CIV Entrance Exam 2019
Physics Chemistry

Length: 3 hours

CENTRE INTERNATIONAL DE VALBONNE

Candidate's registration number : ☐☐☐☐☐☐☐☐☐☐

Instructions to candidates

- Write above your registration number.
- Do not open the examination paper until instructed to do so.
- No calculators, tables or formula sheets may be used.
- Answers should be written in **english or french** on separate provided answer sheets.
- Do not forget to fill out your registration number and the correct page numbering (page .. out of ..) on each of your answer sheets (for example : page 1/5, 2/5 ... 5/5).
- A partial answer is always interesting. Don't hesitate to write down your ideas, even incomplete.
- Marks are indicated at the start of each exercice. You are advised to divide your time according to the marks allocated.
- The maximum mark for this examination paper is 100.

BONNE CHANCE / GOOD LUCK !

PHYSICS

Instructions :

All the equations must be written literally before doing numerical calculus. Numerical results will be written with at least one significant figure.

Exercise 1: (/6 pts)

The following is part of a student's report on an experiment to verify the principle of conservation of momentum.

"I ensured that no net external forces acted on body A or body B. When I released body A it was moving at a constant velocity; body B was at rest. I allowed body A to collide with body B and they moved off together after the collision."

The following data was recorded:

Mass of body A Ma = 300 g

Mass of body B Mb = 180 g

Velocity of body A before the collision Va = 0,8 ms^{-1}

Velocity of bodies A and B after the collision Vab = 0,5 ms^{-1}

1. Draw a labelled diagram of the apparatus used in the experiment.
2. State what measurements the student took and how these measurements were used to calculate the velocities.
3. Using the recorded data, show how the experiment verifies the principle of conservation of momentum.
4. When carrying out this experiment the student ensures that there is no net external force acting on the bodies. What are the two forces that the student needs to take account of to ensure this?
5. Describe how the student reduced the effects of these forces.

Exercise 2: (/13 pts)

Blood pressure can be measured in many ways. One technique uses the Doppler effect : another uses strain gauges contained in Wheatstone bridges.

A. Doppler effect

1. What is the Doppler effect? Explain, with the aid of labeled diagrams, how the Doppler effect occurs.

2. Chose from the following formulas the correct ones :

   (V denotes the vehicle speed, V_s the speed of the sound wave, f_E the frequency of the emitted wave and f_R the frequency of the received wave).

$$f_E = f_R\left(2V - \frac{V}{V_s}\right)$$

$$f_R = V\left(f_E - \frac{2V}{V_s}\right)$$

$$f_R = f_E\left(\frac{V_S}{V_s - V}\right)$$

An ambulance siren emits a sound of frequency 950 Hz. When the ambulance is traveling towards an observer, the frequency detected by the observer is 1000 Hz.

3. What is the speed of the ambulance?
4. State two other practical applications of the Doppler effect.

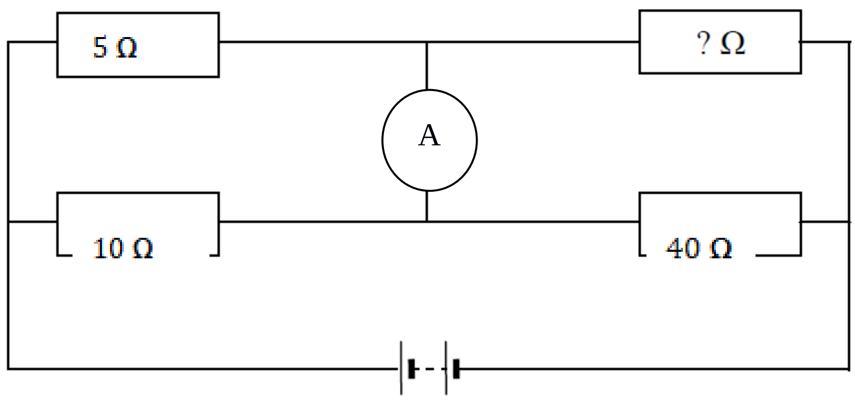
Data : speed of sound in air = $340\ m\ s^{-1}$

B. Wheatstone bridge

The resistance of the conductor in a strain gauge increases when a force is applied to it.

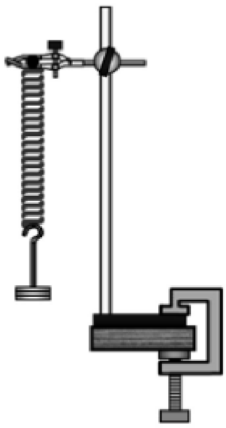
Strain gauges can act as the resistors in a Wheatstone bridge (see diagram below), and any change in their resistance can then be detected.

The Wheatstone bridge in the diagram is balanced, which means that the intensity measured by the ammeter is null. The ammeter is supposed without intern resistance.



1. What is the resistance of the unknown resistor?

2. Write an expression for the resistance of a wire in terms of its resistivity, length and diameter. The radius of a wire is doubled. What is the effect of this on the resistance of the wire?



Exercise 3 : Hooke's law (/9 pts)

1. State Hooke's law

The elastic constant of a spring is $k = 10\ Nm^{-1}$ and it has a length l_o of 25 mm. An object of mass m= 20 g is attached to the spring.

2. What is the new length le of the spring?

The object is then pulled down until the spring's length is increased by a further 5 mm and is then released. The object oscillates with simple harmonic motion.

3. Sketch a velocity-time graph of the motion of the object.
4. Calculate the period of oscillation of the object.

Data : acceleration due to gravity $g = 10\ m.s^{-2}$

Exercise 4 : Boyle's law (/4 pts)

In an experiment to verify Boyle's law, a student measured the volume V of a fixed mass of gas at different values of the pressure p. The temperature of the gas was the same for each measurement. The following data were recorded.

V (cm^3)	80	120	160	200	240	280
p (kPa)	324	214	165	135	112	100

1. Draw a suitable graph to show the relationship between the pressure of the gas and its volume. Explain how the graph verifies Boyle's law.
2. Use your graph to estimate the pressure of the gas at a volume of 250 m^3 .
3. Why might the temperature of the gas have changed significantly during the experiment? How did the student ensure that the temperature of the gas was the same for each measurement?

<u>Exercise 5 : Snell-Descartes 's Law (/ 4pts)</u>

In an experiment to measure the refractive index of a substance, a student used a rectangular block of the substance to measure the angle of incidence i and the corresponding angle of refraction r for a ray of light as it passed from air into the substance.

The student repeated the procedure for a series of different values of the angle of incidence and recorded the following data.

i (degrees)	20	30	40	50	60	70	80
r (degrees)	13	20	27	23	36	40	43

1. One of the recorded angles of refraction is inconsistent with the others. Which one ?
2. Describe, with the aid of a labeled diagram, how the student found the angle of refraction.
3. Calculate a value for the refractive index of the substance by drawing a suitable graph based on the recorded data.

<u>Exercise 6 : Glass water (/11 pts)</u>

1. Define specific latent heat.

A drinking glass contains m= 500 g of water at a temperature of Tw = 24 °C. Three cubes of ice, of side 2 cm, are removed from a freezer and placed in the water. The temperature of the ice is Ti = –20 °C.

2. Calculate the mass m_{itot} of the ice.
3. Give a expression of the minimum temperature of the water when the ice has melted.

density of ice ρ = 0.92 $g\ cm^{-3}$

specific heat capacity of water c_{water} = 4200 $J\ kg^{-1}\ K^{-1}$

specific heat capacity of ice c_{ice} = 2100 $J\ kg^{-1}\ K^{-1}$

specific latent heat of fusion of ice l_{ice} = = $3.3 \times 10^5\ J\ kg^{-1}$

Exercise 7 : Golfer (/ 13 pts)

A golfer pulls his trolley and bag along a level path. He applies a force F of 300 N at an angle θ of 45° to the horizontal.

The weight P of the trolley and bag together is 210 N and the force of friction T is 206 N.

1. Draw a diagram showing the net force acting on the trolley and bag.
2. What does the net force tell you about the golfer's motion?
3. Use Newton's second law of motion to derive an equation relating force, mass and acceleration.

A force Fg of 9.0 kN is applied to a golf ball by a club. The mass of the ball mb is 45 g and the ball and club are in contact for $\Delta t =$ 0.25 ms.

4. Calculate the speed of the ball as it leaves the club.
5. The ball leaves the club head at an angle of 30° to the horizontal. Calculate the maximum height reached by the ball. Ignore the effect of air resistance.

Help :

cos(45°) = sin(45°) = 0.7

sin(30°) = 0.50

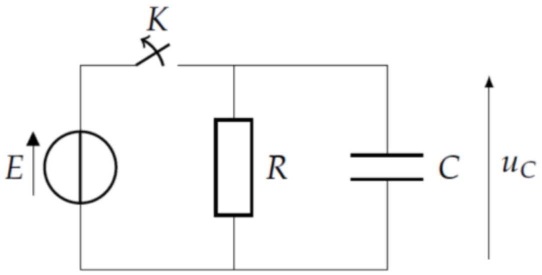
cos(30°) = 0.86

$g = 10\ m.s^{-2}$

2.5*2.5 = 6.25

Exercise 8 : Circuit RC (/ 10 pts)

The electrical circuit shown in this scheme let a lamp (not shown in the scheme) light during a little time after the K switch is opened.



Before the beginning, the K switch is closed for a long time.

At the beginning (t = 0s), the K switch is opened.

The lamp remains alight for **6 ms**.
The light goes out when $\mathbf{u_C}$ is lower than 5% of **E**
The capacitor has a capacitance of **C = 20 µF**.

When the K switch is opened, $\mathbf{u_c}$ is solution of equation (1):

(1) $RC\frac{du_C}{dt} + u_C = 0$

1°) Verify that $u_C = Ae^{-\frac{t}{\tau}}$ is a solution of equation (1).
2°) Express the value of **A** and τ in terms of E, R and C.
3°) Express in terms of R and C the value of **t** when the lamp turns off.
4°) Knowing that $ln(0{,}05) \approx -3$, estimate the value of the resistor **R**.
5°) What's going to happen if we use a lower value of **R** ?

CHEMISTRY : About Fluorine

Fluorine is the most reactive and the most electronegative of all the elements.
Fluorine and its compounds – mostly uranium hexafluoride – are used in processing nuclear fuel.
Fluorochemicals, including many high-temperature plastics such as Teflon, are also made using fluorine.
Hydrofluoric acid, **HF**, can dissolve glass. Its fluoride ions have a high affinity for calcium and can be used in many applications.
Fluorine has 11 isotopes whose half-lives are known, with varying mass numbers from 15 to 25. Naturally occurring fluorine consists of its one stable isotope, $^{19}_{9}F$.

Describing the atom: (approx. 10 points)

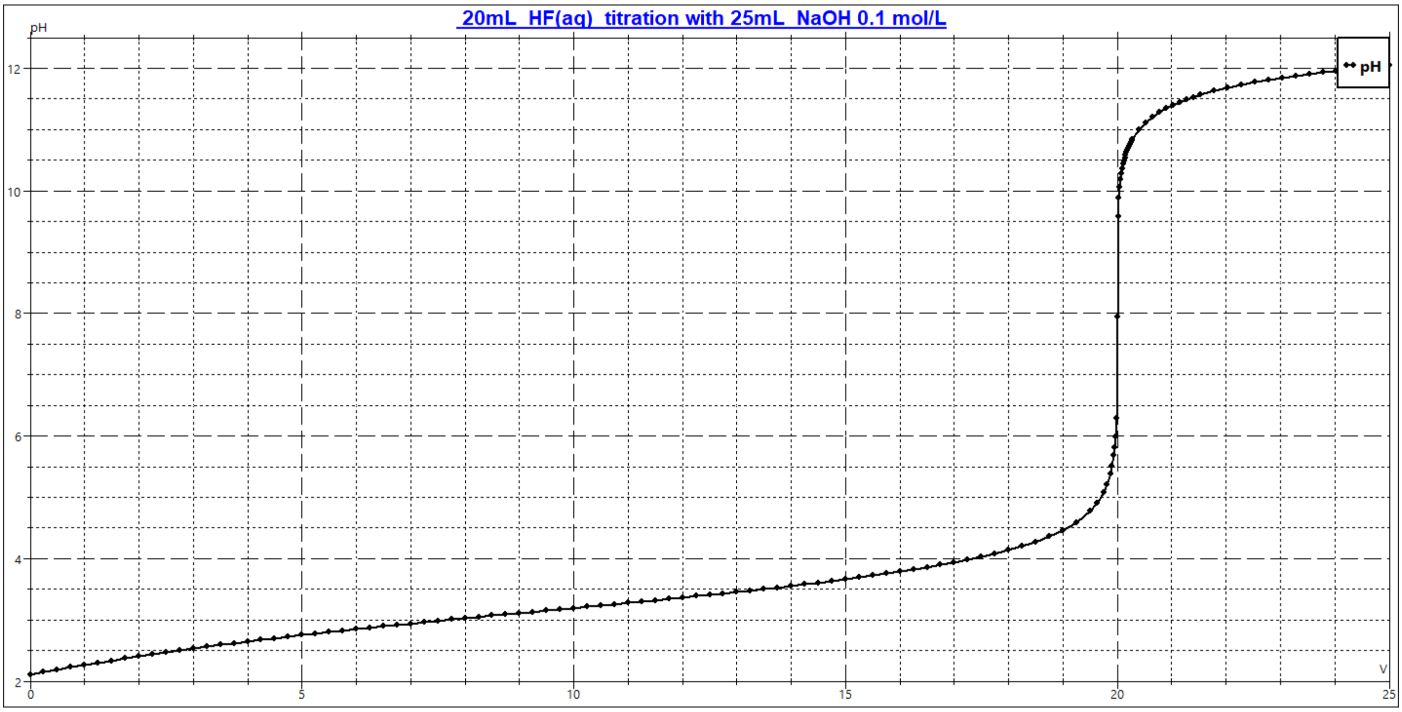
1) Define the atomic number of an element.
In terms of particles, $^{19}_{9}F$ and $^{18}_{9}F$ are atoms of the same element, but how do they differ?

2) Define an atomic orbital. Write the ground state *s*, *p* electron configuration for a fluorine atom.
How many valence electrons are there? In which group and period can we find this element?

3) Define electronegativity.
Draw dot and cross diagrams to show the covalent bonding in **HF**.

Titration of HF with NaOH: (approx. 14 points)

To determine the concentration of hydrofluoric acid HF in a sample, 20.0 mL of the acid solution was titrated with a previously standardized solution of 0.10 mol.L^{-1} sodium hydroxide.
The pH-curve obtained is shown below:



The equation for the titration reaction is:

$$\mathbf{HF + NaOH = NaF + H_2O}$$

4) The sodium hydroxyde solution was prepared using solid **NaOH** dissolved in 100 mL (1 mL = 1cm^3) of water. Calculate the mass of **NaOH** needed to obtain the 0.10 mol.L^{-1} solution.
<u>Molar mass M(NaOH)</u> = 40 g.mol^{-1}

5) Using the pH-curve and the titration reaction, calculate, in moles per liter, the concentration of the **HF** solution that was titrated against the 0.10 mol.L^{-1} **NaOH** solution.

6) The acid dissociation constant for the acid-base couple **HF/F$^-$** is : Ka(HF/F$^-$) = $10^{-3,2}$ = 6.3*10^{-4}
Calculate the equilibrium constant for the titration reaction.
Ionic product for water : $K_W = 10^{-14}$

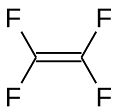
7) Calculate the molar quantities of **HF** and **NaF** (or Na$^+$, F$^-$) when the added volume of sodium hydroxide solution is V(NaOH) = 10 mL.
Using the pH-curve, read the pH value for this same volume, and compare it to the pKa value.

8) Here is a list of usual indicators , used during acid-base titrations.
Using the pH-curve, explain which indicator(s) can be suitable for this titration.

Indicator	pK_a	pH range	Acid color	Alkali color
methyl orange	3.7	3.1- 4.4	red	yellow
phenol red	7.9	6.8-8.4	yellow	red
phenolphthalein	9.3	8.3-10.0	colorless	red

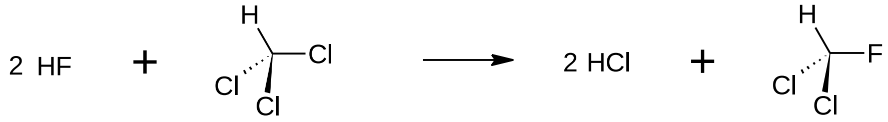
<u>Organic fluorinated compounds</u>: (approx. 6 points)

Many organic fluorinated compounds are used in industry to create polymers or pharmaceuticals.

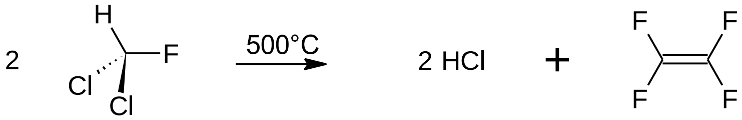
Tetrafluoroethylene, 

, is an unsaturated fluorocarbon used to produce <u>polytetrafluoroethylene</u> (PTFE) polymers such as <u>Teflon</u>.

Tetrafluoroethylene is produced from chloroform, fluorinated by reaction with **HF**, following a 2-step process :



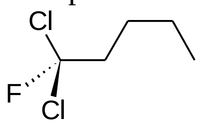
(1)



(2)

8) Classify equation (1) as an addition, a substitution, or as an oxidation reaction.

9) Classify equation (2) as an addition, a substitution, or as an elimination reaction.

10) Using the example of reaction (1), which organic compound will be necessary to produce this molecule :  ?

11) Balance the following equation :