Normale Physics Review

Fights Bohr-dom

11th of April 2021

Édito N_{10}: La newsletter physicienne pour Normaliens confinés

Chères lectrices, chers lecteurs,
Nous sommes heureux de vous présenter aujourd'hui la 10ème édition de la Normale Physics Review! Après une période de pause bienvenue, c'est une édition à la voilure réduite que vous pourrez lire. Mais pas d'inquiétude: nous prévoyons de retrouver notre rythme de croisière d'ici quelques éditions. Mais déjà, nous vous proposons la traditionnelle rubrique de questions, une nouvelle photo mystère et des nouvelles du Journal Club, avec un compte-rendu d'une session. Merci aux organisateurs et aux participants pour leur collaboration!
(L.Brivady)

[Announcements]

— The Physics Journal Club cordially invites you to its next meeting on May 15th at 10am in room L369. We will discuss "Fermilab's g-2 First Measurement Results" published in *Physical Review Letters* 126, 1411801 (2021). To sign up (6 spots max), please write your name on the journal club website or contact Yann Bouchereau or Marco David. Looking forward to see you there !

Reference : Direct link to the paper
Journal Club Website

[Class' life]

Online Lectures

Last year, French Universities knew a revolution. Since Mid-March and for at least 4 Month, students leaved halls and get full lectures online. This situation was obviously novel for everyone, including teachers who had to convert themselves in a hurry to new format of teaching. Newness of the thing gave us funny sequences bringing a glow of happiness in this particular times. Among foolish set-up, crazy moments or remarkable adaptation we would like to share you some schoolboy anecdotes !

Seasickness

After several sessions of "test and try", teachers and students finally found their daily round despite the particular circumstances. During the first lectures (see last edition), some teachers tried to reproduce the class atmosphere writing on a home-made blackboard but due to webcams' performances this set-up should be give up. Quickly the different set-ups converged to the same installation [1] : sitting on desk, the teacher is writing on classic paper and film its. Simple, but ingenious and surprisingly efficient.

Yes, but No. During experiments you should encounter small hurdles which at least hinder the good process of your set up (if not, it's suspect, check that anything is burning). Have you ever set the focus of your own webcam ? No of course, because there's an autofocus to make this comfortable to us. Now imagine the set-up : the webcam (or a cam), filming a hand writing. There are two points of interest for the autofocus : the hand, which is moving, and the text, the background. Nevertheless, this two points are very close and sometimes mix ! Which one should it choose ? Anyone. That's the issue. Without further instructions (if it is possible to constraint more the focus), the cam is going to focus alternatively on this two points, making the visual alternatively sharp and blurry.

This was particularly remarkable during the Optics lectures. The switches were quickly, occurring frequently. And student could feel as they got seasickness. Nonetheless this was also the starting point of good laughs in the chat !

[Physicists' life]

i. Journal Club : Bose's Derivation of Planck's Law

Saturday March 27$^{\text{th}}$, a new meeting of the Journal Club took place in room L369 of the Physics Department. Following a recommendation of Professor Kaiser, we discussed a landmark paper by R. Bose published in 1924 : "Planck's law

1. Question : Is it a stable fixed point ?

and the Light-Quantum Hypothesis". In the paper he presented a derivation of Planck's distribution of the energy in the radiation field of a black body. Without explicitly stating it in the body of the paper, the key assumption made is the indistinguishably of the *quanta* of energy. Following the whole derivation and understanding the key insights was a nice and fun exercise for us. What at the beginning looked like a usual exercise of Statistical Physics course turned out to be full of subtle assumptions. Following, a brief and non-rigorous sketch of the approach :

The state of each particle (or *quantum*) lives in a six dimensional phase space. In this phase space, the surfaces of constant energy for an ideal gas (free radiation field), are cylinders described by the equation :

$$p_x^2 + p_y^2 + p_z^2 = \frac{h^2\nu^2}{c^2} \tag{1}$$

The volume in the phase space corresponding to the frequency range $\mathrm{d}\nu$ is

$$\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}z\,\mathrm{d}p_x\,\mathrm{d}p_y\,\mathrm{d}p_z = 4\pi\frac{h^3\nu^2}{c^3}V\,\mathrm{d}\nu. \tag{2}$$

In his derivation, Bose breaks the phase space in unit volumes of h^3, associating each of these hypercubes to a *state* of a quantum. The whole problem now consist, as usual, in maximizing the entropy $S = k_B \ln(\Omega)$ in the canonical ensemble (constant energy). The task is then to determine the number of micro-states of the system. And is at this point that the key insight of the derivation arrives by considering, even without making it explicit, the indistinguishability of the quanta. Following a maximization procedure of a Lagrange function he derives explicitly, for the first time and not relying on classical results, Planck's formula for the density of energy of black body radiation

$$\rho(\nu) = \frac{8\pi\nu^3}{c^3}\frac{V}{\exp\left(\frac{h\nu}{kT}\right) - 1}. \tag{3}$$

In the words of Albert Einstein, who translated the paper to German for publication (after rejection of the original English version!), this paper constitutes a significant advance and introduced the Quantum Theory of an ideal gas, which Einstein himself later largely formalized.

After five sessions already held, we cannot more than invite you all to take part in our enriching discussions, once every 14 days. Discussions on any frame of physics are welcome and just as a matter of advertising, soon we plan to discuss the Black Hole Information Paradox, Quantum Teleportation, Fermilab's $g-2$ results... and we remain certainly open for suggestions! (**Carlos Lopetegui**)

Sir, I have a question

Vous êtes khôlleur ou tout simplement curieux ? Peut-être trouverez-vous dans les questions suivantes un problème ouvert intéressant. Vous observez un phénomène étrange ? Arrêtez de regarder *The Lupin* et envoyez-nous une question (adresses mail en fin de review) !

I : How the behavior of a windsock should be linked to wind speed ? ;;

II : Estimate the life expectancy of differents mammals species such as mice, horse, elephant, dog... Is there a relation between life expectancy, gestation time and the number of individual per litter ? ;

III : Could you estimate wind force with a few blades of grass ? ;

IV : What's the heat of combustion of wood ? Could you justify the order of magnitude of this quantity for common combustibles ? ;

V : You use your car to commute. Assuming that you daily travel 10 km (outward and return), how many energy workers (see NPR N_7) would you need ? (Use that the average power delivered by a worker is 100 W). Now, we assume that you can using bus or tram to commute. How many slaves/persons are required if copies of you full the bus/tram ? ;

VI : How many kilometers of highways are there in France ? ;

VII : Let remember some childhood memories : some of us used to put firecracker in cow dung (if you have never done this, try). How the projection lenght should vary regarding the power of the device ? ;

VIII : What is the compression of a teeth during chewing ? And the order of magnitude of young modulus for a human teeth ? ;

IX : What is the angular speed of the pales of an helicopter during stationnary fly ? ;

X : Is it possible to build the Money Bin of Uncle Scrooge ? ;

About the previous questions...

Question II of N_5

In this question we are interessed by the flight length of a spit. And we will consider the case where oone is sneezing. What is the order of magnitude of the radius describing the area where one can expect to find spit ?

During a sneeze, dropplets could be projected at $v_0 \approx$ 50km/h and their radius is around $R \approx 0.1 - 1$ mm. Now, if we consider the simple following equation for the spit (we take **x** as horizontal axis, **z** for the vertical,up-oriented) :

$$M\frac{d\mathbf{v}}{dt} = M\mathbf{g} - 1/2\rho_a \pi R^2 C_x v\mathbf{v} \quad (4)$$

With C_x the aerodynamic coefficient (here 0.5 for a sphere), $v = ||\mathbf{v}||$. To begin, we can easly integrate this equation with Euler method and see when the dropplet reaches the ground. For a person of size $h = 1.80m$, we found that d, the flight length is $d \approx 1.3$m ($R = 0.1$mm). Could we get this value with analytic arguments ?

First, we need to see when the gravity and the aerodynamic drag are of the same order of magnitude in the previous equation. It is the case for $V_f^2 = \frac{16\rho R g}{3\rho_a}$. This speed separates the motion into two parts : For $V > V_f$, the aerodynamic drag predominates. Then the previous equation is approximated with :

$$\frac{dv_x}{dt} = -\frac{v_x^2}{v_f^2} g \quad (5)$$

$$v_z = 0 \quad (6)$$

For $V < V_f$, we are in the case a vertical free-fall motion. The first equation could be integrated and we get :

$$v_x(t) = \frac{v_0}{1 + \frac{v_0 g}{v_f^2} t} \quad (7)$$

And

$$x(t) = \frac{v_f^2}{g} \ln\left(1 + \frac{v_0 g}{v_f^2} t\right) \quad (8)$$

With equation 7, we get the time when $v_x = V_f$: $t_f = \frac{v_f}{g} - \frac{v_f^2}{g v_0} = \frac{v_f}{g}(1 - \frac{v_f}{v_0}$. Then, the flight length is :

$$d = \frac{v_f^2}{g} \ln\left(\frac{v_0}{v_f} - 1\right) \quad (9)$$

There is something surprising here. If we consider $v_f \to 0$, $d \to 0$, which is physically incoherent (we expect on the contrary that d increases). So we might be carefull when we manipulate the limits cases in this problem. Moreover, we see that our computation is valable until $v_0 > 2V_f$ (but we also need that $v_0 >> v_f$).

For our parameters, ($R = 0.1$mm, $h = 1.8$m), we get : $v_f \approx 8.3$km/h, $t_f \approx 190$ms and $d \approx 0.86$ m. We need to add the horizontal distance flight during the free fall. Time of free fall is $t_2 = \sqrt{2h/g} \approx 0.6s$ and 1.4m are crossed. Then the total flight length is $d_f = 2.2$m. Obviously, this value is larger than the one get with simulations, since the spit is also falling during the first part of the motion... (**L.Brivady**)

Figure 1

Mystery photo

Here is the mystery photo of this edition ? Could you manage to guess what is it ? Thank **E. Foucher** for your photo !

[Acknowledgements]

We thank our contributors for their fantastic articles and questions. We also thank everyone who send us their feedback and encouragements. And thank you dear reader !

We need you !

If you would like to contribute or support us, don't hesitate to contact us :

- **Esteban Foucher** φ20 : esteban.foucher@ens.fr
- **Rodrigue Orageux** φ20 : rodrigue.orageux@ens.fr
- **Basile Dhote** φ19 : basile.dhote@ens.fr
- **Ludovic Brivady** φ19 : ludovic.brivady@ens.fr