain quantity of milk containing $N_0 = 2.6\times10^{16}$ nuclei of iodine 131. We suppose that all these nuclei were captured by the thyroid of that person, and that the person drank the first quantity at the instant $t_0 = 0$.

1) Determine , in terms of N_0 and λ (expressed in day^{-1}), the number of iodine 131 nuclei that remained in the thyroid, at the instant:
   a) $t_1 = 1$ day, (just after drinking the 2nd quantity of milk);
   b) $t_2 = 2$ days, (just after drinking the 3rd quantity of milk).
2) Deduce, at the instant $t_3 = 3$ days just after drinking the 4th quantity of milk that the number N_3 of the iodine 131 nuclei that remained in the thyroid is: $N_3 = N_0\,(1 + e^{-\lambda} + e^{-2\lambda} + e^{-3\lambda})$ where λ is expressed in day^{-1}.
3) Serious troubles in the thyroid gland will take place if the activity of the iodine 131 exceeds 75×10^9 Bq. Show that at the instant t_3, the person was in danger.

Problem 14: **Dating by Carbon 14**

PHYSICS
LS-2013-1

The radioactive carbon isotope $^{14}_{6}C$ is a β^- emitter. In the atmosphere, $^{14}_{6}C$ exists with the carbon 12 in a constant ratio.

When an organism is alive it absorbs carbon dioxide that comes indifferently from carbon 12 and carbon 14. Just after the death of an organism, this absorption stops and carbon 14, that it has, disintegrate with a half life T = 5700 years.

In living organisms, the ratio of the number of carbon 14 atoms to that of the number of carbon 12 atoms is: $r_0 = \dfrac{\text{initial number of carbon 14 atoms}}{\text{number of carbon 12 atoms}} = \dfrac{N_0(^{14}C)}{N'(^{12}C)} = 10^{-12}$.

After the death of an organism by a time t, the ratio of the number of carbon 14 atoms to that of the number of carbon 12 atoms becomes: $r = \dfrac{\text{remaining number of carbon 14 atoms}}{\text{number of carbon 12 atoms}} = \dfrac{N(^{14}C)}{N'(^{12}C)}$.

1) The disintegration of $^{14}_{6}C$ is given by: $^{14}_{6}C \rightarrow {}^{A}_{Z}N + \beta^- + {}^{0}_{0}\bar{\upsilon}$.
   Calculate Z and A , specifying the laws used.
2) Calculate, in year^{-1}, the radioactive constant λ of carbon 14.
3) Using, the law of radioactive decay of carbon 14, $N(^{14}C) = N_0(^{14}C)\times e^{-\lambda t}$.
   Show that $r = r_0\, e^{-\lambda t}$.
4) Measurements of $\dfrac{r}{r_0}$, for specimens a, b and c, are given in the following table:

ratio	specimen a	specimen b	specimen c
$\dfrac{r}{r_0}$	0.914	0.843	0.984

   a) Specimen b is the oldest. Why?
   b) Determine the age of specimen b.

5) **a)** Calculate the ratio $\frac{r}{r_0}$ for $t_0 = 0$, $t_1 = 2T$, $t_2 = 4T$ and $t_3 = 6T$.

b) Trace then the curve $\frac{r}{r_0} = f(t)$ by taking the following scales:

- On the abscissa axis: 1 cm $\rightarrow$ 2T
- On the ordinate axis: 1 cm $\rightarrow \frac{r}{r_0} = 0.2$

c) To determine the date of death of a living organism, it is just enough to measure $\frac{r}{r_0}$.

Explain why we cannot use the traced curve to determine the date of the death of an organism that died several millions years ago.

Problem 15: **The radioactivity of cobalt-60** PHYSICS LS-2016-1

The cobalt isotope ${}^{60}_{27}Co$ is radioactive of a radioactive constant $\lambda = 4.146\times10^{-9}$ s^{-1}. Consider a sample of this isotope of mass $m_0 = 1$ g at the instant $t_0 = 0$.

Given:

Symbol	${}^{60}_{27}Co$	${}^{60}_{28}Ni$	${}^{A}_{Z}X$
Mass (in u)	59.9190	59.9154	0.00055

- 1 year = 365 days.
- 1u = 931.5 MeV/c² ; • Avogadro's number: 6.02×10^{23} mol^{-1}; • Molar mass of cobalt: 60 g.mol^{-1};

1) Calculate, in years, the period of the cobalt- 60 nucleus.

2) **a)** Determine, at $t_0 = 0$, the number of nuclei N_0 presented in 1 g of cobalt- 60.

b) Define the activity A of a radioactive sample.

c) Determine the activity of the cobalt sample at the instant t = 15.9 years.

3) The disintegrations of ${}^{60}_{27}Co$ gives rise to a nickel isotope ${}^{60}_{28}Ni$ according to the following reaction:

$${}^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^{A}_{Z}X + ...$$

a) Calculate, specifying the laws used, A and Z.

b) Name the emitted particles.

c) Calculate, in MeV, the energy liberated by this disintegration.

d) Determine the energy liberated by the disintegration of 1g of cobalt- 60.

4) Knowing that the energy liberated by the fission of 1 g of ${}^{235}_{92}U$ is 5.127×10^{23} Mev, calculate the mass of ${}^{235}_{92}U$ whose fission provides an energy equivalent to that liberated by the disintegration of 1 g of cobalt-60.

Problem 16: **Determination of the volume of the blood of a person by radioactivity** PHYSICS LS-2016-2

In order to determine the volume of the blood of a person, we use the radionuclide sodium ${}^{24}_{11}Na$.

Given: • Planck's constant: $h = 6.63\times10^{-34}$ J.s; • Speed of light in vacuum: $c = 3\times10^{8}$ m/s;

- Avogadro's number: $N_A = 6.02\times10^{23}$ mol^{-1}; • Molar mass of sodium 24: M = 24 g; • 1 MeV = 1.6×10^{-13}J.
- Selection from the periodic table:

Element	Fluorine	Neon	Sodium	Magnesium	Aluminium
Nuclide	${}^{19}_{9}F$	${}^{20}_{10}Ne$	${}^{23}_{11}Na$	${}^{24}_{12}Mg$	${}^{27}_{13}Al$

A – Sodium ${}^{24}_{11}Na$ is obtained by bombarding the sodium ${}^{23}_{11}Na$ by a neutron.

1) Write the equation of this nuclear reaction.

2) This reaction is provoked. Justify.

B – The sodium 24 is radioactive β^- emitter.

1) Write [redacted] quation of this disintegration.

2) Name [redacted] btained daughter nucleus.

3) The di [redacted] gration of sodium 24 is accompanied by the emission of a dangerous radiation γ.

a) Ind [redacted] the nature of this radiation.

b) Ind [redacted] the cause of the emission of this radiation.

c) On [redacted] he emitted photons has energy of 3 MeV. Calculate the wavelength of the co [redacted] onding radiation.

C – The radio [redacted] e constant of sodium 24 is $\lambda = 1.28\times10^{-5}\ s^{-1}$.

1) At the [redacted] nt $t_0 = 0$, we inject a solution containing $m_0 = 2.4\times10^{-4}$ g of sodium 24 into the blood of a pers [redacted] alculate the number of nuclei N_0 of sodium 24 in the injected solution.

2) Calcul [redacted] t the instant t = 6 hours, the number of sodium 24 nuclei remaining in the blood of the person [redacted]

3) Suppo [redacted] at the sodium 24 is uniformly distributed in the blood of the person. At the instant t = 6 h [redacted] 10 mL of blood taken from the person contains 9.03×10^{15} nuclei of sodium 24. Calcul [redacted] he volume of the blood of the person.

Problem 1 [redacted]

Scintigraphy in medicine

PHYSICS

LS - 2018-1

The bones sci [redacted] aphy is a medical examination that permits to observe bones and articulations. The aim of this ex [redacted] e is to study a radioactive sample used in this scintigraphy.

This medical [redacted] ination uses technetium-99 produced due to the disintegration of molybdenum-99 according to t [redacted] llowing nuclear reaction: $^{99}_{42}Mo \rightarrow {}^{99}_{43}Tc + {}^{A}_{Z}X + \gamma$

The energy o [redacted] emitted gamma (γ) photon is 140 keV.

Given: c = 3 [redacted] m.s^{-1}; 1eV = 1.6×10^{-19} J; Planck's constant h = 6.6×10^{-34} J.s.

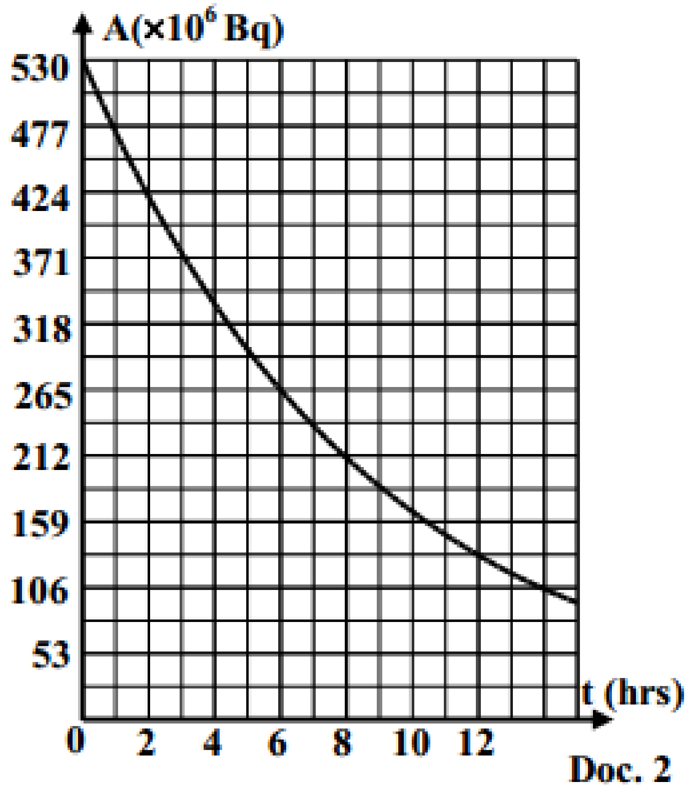
1- Identify [redacted] mitted particle ${}^{A}_{Z}X$, indicating the used laws.

2- The emi [redacted] article ${}^{A}_{Z}X$ is always accompanied with the emission of another particle. Name this particle.

3- Indicate [redacted] use of the emission of the gamma photon

4- Calculate [redacted] wavelength of the emitted gamma photon.

5- Techneti [redacted] 9 is a radioactive substance. The grap [redacted] locument 2 represents the activity of a sample o [redacted] netium-99 as a function of time. Using do [redacted] nt 2, show that the radioactive period (h [redacted] fe) of technetium-99 is T = 6 hrs.



Doc. 2

6- In a sessio [redacted] scintigraphy examination, a patient is injected a [redacted] 0 by techenetium-99 of activity A_0 = 530 [redacted] Bq. At the end of the examination session, the activit [redacted] echnetium in the body of the patient is 63% of its [redacted] al value.

6-1) Write [redacted] nstant t, the expression of the activity A in term [redacted] A_0, t and the decay constant λ.

6-2) Usin [redacted] preceded expression, determine:

6-2-1) [redacted] uration of the examination session;

6-2-2) t [redacted] tio $\frac{A}{A_0}$ of technetium-99 at t = 40 hrs.

Détermination de l'âge d'un liquide

Le tritium $^{3}_{1}H$ est un isotope radioactif de l'hydrogène. Le tritium est produit dans la haute atmosphère par les rayonnements cosmiques et amené sur Terre par la pluie. Le tritium peut être utilisé pour déterminer l'âge des liquides contenant cet isotope d'hydrogène.
Dans cet exercice, on compte déterminer l'âge d'un liquide contenu dans une ancienne bouteille en utilisant l'activité du tritium.

1- Décroissance radioactive du tritium

Le tritium est un émetteur beta-moins (β^-). Il se désintègre pour donner un des isotopes de l'hélium sans émission de rayonnement gamma.

1-1) Compléter l'équation de la décroissance du tritium et déterminer A et Z.

$$^{3}_{1}H \rightarrow {}^{A}_{Z}He + \dots$$

1-2) Le noyau d'hélium est produit à l'état fondamental. Pourquoi ?

1-3) Une particule X accompagne la désintégration ci-dessus afin de satisfaire à une certaine loi. Nommer cette particule et cette loi.

2- Détermination de la période radioactive du tritium

On considère un échantillon de l'isotope radioactif du tritium $^{3}_{1}H$.

À un instant $t_0 = 0$, le nombre des noyaux présents dans cet échantillon est N_0.

L'activité A de l'échantillon radioactif représente le nombre de désintégrations par unité de temps.

L'activité à un instant t est donnée par l'expression suivante : $A = -\dfrac{dN}{dt}$, où N est le nombre des noyaux restants (non désintégrés) à l'instant t.

2-1) Montrer que l'équation différentielle du premier ordre qui décrit les variations de N est :
$\dfrac{dN}{dt} + \lambda N = 0$, avec λ est la constante de décroissance radioactive de l'isotope radioactif.

2-2) Vérifier que $N = N_0 e^{-\frac{t}{\tau}}$ est une solution de l'équation différentielle ci-dessus, où $\tau = \dfrac{1}{\lambda}$.

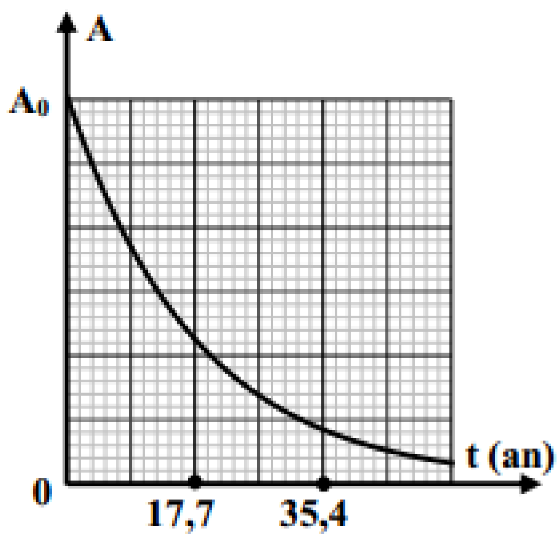
2-3) Déduire que l'expression de l'activité est donnée par :
$A = A_0 e^{-\frac{t}{\tau}}$, où A_0 est l'activité initiale de l'échantillon.

2-4) Calculer A en fonction de A_0 lorsque $t = \tau$.

2-5) Le document 6 représente l'activité d'un échantillon de tritium en fonction du temps.

2-5-1) Montrer que $\tau = 17{,}7$ ans.

2-5-2) Déduire la période radioactive du tritium.



3 Détermination de l'âge d'un liquide

Une ancienne bouteille contient un certain liquide, elle est juste ouverte (en 2018). On a trouvé que l'activité du tritium dans ce liquide est 10,4 % de l'activité initiale du même liquide fraîchement préparé. Déterminer l'année de production du liquide dans l'ancienne bouteille.