



PHYSICS

RESEARCH IN FRANCE

Derived from the Greek word for nature, physics is, etymologically, “the science of nature.” René Descartes—mathematician, physicist, and philosopher—described physics as the knowledge of nature, which corresponded at the time to the natural sciences or natural philosophy. Thus “physics” formerly encompassed present-day physics, chemistry, and the natural sciences. The meaning of the term today is more limited, as it deals in a quantitative and conceptual way with the building blocks of the universe, the forces they exert, and their effects.

Because it is both quantitative in its measurement of the constituent parts of the universe and conceptual in building theories based on the effects of forces, research in physics develops theories using the tool of mathematics to describe and predict the evolution of systems.



FROM BASIC TO APPLIED PHYSICS

Researchers specialize in theoretical physics (quantum physics, thermodynamics and statistical physics, electromagnetism) or in experimental physics (behavior of materials, electronics and components, fluids and flows).

Fields of application extend to energy and the environment, solidphase physical biology, and applied computer science.

INTERDISCIPLINARY RESEARCH

Although living things are not the usual province of physics, biology and physics share some applications. Biophysics uses the principles and processes of physics to analyze the structures and mechanisms of living things. Physics also enters into the methods of measurement used in chemical analysis.

These physico-chemical tools have made possible important progress in analytical chemistry in liquid states. The links between physics and earth and space sciences are the terrain of astrophysics.

In the past, distinctions were made among the various applications of physics to mechanics, electricity, optics, and other fields, whereas modern physics is concerned with phenomenological criteria—particle physics, nuclear physics, atomic and molecular physics, the physics of condensed media (solids and liquids), plasma physics, and so on. Today, experimental work focuses on understanding such fundamental structures, using accelerators to study particles and nuclei, neutron reactors to study condensed phases, and other experimental machinery to study other phenomena.

Since the time of **René Descartes** (1596-1650), **Blaise Pascal** (1623-1662), **André Ampère** (1775-1836) and **Sadi Carnot** (1796-1832), physics, like mathematics, has been one of France’s areas of research excellence, as evidenced by the 14 Nobel prizes awarded to illustrious French physicists—among them **Antoine Henri Becquerel**, **Pierre and Marie Curie**, **Louis de Broglie**, **Alfred Kastler**, **Pierre Gilles de Gennes**, **Georges Charpak**, **Claude Cohen-Tannoudji**, **Albert Fert**, **Serge Haroche** in 2012 and, in 2018, **Gérard Mourou**.

EXPERIMENTATION ON MATTER AND MATERIALS UNDER EXTREME CONDITIONS

French research in physics centers on the study of components, materials, and media: the fundamental constituents of matter, theoretical physics, and hot plasmas; dense media, materials, and components; dilute media and fundamental optics; and the science and physics of materials. Another trend in contemporary experimental physics is propelling investigations into matter subjected to extreme conditions, such as very high or very low temperature or pressure or very intense magnetic or electrical fields. Such conditions often reveal new properties of matter.

The example most often cited to illustrate this new scientific approach is that of superconductivity, of which magnetic levitation is one of the most prominent effects.



FRANCE PARTICIPATES IN MAJOR PHYSICS RESEARCH ORGANIZATIONS

Aeronautics

- **Large-scale wind tunnels for aeronautics and space**, providing aerodynamic conditions in which to test aircraft engines: <http://windtunnel.onera.fr>
- **Service des Avions Français Instrumentés pour la Recherche en Environnement (SAFIRE)**, the office that manages French aircraft equipped to collect data and perform experiments for research in atmospheric physics and chemistry: www.safire.fr



Astronomical observatories

- **ANTARES**, neutrino telescope: <http://antares.in2p3.fr>
- **Atacama Large Millimeter/Submillimeter Array (ESO ALMA)**, an observatory in Chile equipped with a millimeter–submillimeter radio interferometer: www.eso.org/sci/facilities/alma/
- **Cerenkov Telescope Array (CTA)**, ultra-high-energy gamma ray observatory: www.cta-observatory.org
- **CONCORDIA**, international station on the Antarctic continental shelf devoted to research on atmospheric physics and chemistry: www.institut-polaire.fr/ipev/infrastructures/les-bases/concordia/
- **High Energy Stereoscopic System (HESS phases I et II)**, Cerenkov stereoscopic telescope and international ultra-high-energy gamma ray observatory: www.mpi-hd.mpg.de/hfm/HESS/HESS.html
French team: <http://lphess.in2p3.fr/~hess/>
- **European Southern Observatory (ESO)**, the principal European organization in the field of astrophysics, sponsors a variety of scientific programs on planetology and cosmology. www.eso.org/public/france
- When completed, **the ESO European Extremely Large Telescope (ESO E-ELT)** will be the world's largest. Its main eye, 39 meters in diameter, will expand the field of visible light and infrared observation. www.eso.org/public/teles-instr/e-elt
- **The French oceanographic fleet:**
 - Ifremer fleet: <http://flotte.ifremer.fr>
 - Institut National des Sciences de l'Univers (INSU)-CNRS, the national space sciences

institute: www.insu.cnrs.fr

- Instrumentation, analytical equipment, observatories for geophysics and oceanography (IMAGO) - IRD Centre de Bretagne: www.brest.ird.fr/us191/flotte/flotte.htm
- Institut polaire français Paul-Émile Victor (IPEV), French polar institute: www.institut-polaire.fr/ipev/infrastructures
- **GODAE - MERCATOR**, the oceanographic forecasting system: www.mercator-ocean.fr
- **IRAM, the Institut de RadioAstronomie Millimétrique**, is operated by France, Germany, and Spain. Two observatories focused on wavelengths from 0.8 mm to 3.4 mm (70–350 GHz) are located at Pico Veleta near Grenada (Spain) and in France's Hautes-Alpes region. www.iram-institute.org
- The MATISSE and GRAVITY instruments built for the **ESO's large telescopes (INSTRUM ESO)** recombine mid-infrared light from four ESO telescopes with an astrometric precision of 10 microseconds of arc. www.eso.org
- **The Large Synoptic Survey Telescope (LSST)**, under construction in Chile since 2014, will deploy a 3.2 million pixel camera covering a surface equal to 40 times the full moon to map the entire sky over a period of 10 years. <http://lsst.in2p3.fr>
- **The La Silla and Paranal Observatory (ESO LSP)** operates a 3.6-meter telescope focused on exoplanets and a network of four combinable telescopes with 8-meter diameters. www.eso.org/sci/facilities/lpo.html

Nuclear

- **CLIC**, International Compact Linear Collider: www.linearcollider.org
- **European Consortium for the Development of Fusion Energy**: <https://www.euro-fusion.org>
- **European Spallation Source (ESS)**, the European neutron source: <https://europeanspallationsource.se>
- **Facility for Antiproton and Ion Research (FAIR)**, an international heavy ion, proton, and antiproton project scheduled to begin operation in 2013: www.fair-center.eu
- **Grand accélérateur national d'ions lourds**



(GANIL), the French national (CEA-CNRS) heavy-ion accelerator, generating and accelerating radioactive ions since 1983: www.ganil-spiral2.eu

- **Infrastructures de recherche - Résonance Magnétique Nucléaire, Très Hauts Champs (IR-RMN)**, a network high-field nuclear magnetic resonance facilities in Gif-sur-Yvette, Grenoble, Lille, Lyon, and Orléans: www.ir-rmn.fr
- **European Gravitational Observatory-VIRGO (EGO-VIRGO)**, a Franco-Italian consortium that manages the giant VIRGO interferometer that monitors and measures gravitational waves: www.ego-gw.it
- **European Organization for Nuclear Research - Large Hadronic Collider (CERN-LHC)**, the world's largest particle physics research facility: www.lhc-france.fr
- **Petawatt Aquitaine Laser (PETAL)**, a French intense-laser project in Aquitaine coordinated by the Institut Laser-Plasma (ILP): <http://petal.aquitaine.fr>
- **PRACE**, European advanced computing center: www.prace-project.eu
- **Réacteur Thermonucléaire Expérimental International (ITER)**, équipement de recherche en fusion nucléaire contrôlée (mise en service du réacteur en 2018) : www.iter.org/fr
- **Source Optimisée de Lumière d'Énergie Intermédiaire du LURE (SOLEIL)**, the French synchrotron in Saclay: www.synchrotron-soleil.fr
- **Système de production d'ions radioactifs accélérés en ligne (SPIRAL 2)**, a future facility to generate and accelerate radioactive ions: www.ganil-spiral2.eu/science/accélérateurs/spiral
- **Tore Supra**, superconducting magnetic coils: www.fusion-magnetique.cea.fr/cea/ts/ts.htm



CERN, THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

<http://public.web.cern.ch/public>

Founded in 1954, CERN is one of the world's largest and most prestigious scientific laboratories. It is devoted to basic research in physics and to the discovery of the fundamental building blocks and the laws of the universe. CERN uses complex scientific instruments-accelerators, colliders, and particle detectors-to probe the fundamental constituents of matter, or elementary particles. France is one of the 12 founding members of CERN, which now has 22 member states. Researchers from 600 laboratories and universities worldwide use the CERN facilities located on both sides of the border between France and Switzerland near Geneva. CERN scientists, including French physicist Georges Charpak, have been awarded 5 Nobel prizes.

Links to French physics departments and other research organizations can be found at the following CERN Web site: <http://ph-dep-usersoffice.web.cern.ch/ph-dep-usersoffice/MS/FranceWelcome.html>

MAJOR APPLICATIONS OF RESEARCH IN PHYSICS

Research in physics is pursued in several disciplines:

- Astrophysics covers cosmology, planetology, geophysics, physical oceanography, and plasma and astroparticle physics.
- Quantum physics encompasses atomic and molecular physics as well as research in optics and photonics.
- Particle physics is the home of nuclear physics and particle acceleration.
- Condensed matter physics embraces several disciplines: solid-phase physics, materials science, polymer physics, soft matter, mesoscopic physics, and disordered systems.

USUAL LINKS

- Allistene (alliance for digital sciences and technologies): www.allistene.fr
- ANDÈS, National association for Science PhD: www.andes.asso.fr
- ANR (France's national research agency): www.agence-nationale-recherche.fr
- ANRT, National agency for research: www.anrt.asso.fr
- CIFRE (industrial agreements on training through research): www.anrt.asso.fr >CIFRE
- CNRS, the national center for scientific research: www.cnrs.fr
- EURAXESS, mobility for researchers in Europe: http://ec.europa.eu/euraxess/index_en.cfm
- Fondation Alfred Kastler, hospitality and support for foreign researchers in France: www.fnak.fr
- Ministry of Higher Education and Research: www.enseignementsup-recherche.gouv.fr
- Physics at France's lycées, a CNRS profile: www.cnrs.fr/cnrs-images/physiqueaulycee/
- *Reflets de la physique*, the journal of the Société Française de Physique: www.refletsdelaphysique.fr
- Société Française de Physique (SFP, French physical society), since 1873: www.sfnnet.fr

FRENCH PHYSICISTS HAVE WON 14 NOBEL PRIZES

The Nobel prize in physics has been awarded since 1901. Beginning with **PIERRE** and **MARIE CURIE**, who won the prize in 1903 for their research into the phenomenon of radiation (discovered by **HENRI BECQUEREL**), French physicists have won a total of 14 Nobels in physics, including 4 in the last 20 years.

■ A 1955 graduate of the *École Normale Supérieure de Paris*, **PIERRE-GILLES DE GENNES** (1932–2007) became a research engineer at France's atomic energy commission and professor at the *Faculté d'Orsay* and the *Collège de France*. He later directed the *École supérieure de physique et de chimie industrielles de la Ville de Paris* and was a research fellow at the *Institut Curie*. He won the prize in 1991 for his work on liquid crystals.

■ **GEORGES CHARPAK** (1924–2010) was affiliated with the *École supérieure de physique et de chimie industrielles de la Ville de Paris* and with CERN, the European nuclear research organization, when he took home the 1992 Nobel prize in physics in recognition of his invention and developmental work with particle detectors (the multiwire proportional chamber).

■ **CLAUDE COHEN-TANNOUDJI** held the chair in atomic and molecular physics at the *Collège de France* from 1973 to 2004. The French national center for scientific research (CNRS) awarded him its gold medal in 1996. While a research scientist with the Kastler-Brossel laboratory at the *École Normale Supérieure de Paris*, he shared the 1997 Nobel prize in physics for his development of methods to cool and isolate atoms using lasers.

■ A specialist in the physics of condensed matter, **ALBERT FERT** is professor emeritus at the *Université Paris-Sud 11* and scientific director of the CNRS-Thales joint research unit. He shared the 2007 prize with Germany's Peter Grünberg for the discovery of giant magnetoresistance.

■ **SERGE HAROCHE** received the Nobel Prize in Physics in 2012 for research in quantum physics performed at the Kastler Brossel Laboratory (ENS-UMPC) in collaboration with American David Wineland (NIST Boulder Laboratories, Colorado). Their work made it possible to measure and manipulate discrete quantum systems, photons, and ions. Haroche graduated from the *École Normale Supérieure (ENS)*. He is a lecturer at the *École Polytechnique*, a professor at *Sorbonne Université*, and a research scientist at CNRS, France's national center for

scientific research, which awarded him its gold medal in 2009. For nine years he also taught at Yale University and chaired the physics department at ENS (1994–2000). He was named a professor at the Collège de France in 2001.

■ **GERARD MOUROU** shared the 2018 Nobel Prize in Physics with American Arthur Askin and Canadian Donna Strickland for their work on lasers. Mourou is professor emeritus at the *École Polytechnique*, where he directed the applied optics laboratory from 2005 to 2009 following a 30-year research career at the University of Michigan (United States). He initiated the Extreme Light Infrastructure project, which will equip Europe with large intense laser facilities in Romania, Hungary, and the Czech Republic.

FRENCH RESEARCH

PORTAL

www.campusfrance.org/en/researcher

A UNIQUE, **ONLINE-ACCESS INFORMATION POINT**
FOR LOCATING RESEARCH PROJECTS



◆ UNDERSTANDING FRENCH RESEARCH

- > Understanding how PhDs operate in France;
- > Knowing how to start and finance a PhD;
- > Applying to international research programs (Hubert Curien Partnerships, *Make Our Planet Great Again*, etc.).



◆ DIRECTORY OF DOCTORAL SCHOOLS

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