FIMI – *SCAN section*

TRANSVERSAL PROJECTS 2024 – 2025
SCAN *first*

General presentation

&

Description of the projects

General presentation:

From January 27nd to February 7th, you will be given the opportunity to undertake a transversal team project in groups of 5. The proposed subjects cover a wide range of applications and they are rather different both from a formal and scientific point of view. A description of the projects for this year is enclosed to this document.

The projects will start on **Monday 27nd at 11AM**. Please note that teams can be composed of students from any SCAN 1st groups. A brief presentation of the organisation of the SCAN projects will be given on **January 21th at 2PM (Amphi Vannier.)**

In order to anticipate the kick-off of the projects, you are invited to **build-up your own groups** and **rank the different project** by order of preference by filling up the following online form:

Register on project's groups and rank the project (before January 23rd 2PM):

Based on this survey, each group will be assigned a project.

One of the key objectives is to confront you with a problem scenario requiring more than simply a direct application of academic knowledge. Concretely, some theoretical notions needed to accomplish these tasks have not yet been studied in class. Therefore, you may have to look for relevant information in an autonomous way. The role of your tutors is to help you complete your project by offering guidance. This means that they will not resolve the scientific difficulties for you! Tutor presence time will be approximately 6 hours per tutor and per project excluding the oral presentation. You are therefore encouraged to make appointments with your tutor(s) depending on your needs and their availability.

These transversal projects are aimed at producing tangible results to be given in the form of:

a) a 15 minutes **oral presentation** followed by 5 minutes of questions on **Friday February 7th PM (1:30-5 pm)** in front others student project groups and a jury composed of tutors and other teachers who have contributed to the project.

b) a **written report** in the form of a **4-pages scientific article** detailing your methodology and outlining your findings to be received by your tutor by **Friday 28th February**.

Assessment: the overall mark will be broken down as follows:

a) 1/3 to be given by the tutor on an individual basis for commitment and team work**. Please note that only English must be spoken and that presence is compulsory,**

b) 1/3 to be given by the jury for the oral presentation, this will be assessed based on presentation techniques, scientific/technical production and linguistic fluency,

c) 1/3 to be awarded for the written report; linguistic accuracy, bibliographical research and scientific clarity will form the basis for this group evaluation.

Throughout the course of the projects, emphasis will be placed on team work and communication in English. We hope you will find these activities not only challenging and demanding but also fun.

Summary of key dates

Tuesday January 21st at 2PM	**Presentation of SCAN projects (Amphi Vannier)**
before January 23rd 2PM	**Group constitution and project ranking: see online form**
January 24th	**Project Assignment to each group**
From January 27th PM to February 7th AM	**SCAN projects**
February 7th 1:30-5PM	**Project presentations (details will be provided during the 2nd week of the projects)**

List of the projects:

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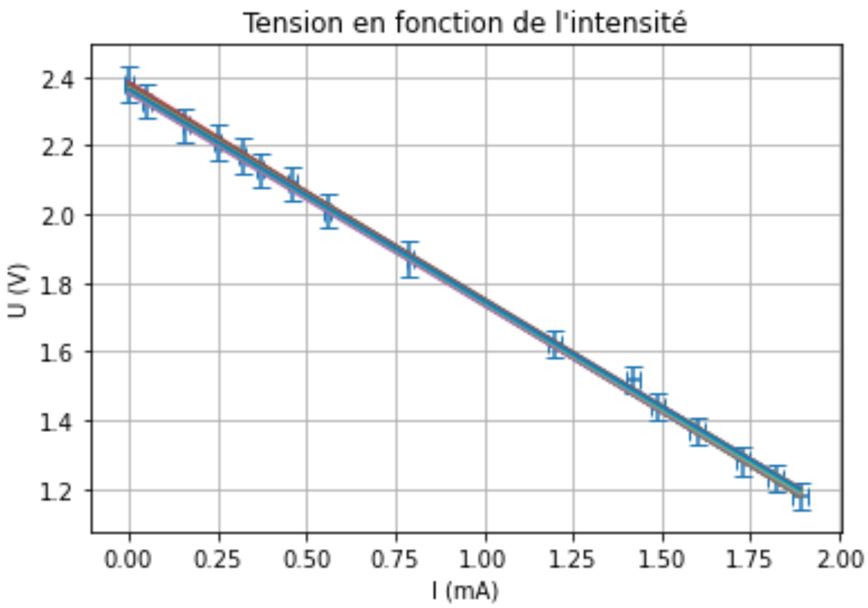
Project 1: An app for the labs

Description :
In the physics lab, you are often required to plot graphs and draw the best linear fit. This can easily be done using commercial software. But things worsen as soon as you need to add uncertainty boxes and extract the lines of extreme slopes!

This project aims at defining a protocol, based on statistics, to determine numerically the value and the uncertainty on the slope of the best linear fit. You will then investigate how to implement this protocol.
Ideally, your output will be made available for the scan section, so that all scan students can use it for the labs in the second semester.



Example of plot with error bars and several lines (slope around that of the best linear fit)

Objectives :
- Understand the principle of linear regression.
- Propose a script (in Python) that computes the parameters of the best linear fit using linear regression.
- Test your script on data sets obtained in the physics labs, and compare the output of the script with what you obtained by hand.
- Eventually, find a method to identify outliers in the data set.

A tour of the microscopy lab will be organized and if possible, you will be allowed to take part to experiments. You may have the impression it has nothing to do with uncertainty, but actually you will be able to discover small scale devices, with high sensitivity. And seeing atoms is fun anyway.

Project 2: From Leonardo do Vinci to Augustin Coulomb

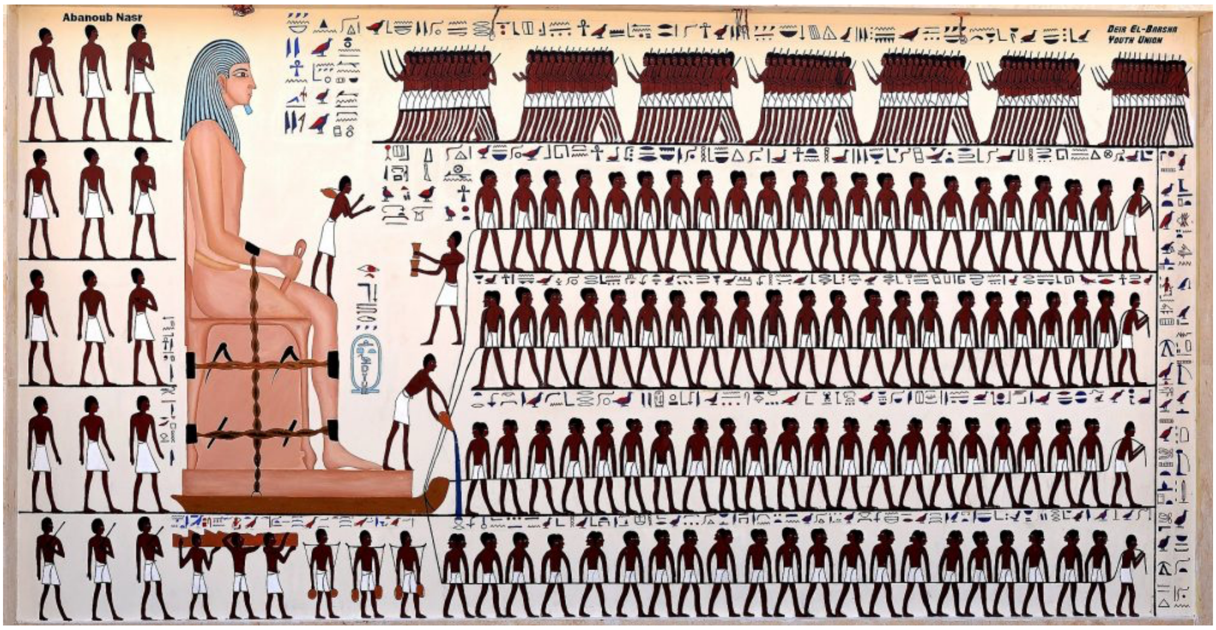


Figure 1 Transportation of a colossal statue in ancient Egypt with a help of a lubricant.

Humans have toiled from immemorial times pulling heavy loads, materials, carts and everything else. The friction problem intrigued the humankind from the earliest stage. However, its origins and description were ignored until the pioneering, albeit forgotten tests by Leonardo da Vinci. Leonardo da Vinci brought the first elements of understanding before 1519. The fist mathematical model was developed only in 1785.

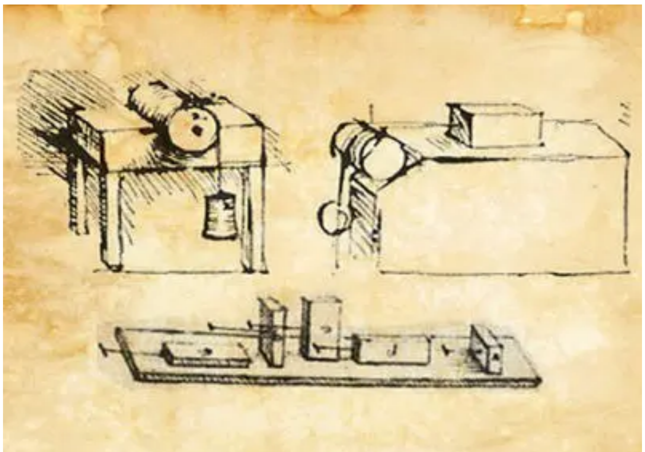


Figure 2 Experiments by Leonardo da Vinci.

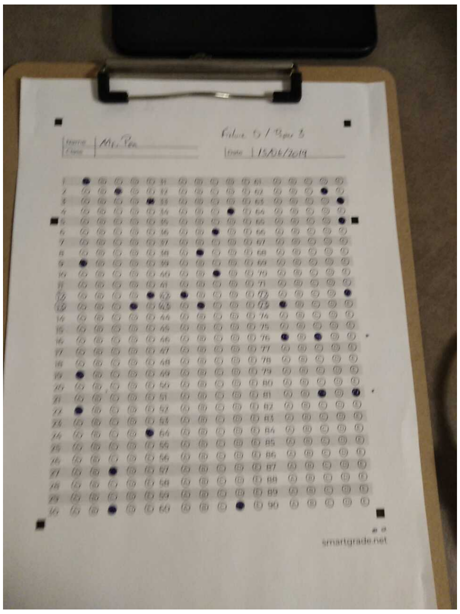
Project

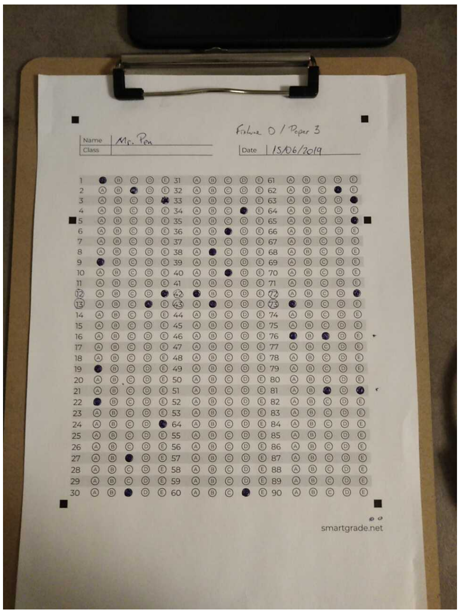
Your task will be to measure experimentally the friction between to materials.

- What model would you propose?
- How does the measurements comply with the model of Coulomb and experiments of Leonardo da Vinci?
- In the end:
- How does lubricant change the experimental results?

Project 3: Quantifying (and correcting) the blur in pictures

Description :
Communication in Today's society is largely based on images and movies. An image is indeed said to be worth a thousand words (proverb popularly attributed to Confucius). From a scientific point of view, psychologist Albert Mehrabian demonstrated in the 1960s that 93% of communication is non-verbal.
Visual communication is "non-verbal" communication that is transmitted through a visual medium, and is described as the transmission of ideas and information in forms that can be perceived in whole or in part by sight. It is often presented or expressed in two-dimensional images, and includes: signs, typography, drawings, graphics, illustrations, industrial design, advertising, animation, color and electronic resources. The roots of visual communication extend to the earliest expressions of humanity with the prehistoric cave drawings. Nowadays, it includes images and videos on social media (Tiktok, Pinterest, …). Having the perfect image is difficult! One of the most common defects is blur. There are 2 types of blur: motion blur (for objects in motion) and defocus blur (when the image is out of focus). In this project, you will investigate how to quantify defocus blur in greyscale images.





Blurry and sharp images
From https://rbaron.net/blog/2020/02/16/How-to-identify-blurry-images.html

Objectives :
- Take pictures with different conditions of defocus blur.
- Understand the role of Fast Fourier Transform (FFT) in ImageJ.
- Propose a script (in Python) to quantify the level of blur in the images, based on FFTs.

- Test your script on images acquired with an Environmental Scanning Electron Microscope (images already available)

A tour of the microscopy lab will be organized and if possible, you will be allowed to take part to an experiment!

Project 4: Would the Saint Simeon Stylites column buckle?

In a fifth century Syria, monk Simeon had become too famous. And with the fame came a drawback. All day along flocks of pilgrims sought his advice leaving him with no spare time.

One day, enough was enough. The monk took a radical decision. From now on, he would spend the rest of his life on top of an abandoned column, far from hustling crowds down below.

But crowds gathered none the less and make a lot of noise. A higher column would be preferable for a silence-loving hermit. Would you advice a to-be saint Simeon Stylites how high he could safely go? At which point would the column buckle? Is there a relationship predicting such a limiting height?

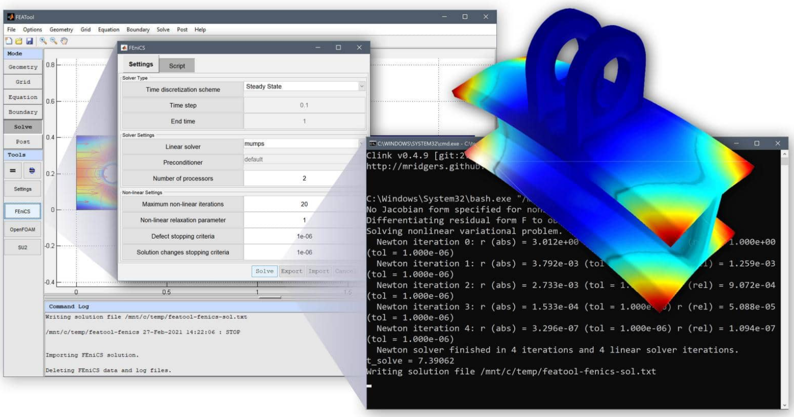
Project

Far from Syrian fifth century, we will investigate the problem with reduced experimental model of spaghetti and calibrated masses.

An experimental data will show the validity and limits of available models in the literature.

Project 5 : An introduction to computational physics

The use of computers to solve physics problems has revolutionized the way we understand and interact with the natural world. From simulating planetary orbits to modeling quantum systems, computational methods enable us to explore complex phenomena that are often inaccessible to analytical solutions. Applications of computational physics span diverse fields, including astrophysics, material science, fluid dynamics, and climate modeling. These tools not only enhance our ability to solve equations but also provide visualizations that deepen our comprehension of physical laws.



This student project serves as an introduction to computational physics, with a focus on solving problems in mechanics using Python. Centered around Newton's laws, the project will involve building computational tools to tackle a variety of scenarios.

Objectives:
The first objective is to create a program capable of solving simple mechanics problems based on examples discussed in tutorials, such as the motion of a mass on an inclined plane or the trajectory of a projectile.

The second objective is to develop a tool for generating "free body diagrams," which are critical in understanding forces acting on a system.

To achieve these goals, students will have the opportunity to leverage free Python libraries available in the community (e.g. SymPy for symbolic computation and Numpy tools for numerical resolutions among others…). These resources will complement the custom modules developed during the project. By the end of this project, students will not only enhance their programming skills but also gain a deeper understanding of how computational approaches can be applied to solve real-world physics problems. This hands-on experience is designed to prepare them for future challenges in the growing field of computational science.

Project 6: Using Photovoltaic panels to power a system

Project description:

In recent years, there has been a remarkable surge in the adoption of photovoltaic (PV) panels, marking a significant shift towards sustainable energy solutions. As global awareness of environmental issues intensifies, individuals and businesses alike are increasingly turning to PV panels to harness clean and renewable solar energy. The declining costs of PV technology, coupled with government incentives and a growing emphasis on carbon footprint reduction, have fueled this upward trend. n this project, you are proposed to dimension a PV installation to sustain a given system with its energy needs. You will be presented with different target applications (e.g., an isolated cottage in the French Alps, energy sustainment of a camping car, meeting the water energy needs of INSA residences…) but the project will also be open to any suggestions from you.

Useful link:

- PV energy calculation tool : http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

Project 7:
Prime Numbers and Cryptography
or
Measuring the Internet

Choose one of the two projects

<u>Prime Numbers and Cryprography</u>

Project objectives

The goal of this project is to implement and study methods used to find prime numbers, which are required in several modern cryptographic systems used on our everyday life (Internet, smartcards, phones, etc.).

1 Introduction

A prime number is a natural number that can only be divided by itself and one. Prime numbers have been studied since the antiquity when Euclid showed around 300 BC that there exist an infinite number of prime numbers. Prime numbers are associated with a number of interesting mathematical problems. In the 1970's one of these problem have been used to create a revolutionary cryptographic system called RSA.

2 Finding prime numbers

Finding a prime number is not a straightforward task. Prime numbers can be obtained using two types of methods :

- Trial division and Sieves
- Primality testing

2.1 Trial division and Sieves

The trial division consist in testing if a number n is prime by checking if any of the integers $i \in [2..\lceil \sqrt{(n)} \rceil]$ is a divisor of n. If no number in $[2..\lceil \sqrt{(n)} \rceil]$ is a divisor of n, then it is prime. A variant of this method is to use sieves to perform an exhaustive search of the prime numbers in a given interval $[2..M]$. This method uses a table containing all the number of the considered interval. The method works as follow: starting from one and for each number i

in the interval, mark all the multiple of *i* in the table as non-prime. At the end of this process only the prime numbers will be left unmarked in the table.

2.1.1 Program implementation

The previously presented can be automatized and left to a computer.

- Implement a program testing if a number *n* is prime.
- Implement the Sieve method: given an integer *M* compute all the prime numbers in [2..*M*]
- Try these algorithms by progressively increasing the input (*n* or *M*). What can you observe?

2.1.2 Complexity evaluation

The complexity of an algorithm is the number of basic operations that are performed by it. This complexity is tightly linked to the execution time and some algorithm are so complex that for some inputs, they cannot be finished in a reasonable time (less than a year for instance). As previously said, the number of operations performed by an algorithm often depends on the input. This is the case with the two previously implemented algorithms.

- Count the number of basic operation performed during the execution of each algorithm (1 basic operation = 1 test division / 1 multiplication)
- Plot the number of operation as a function of the input (*n* or *M*)

2.2 Primality testing

With the previously presented methods, one can say with 100% certainty if a number is prime or not. However, their complexity can become a problem. Indeed the number of operation required to finish the algorithm may be so large that the program may take hours, day, years or even centuries to complete. This is why a second class of method, called probabilistic primality tests, have been invented. They return an answer that is true with a certain probability (often close to 1 - e.g. 99.999%), but have a much lower complexity.

The Miller-Rabin primality test is a probabilistic algorithm commonly used to test numbers in real world application. The Miller-Rabin test if a number is prime by testing a set of properties.

Let *s* and *d*, two positive integers such that $n-1=2^s.d$ and given an integer $a\in[1..n-1]$ if

$$a^d \neq 1 (mod n)$$

AND

$$a^{2^r d} \neq -1 (mod n) \text{ for all } 0 \leq r \leq s-1$$

then *a* is called Strong Witness for the primality of *n*. Each Strong Witness is an additional evidence that the number is prime. However, if for some *a* the previous relations do not hold, then *n* is not prime.

The accuracy of the test is the probability of *n* being prime knowing that *k* Strong Witness have been found.

$$P(n \text{is Prime}|k) < 4^{-k}$$

- Implement the Miller-Rabin test
- Plot the complexity of the algorithm along with the accuracy as a function of the number of Strong Witness

3 Application to RSA

RSA is a cryptosystem invented by Rivest, Shamir and Adleman, which is based on prime numbers. Cryptography relates to the art of concealing information. RSA cryptosystem employs two keys: private key (K_{priv}) and public key (K_{pub}). A message *m* is encrypted into a ciphertext *m* as follows:

$$E_{K_{pub}}(m)=c$$

where $E_{K_{pub}}(.)$ is the encryption function.

Then the ciphertext *c* can be deciphered into *m* using the associated private key as follows:

$$D_{K_{priv}}(c)=m$$

. where $D_{K_{priv}}(.)$ is the decryption function.

The internals of the RSA cryptosystem are presented on the following page: `http://en.wikipedia.org/wiki/RSA`

Using this information:

- Implement the method generating the public and private key pair;
- Implement the Encryption and Decryption functions.

RSA in our everyday life

RSA and other public key cryptosystems are found in many objects and application. Explain where and how they are used.

Resources

- `http://en.wikipedia.org/wiki/Primality_test`
- `http://en.wikipedia.org/wiki/Miller%E2%80%93Rabin_primality_test`

Measuring the internet

1 Introduction

The Internet is part of our daily lives. We use it to access websites, call relatives on the other side of the planet or to stream movies on our TV. Behind those services lies a huge communication network composed of millions of elements communicating with each other. The goal of this project is to explore this complex structure, study the propagation time of information on the network, and to “measure” this worldwide network.

2 Preliminaries

Search the definition (in the context of computer networks) of the following terms:

- host
- packet
- hop

3 Network measurement tools

3.1 Ping

Ping is a tool used to measure the time taken by a network packet to perform a round trip to a given host on the Internet. This tool is installed by default on most operating system and must be called from the command line, ie a terminal. For instance, to "ping" the host google.com we use the command *ping google.com* and get the following result:

```
$ ping google.com
PING google.com (216.58.211.78) 56(84) bytes of data.
64 bytes from par03s14-in-f14.1e100.net (216.58.211.78): icmp_seq=1
ttl=54 time=1859 ms
64 bytes from par03s14-in-f14.1e100.net (216.58.211.78): icmp_seq=2
ttl=54 time=1208 ms
--- google.com ping statistics ---
3 packets transmitted, 2 received, 33% packet loss, time 2005ms
rtt min/avg/max/mdev = 1208.805/1534.291/1859.778/325.488 ms, pipe 2
```

Explain the information **icmp_seq** and **time** displayed for each ping:

```
64 bytes from par03s14-in-f14.1e100.net (216.58.211.78): icmp_seq=1
ttl=54 time=464 ms
```

Explain the meaning of the **min/avg/max/mdev** values in the statistics section:

```
--- google.com ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4000ms
rtt min/avg/max/mdev = 264.162/554.923/905.220/251.696 ms
```

Which of this value represents the best estimation of the packet travel time ?

3.2 Traceroute

Traceroute is a tool used to identify the hosts through which network packets are going to reach their destination. As *ping*, it is used through the command line. In order to identify the hosts between us and google.com, we use the command *traceroute google.com.*

```
$ traceroute google.com
traceroute to google.com (64.15.116.23), 30 hops max, 60 byte packets
 1  192.168.0.254 (192.168.0.254)  1.290 ms  2.096 ms  2.580 ms
 2  88.174.96.254 (88.174.96.254)  45.584 ms  55.760 ms  55.854 ms
 3  78.254.9.254 (78.254.9.254)  66.968 ms  67.112 ms  67.433 ms
 4  sto93-1-v902.intf.nra.proxad.net (78.254.255.89)  55.937 ms  56.036
ms  56.131 ms
 5  cbv-6k-2-po11.intf.nra.proxad.net (78.254.255.85)  57.146 ms  57.143
ms  57.141 ms
 6  bzn-crs16-2-be1009.intf.routers.proxad.net (194.149.161.9)  58.640 ms
48.501 ms  48.612 ms
 7  g-pni-1.routers.proxad.net (212.27.40.6)  45.827 ms  47.541 ms
49.955 ms
…
```

Using the traceroute command, observe the path between your computer and some the hosts listed in Annex A.

What is the meaning of * (stars) in the output of traceroute ?

4 Propagation time on the Internet

Select a list of host on the Internet

At what speed does the information propagate on an Internet link (copper cable, fiber-optic cable, satellite link) ?

The round trip time is not time is composed of the propagation time over the link. What are the other elements composing this round trip time ?

Measure the propagation time to an host in the USA (see annex A). From the measured round trip time, determine if the packet have traveled through a satellite or another path.

5 Routing

Information on the Internet is transmitted over links between hosts. Connexion between hosts often follow other major communication axis. In addition, the path taken by a packet to reach its destination can be influenced by many factors (e.g. peering contracts between network operators). As a consequence the path is rarely direct and straightforward.

Draw a map of the routing between your computer and some remote hosts (e.g. from Annex A). You can use tools such as Visual traceroute (http://www.yougetsignal.com/tools/visual-tracert/) or you can manually get the coordinates of each host from its IP using IP geolocation tools (https://www.iplocation.net/).

What can you observe ? Can you identity the highways of the Internet ?

6 Applications

6.1 Host geolocalisation

Measure the round trip time to the hosts of annex A. For each host, retrieve the GPS coordinates. Using the previous measurements, compute the barycenter of the hosts. Compute this barycenter with all the host located in 1) France 2) Europe 3) World.

What can you observe ?

Is this method reliable ?

Some web sites are providing Internet host geolocation (http://whatismyipaddress.com/ip/). Try this service to get the geolocation of some hosts. What can you say about those results ? What method is employed by those services to get the geolocation ?

6.2 Physical distance, round trip time and number of hop.

Given a host on the Internet, you have all the tools to measure the physical distance from your host, the round trip time over the Internet as well as the number of hops between your computer and the remote host.

Plot on a graph, the round trip time (resp. the number of hop) as a function of the physical distance.

What can you say of the relation between the physical distance and the the round trip time (resp. the number of hop) ?

According to those results, what do you think is the best way to “measure” the Internet ?

References

[1] Understanding Computers and the Internet (Lectures 3 & 4)
http://computerscience1.tv/2011/spring/

http://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-033-computer-system-engineering-spring-2009/video-lectures/lecture-9/

[2] TeleGeography, Global Internet Map

https://www.telegeography.com/telecom-maps/global-internet-map.html

[3] How-to Geek 8 Common Network Utilities Explained
http://www.howtogeek.com/190148/8-common-network-utilities-explained/

[4] The 2015 Internet Measurement Conference (IMC)
http://conferences2.sigcomm.org/imc/2015/program.html

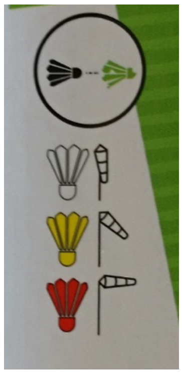
Annex A

Country	**Entity**	**Host name**
France	University of Strasbourg	*unistra.fr*
France	University Pierre et Marie Curie	*upmc.fr*
Germany	Technische Universität Berlin	tu-berlin.de
Spain	University of Barcelona	*ub.edu*
Italy	University of Turin	*unito.it*
England	University College London	*ucl.ac.uk*
Ireland	Trinity College Dublin	*tcd.ie*
Scotland	University of St Andrews	*st-andrews.ac.uk*
Egypt	Cairo University	*cu.edu.eg*
Turkey	Istanbul Technical University	*itu.edu.tr*
India	Indian Institute of Technology Delhi	*iitd.ac.in*
Japan	*Keio University*	*keio.ac.jp*
Brazil	University of São Paulo	usp.br
Australia	University of New South Wales	unsw.com
U.S.A	University of California: Berkeley	*berkeley.edu*
U.S.A	MIT - Massachusetts Institute of Technology	*mit.edu*

China	Shanghai Jiao Tong University	*en.sjtu.edu.cn*
South Africa	University of Pretoria	*up.ac.za*

Projects 8&9: Shuttlecock dynamics

This project is a joint project involving two student groups



When playing badminton, the shuttlecock (also referred to as *shuttle* or *birdie*) plays a central role, and its quality may impact significantly your play. Many types and materials exist, for different performances (speed, control, for instance). Among the different technologies, a sports gear store proposes three shuttles, adapted to slow, moderate and high wind (see Figure). What can make this difference?

This project aims at understanding and explaining this property, by studying the three shuttlecocks presented in the picture. What are their differences, and how do these differences play on their response to wind? Several features can be considered, such as mass, shape, fall velocity, color (…!) and so on.

To that end, two projects can be conducted:

- An experimental project, where you will have to
- measure the different shuttlecock properties
- design a holding support for performing wind tunnel measures
- conduct different experiments (fall, throw, wind tunnel…)

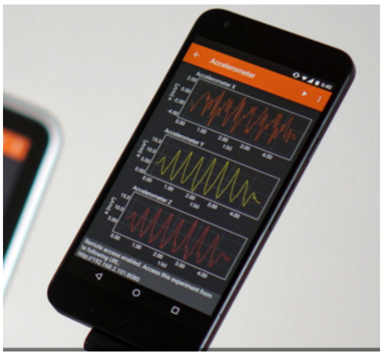
use computer image analysis to track trajectories and velocities (Python, ImageJ for instance), in order to extract key features of the shuttlecock's flight.

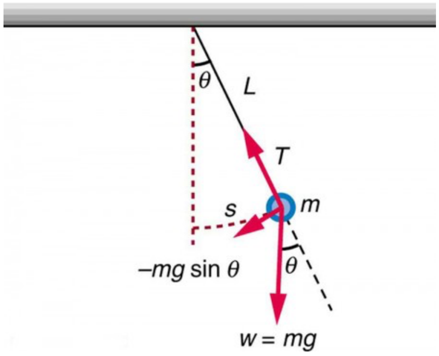
A numerical project using Python, where the goal will be to write a model able to predict the shuttlecock motion based on initial information (throw) and the physical properties on the forces. The trajectories will then be compared to experimental trajectories.

Two groups can work on this project, with close interactions regarding the force modeling, and the comparison between numerically predicted trajectories and real trajectories.

Project 10: Design of a lab experiment using your smartphone: pendular motion

We use the sensors embedded in our smartphones every day, often without even realizing it. The screen flips as you hold your phone in a landscape position because an accelerometer has detected the change. The ambient light sensor tells your screen to brighten when you go outside, and the proximity sensor tells your device to deactivate the touch screen when you hold the phone to your ear.
These accurate sensors (accelerometer, gyroscope, barometer, magnetometer, thermometer…) make your phone aware of its environment and actively interface with it.





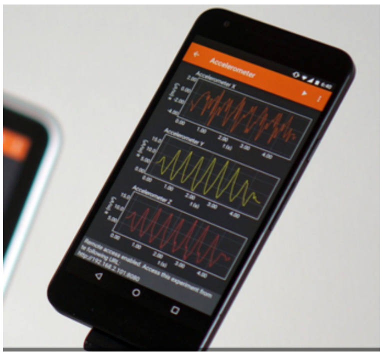
The objective of this project is to do design a lab experiment aiming at studying the motion of a simple pendulum. To turn your mobile phone into a pocket measurements lab, you will use the free application Phyphox – **Phy**sics **pho**ne e**X**periment (https://phyphox.org) available for Android and IoS systems. This application will allow you to visualize, record and export data from your smartphone's sensors.

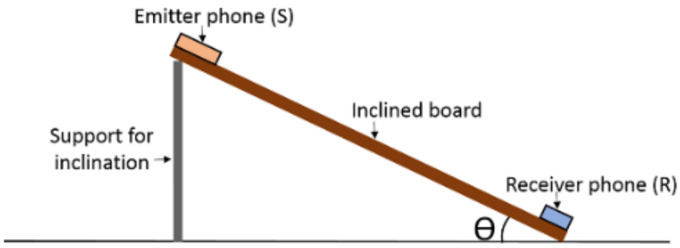
Tasks

- Understand the physics behind the pendular motion, progressing from the simplest idealized pendulum model to more complex scenarios, such as pendulums involving extended objects and distributed masses.
- Design experiment(s) and protocol(s) to record and anlayse the motion of pendular systems
- Confront experimental results to physical models and discuss model validity and uncertainties

Project 11: Use your smartphones to measure a physical quantity

We use the sensors embedded in our smartphones every day, often without even realizing it. The screen flips as you hold your phone in a landscape position because an accelerometer has detected the change. The ambient light sensor tells your screen to brighten when you go outside, and the proximity sensor tells your device to deactivate the touch screen when you hold the phone to your ear.
These accurate sensors (accelerometer, gyroscope, barometer, magnetometer, thermometer…) make your phone aware of its environment and actively interface with it.





The objective of this project is to do experimental physics with your smartphone. You will design a lab experiment aiming at determining the friction coefficient of an inclined plane.
To turn your mobile phone into a pocket measurements lab, you will use the free application Phyphox – **Phy**sics **pho**ne e**X**periment (https://phyphox.org) available for Android and IoS systems. This application will allow you to visualize, record and export data from your smartphone's sensors.

Tasks:

- Understand the physics behind the dynamics of the sliding smartphone;
- Design 2 experiments to measure the friction coefficient of an inclined plane;
- For each experiment, determine the protocol, get measures, and analyze them with a simple physical model;
- Confront the results of the 2 experiments and discuss their consistency and uncertainties.

Project 12: Microscopic image analysis with Python

Microscopic images are used in a variety of domains to analyze, for examples, the structure of metal grain, the deposit of silicon nanocrystals or biological organisms. In order to efficiently extract information from these images, one need images analysis tools that can extract and count structures in such images. In this project, we will focus on microscopic images showing the structure of materials (such as metals or crystals). The exact subject of analysis will be decided upon the start of the project (e.g. count the grains in the image, remove the noise…).

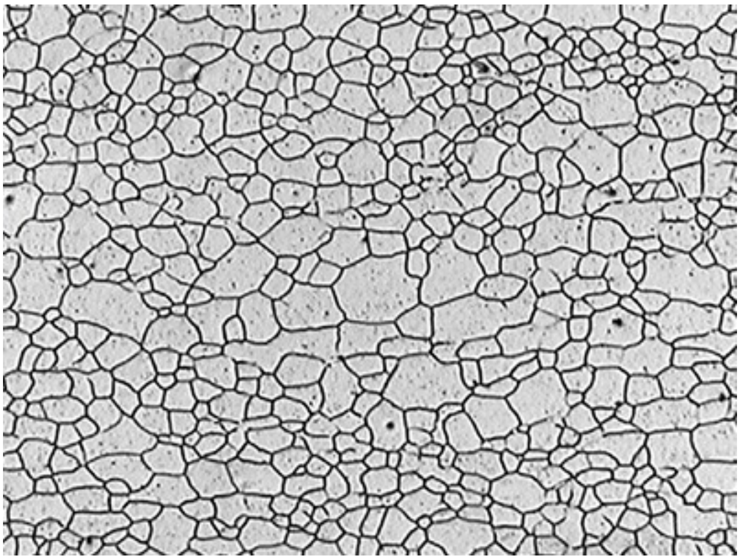


Figure 3 Microscopic structure of metal, showing grains that can be counted and measured. The size or density of the grains is crucial to verify the compliance with industrial norms.

In order to extract such information, the image will undergo a variety of mathematical operations to transform it and make it usable for computation. Typical image analysis operations include: convolution filtering, morphological operators, thresholding, flood filling algorithms and more. A popular tool to perform such operations is ImageJ, a scientific software for microscopic images. The goal of this project is to implement your own library for image analysis in Python, and use it to analyze microscopic images. The project will be done in collaboration with the MATEIS research lab that will provide microscopic images to be analyzed.

You will be allowed to use existing python libraries to load and visualize images, but not to perform any operations on them.

Objectives:

- Find and understand the main image filtering algorithms that are typically used to analyze microscopic images

  - list the main algorithms
  - identify the ones you will need to perform the given task
  - understand how they work and test them using existing libraries
- Implement a python library that allows to implement these operations without relying on existing libraries
- Use your library to analyze microscopic images
  - identify the different steps
  - explore the parameters that will allow to perform the task the best
  - analyze the resulting data

Deliverables:

- Your presentation should explain the different image filtering algorithms you used to extract the information from a microscopic image, and the important parameters that you had to chose
- The report should detail the different image algorithms that are included in your library with a basic explanation on them as well as the different steps you used to analyze the microscopic image and what information about the material it
- The python library and the code to analyze the image

Project 13: Tensegrity

Tensegrity, a portmanteau of "tensional integrity," represents a unique structural concept where elements are arranged in a state of continuous tension and compression. This innovative design principle has applications ranging from architecture (Fig1) to biomechanics. This student project aims to delve into the fascinating world of tensegrity structures by constructing a demonstrator using a 3D printer. Through this hands-on experience, participants will gain a deeper understanding of tensegrity's principles and its real-world applications.

Fig. 1: Kurilpa Bridge, Brisbane (Australia), is the world largest tensegrity bridge

Tasks and Objectives:

The primary objective of this project is to introduce and understand the underlying principles of tensegrity (i.e. intricate balance between tension and compression in structural design). By utilizing 3D printing technology and any other technique you would judge relevant, you will be invited to build and study a demonstrator consisting in a mechanical structure whose mechanical equilibrium rely on tensegrity principles.

Project 14: Felix Baumgarten's free fall

The aim of this project is to simulate the free fall of Felix Baumgarten an Austrian skydiver and former professional BASE jumper. On 14th October 2012, Baumgartner flew at a height of 39.045 kilometers into the stratosphere over New Mexico, United States, in a helium balloon before free falling in a pressure suit and then parachuting to Earth. The total jump, from leaving the capsule to landing on the ground, lasted approximately ten minutes. Baumgartner deployed his parachute after 4 minutes and 19 seconds, completing a total free fall distance of 36,529 meters.
At approximately 30,000 meters (98,000 ft), Baumgartner reached the speed of sound after approximately 40 seconds of free-fall, thus becoming the first human to brake the sound barrier without any form of engine power. The maximum speed achieved was measured 1,342.8 km/h (Mach 1.24).
From http://en.wikipedia.org/wiki/Red_Bull_Stratos

The idea of the project is to compare the numerical values from this "experiment" with the outputs from models of increasing complexity: you will first start with a very simple model that you'll solve analytically. You will then look into more details into some of the simplifying assumptions you made, for example:

- dependence of the gravitation with altitude?
- drag, air friction (how does it depend on Felix position, on the air pressure? How does the air pressure vary with altitude?)
- dependence of the speed of sound with altitude?

You will then have to solve the new movement equation numerically, and apply to different situations (balloon ascent, free fall and parachute landing)
You will discuss how well you can reproduce the values from the experiment and summarize clearly the impact of each model improvement and each parameter change you made You could also compare Felix's fall to the one from Alan Eustace on 24th October 2014.

Curriculum put into practice:
Numerical integration of ODEs using python. Mechanics: trajectory equations, drag force, fluids statics (equilibrium of the atmosphere) .