

# WASHINGTON UNIVERSITY

## DEPARTMENT OF PHYSICS

St. Louis, Missouri 63130

Students Accepted For Degree	FIELDS		
	Physics	Astronomy	Related Fields
Doctorate	X		
Master's	X		

### 1. General

*Chancellor:* Mark S. Wrighton  
*Dean of Graduate School:* Richard Smith  
*Type of Institution:* Private University  
*Department Chairman:* Kenneth F. Kelton  
*Department Telephone Number:* (314) 935-6276  
*Web site:* physics.wustl.edu  
*E-mail:* jmh@wustl.edu  
*Type of Institution:* University  
*Control:* Private  
*Setting:* Suburban  
*Total Faculty:* 3,297  
*Total Students:* 13,761  
*Total Graduate Students:* 6,651  
*Annual Graduate Tuition:*  
*All Graduate Students:* Full-time—\$39,400  
 Part-time—\$1,642/credit  
*Tuition rates for:* 2010-11  
*Deferred tuition plan:* No  
*Annual Other Fees:* None  
*Term:* Semester

### 2. Number of Faculty in Department

The combined total of full-time faculty in the three professorial ranks is 27. The combined total of full-time, part-time, and other faculty at all ranks is 36.

### 3. Admission, Financial Aid, and Housing

*Address admission inquiries to:* Julia M. Hamilton, Washington University, Department of Physics, One Brookings Drive, CB 1105, St. Louis, MO 63130-4899, jmh@wustl.edu  
*Graduate application fee required:* \$45  
*Admission deadline (Fall admission):* 12/31  
*Admission information:* For fall admission, 2009-10, 14 students were admitted. There were 139 applicants.  
*Admission requirements:* For admission to the graduate programs, a Bachelor's degree is required with no minimum undergraduate GPA specified. The average GRE scores for those who were offered admission for 2008-09 were: verbal-546; quantitative-772; analytic-N.A.; and advanced-760. Both the GRE and GRE Advanced are required. No minimum acceptable score is specified. Students from non-English speaking countries are required to demonstrate proficiency in English via the TOEFL. The minimum acceptable score is 550.  
*Undergraduate preparation assumed:* Mechanics: Marion, *Classical Dynamics of Particles and Systems*; Electromagnetic Theory: Lorrain and Corson, *Electromagnetic Fields and Waves*; Statistical Physics: Reif, *Statistical and Thermal Physics*; Mathematics, through the level of advanced calculus.  
*GAPSAS application required:* No

*Financial aid deadline:* 12/31

*Loans available:* No

*Address housing inquiries to:* Off-Campus Housing, Box 1075, Telephone (314) 935-5092

*On-campus, student housing available:* No

**Table A—Faculty, Enrollments, and Degrees Granted**

Research Specialty	2008-09 Faculty	Enrollment <sup>1</sup> Fall 2009		No. of Degrees Granted <sup>2</sup> 2009-10 (2005-09)			Median No. of Years for 2009-10 Ph.D.'s
		Master's	Doc-torate	Master's	Terminal Master's	Doc-torate	
<b>Astrophysics</b>	5	–	8	0(0)	0(0)	1(10)	6.0
<b>Biological</b>	3	–	8	0(0)	0(0)	2(9)	4.6
<b>Biomedical &amp; Health Physics</b>	2	–	13	0(0)	0(0)	1(12)	5.0
<b>Condensed Matter Physics</b>	7	–	15	0(1)	0(1)	2(18)	5.6
<b>Nuclear Physics</b>	2	–	4	0(1)	0(1)	0(2)	5.5
<b>Particles &amp; Fields</b>	5	–	4	0(0)	0(0)	1(6)	5.5
<b>Relativity &amp; Gravitation</b>	2	–	2	0(0)	0(0)	0(7)	6.0
<b>Space Physics</b>	6	–	2	0(0)	0(0)	1(2)	6.0
<b>Non-specialized</b>	0	–	27	7(52)	1(6)	0(0)	–
<b>Total</b>		–	83	10(68)	1(6)	8(62)	
<b>Full-time Grad. Stud.</b>		–	82				
<b>Part-time Grad. Stud.</b>		–	1				
<b>First-year Grad. Stud.</b>		–	14				
<b>Median Years in Grad. Study (2008-09 Degrees)</b>				2	–	5.5	–
<b>Undergraduate Degrees, 2008-09 (2003-08):</b>							14(96)

<sup>1</sup>Students not yet committed to a research specialty are entered under non-specialized.

<sup>2</sup>Five-year totals in parentheses.

### 4. Graduate Degree Requirements

*Master's:* 30 semester-hours, with "B" average; one year in residence required. No foreign language requirement. 30 semester hours of satisfactory course credits, at least 24 in graduate-level classroom or seminar courses, and at least 12 hours in core graduate courses. Students must maintain a grade point average of B or better. A thesis is not required, but if a satisfactory thesis is submitted, only 24 semester-hours are required.

*Doctorate:* 72 graduate semester-hours in physics, mathematics, and other approved subjects, including credit earned on thesis research and in supervised teaching. GPA of "B" required in classroom courses. At least two years full-time residence. Experience and demonstrated competence in the teaching of physics is required. No foreign language requirement. Students must take a total of six core 500-level courses. Students are required to pass an oral examination on advanced physics at a level appropriate for a student beginning research in that area. Submission of an original research dissertation, and an oral examination in defense of the dissertation.

*Thesis:* Thesis may be written in *absentia*.

*Special Equipment, Facilities, or Programs:* McDonnell Center for the Space Sciences. NANOSIMS—This first-of-its kind instrument is capable of making precise isotopic measurements at a spatial resolution  $\leq 1000\text{\AA}$ . Laboratory for Experimental Astrophysics. Laboratory for Ultrasonics with the as-

sociated Biomedical Physics Program. Cardiovascular Biophysics Laboratory in collaboration with the Washington University School of Medicine. Center for Materials Innovation in collaboration with the departments of Chemistry and Earth and Planetary Sciences, and the School of Engineering and Applied Science, Laboratory for High Pressure Physics. The JEOL 2100F scanning transmission electron microscope measures structure and composition of materials at nm-scale. Laboratory for high precision isotope analyses of noble gases.

**Table B—Appointments to Graduate Students, 2009–10**

Title of Appointee	Appointments		Academic Load Allowed in Credit Hours	Hours of Service Per Week	Stipend for Academic Year (\$)
	Total	First year			
	<b>Semester</b>				
Teaching Fellow	23	0	11 <sup>1</sup>	15	19,110 <sup>2,5</sup>
Dean's University Fellow	15	14	12		19,110 <sup>2,5</sup>
Compton Fellow	1	1	12		6,644
Research Assistant	27	0	9	variable	19,110 <sup>2,5</sup>
GAANN	7	0	12	0	30,000 <sup>8</sup>
McDonnell Graduate Fellow	1	0	9	0	25,000 <sup>3,10</sup>
McDonnell Astronaut Fellow	0	0	9	0	30,000 <sup>3,4</sup>
NASA Graduate Fellow	3	0	9	0	22,000 <sup>3,9</sup>
NIH Graduate Fellow	1	0	9	0	N.A.
NSF Graduate Fellow	0	0	9	0	30,000
Dissertation Fellow	1	0	0	0	19,110 <sup>2,3</sup>
Academic Hughes Fellow	0	0	11 or 12	0	3,000 <sup>6</sup>
Summer Hughes Fellow	5	0	0		
Olin Fellow	0	0	12	0	26,250 <sup>3,7</sup>
<b>Total</b>	<b>84</b>	<b>15</b>			

<sup>1</sup>Includes 9 credit hours for physics courses, 2 for supervised teaching.  
<sup>2</sup>\$19,110 for 2009–10.  
<sup>3</sup>Plus tuition remission.  
<sup>4</sup>\$30,500 for 2008–09.  
<sup>5</sup>During the first 5 years of graduate study, a Tuition Remission Scholarship is usually concurrent with a Teaching or Research Assistantship.  
<sup>6</sup>This is in addition to the stipend from a concurrent appointment, such as a Teaching Fellowship. It is awarded in recognition of superior academic achievement or promise. \$3,000 for 2008–09.  
<sup>7</sup>\$21,735 for 2008–09. May be supplemented by a Research Assistantship in the summer.  
<sup>8</sup>\$30,000 for 2008–09. Graduate Assistance in Areas of National Need, appointment from September–August.  
<sup>9</sup>Academic-year rate.  
<sup>10</sup>\$25,000 for 2008–09.

**5. Personnel Engaged in Separately Budgeted Research, 7/09–6/10**

Professorial faculty	23
Other faculty—Res. Prof.	7
Postdoctoral appointments	11
Graduate students	42
Undergraduate students	16
Nonteaching research personnel	7
<b>Total</b>	<b>106</b>

**6. Separately Budgeted Research Expenditures by Source of Support**

	Departmental Research
Federal government	\$5,983,076
Business and industry	83,300
<b>Total</b>	<b>\$6,066,376</b>

**Table C—Separately Budgeted Research Expenditures\***

Research Specialty	No. of Grants	Expenditures (\$)
Astrophysics	18	1,824,412
Space Physics	19	1,887,332
Biophysics	3	406,421
Condensed Matter Physics	14	541,147
Medical & Health Physics	14	735,652
Particles & Fields	4	511,686
Relativity & Gravitation	2	159,726
<b>Total</b>	<b>74</b>	<b>6,066,376</b>

\*Entries based on 10 months.

**FACULTY**

**Professors**

- Bender**, Carl M., Ph.D., Harvard, 1969. Konneker Distinguished Professor of Physics. Theoretical physics; mathematical physics; particle physics.
- Bernard**, Claude W., Ph.D., Harvard, 1976. Theoretical physics; particle physics; computational physics.
- Bernatowicz**, Thomas, Ph.D., Washington (St. Louis), 1980. Astrophysics; extraterrestrial materials; mass spectrometry and transmission electron microscopy.
- Buckley**, James H., Ph.D., Chicago, 1994. Gamma-ray astronomy; cosmic ray astrophysics.
- Carlsson**, Anders E., Ph.D., Harvard, 1981. Theoretical biophysics of cells.
- Clark**, John W., Ph.D., Washington (St. Louis), 1959. Wayman Crow Professor of Physics. Theoretical physics and astrophysics; many-body theory; neural networks; quantum control theory.
- Conradi**, Mark S., Ph.D., Washington (St. Louis), 1977. Experimental condensed matter physics; high-pressure systems; hydrogen storage in solids; applications of magnetic resonance; MR in medical imaging; hyperpolarized gases.
- Cowsik**, Ramanath, Ph.D., Bombay, 1968. National Academy of Sciences. Theoretical astrophysics; dark matter; experimental astroparticle physics; gravitation.
- Dickhoff**, Willem H., Ph.D., Free Univ. of Amsterdam, 1981. Theoretical physics; many-particle theory, nuclear physics.
- Gibbons**, Patrick C., Ph.D., Harvard, 1971. Experimental condensed matter physics; electronic and lattice structure determinations by electron scattering.
- Hohenberg**, Charles M., Ph.D., California, Berkeley, 1968. Experimental space science: astrophysics; rare gas mass spectroscopy.
- Israel**, Martin H., Ph.D., Caltech, 1968. High-energy astrophysics.
- Katz**, Jonathan I., Ph.D., Cornell, 1973. Theoretical astrophysics; applied physics.
- Kelton**, Kenneth F., Ph.D., Harvard, 1983. Arthur Holly Compton Professor of Arts & Sciences. Professor of Materials Science and Chairman of Department of Physics. Experimental solid-state physics and materials science.

**Miller**, James G., Ph.D., Washington (St. Louis), 1969. Albert Gordon Hill Professor. Ultrasonics; biomedical physics; elastic properties of inhomogeneous media.

**Ogilvie**, Michael C., Ph.D., Brown, 1980. Quantum field theory and particle physics; theoretical physics; computational physics.

**Schilling**, James S., Ph.D., Wisconsin, Madison, 1969. Experimental solid state physics; high-pressure physics; magnetism and superconductivity.

**Solin**, Stuart A., Ph.D., Purdue, 1969. Charles M. Hohenberg Professor of Experimental Physics. Professor of Materials Science, Director of the Center for Materials Innovation. Experimental condensed matter/materials physics.

**Suen**, Wai-Mo, Ph.D., Caltech, 1985. General relativity; cosmology; theoretical astrophysics.

**Will**, Clifford M., Ph.D., Caltech, 1971. James S. McDonnell Professor of Physics. National Academy of Sciences. Theoretical astrophysics; general relativity.

### Joint Professors

**Sastry**, Shankar M. L., Ph.D., Toronto, 1974. Materials science; metallurgy.

**Sobotka**, Lee G., Ph.D., California, Berkeley, 1982. Nuclear physics.

### Research Professors

**Amari**, Sachiko, Ph.D., Kobe University, Kobe, Japan, 1986. Presolar grains, meteorites, noble gas and secondary ion mass spectrometry.

**Binns**, W. Robert, Ph.D., Colorado State, 1969. Astrophysics.

**Meshik**, Alex P., Ph.D., Vernadsky Institute, Moscow, 1988. Space physics; rare-gas mass spectrometry.

**Zinner**, Ernst, Ph.D., Washington (St. Louis), 1972. Astrophysics; experimental space science; extraterrestrial materials.

### Associate Professors

**Alford**, Mark G., Ph.D., Harvard, 1990. Quantum field theory and particle physics; color superconductivity.

**Krawczynski**, Henric, Ph.D., Hamburg, 1997. High-energy astrophysics; gamma-ray astronomy.

**Wessel**, Ralf, Ph.D., Cambridge, 1992. Biophysics of neurons and neural computation.

### Research Associate Professors

**Floss**, Christine, Ph.D., Washington (St. Louis), 1991. Space Physics; cosmochemistry

**Holland**, Mark R., Ph.D., Washington (St. Louis), 1989. Ultrasonics; biomedical physics; biomedical ultrasound.

**Leopold**, Daniel J., Ph.D., Washington (St. Louis), 1983. Semiconductor physics; electro-optics; materials science; magnetic resonance.

### Assistant Professors

**Ferrer**, Francesc, Ph.D., Universitat Autònoma de Barcelona, 2001. Particle cosmology: Composition and evolution of the universe, the nature of dark matter and dark energy; ultra high-energy cosmic rays.

**Nussinov**, Zohar, Ph.D., UCLA, 2000. Condensed matter and materials theory.

**Seidel**, Alexander, Ph.D., MIT, 2003. Condensed matter and materials theory.

**Wang**, Yan Mei, Ph.D., California, Berkeley, 2002. Experimental biophysics, single-molecule imaging

**Yang**, Li, Ph.D., Georgia Institute of Technology, 2006. Condensed matter and materials theory.

### Senior Lecturer

**Hynes**, Kathryn, Ph.D., Washington University (St. Louis).

### Emeritus Faculty

**Friedlander**, Michael W., Ph.D., Bristol, 1955. Cosmic rays; astrophysics; archaeoastronomy.

**Luszczynski**, Kazimierz, Ph.D., London, 1959. Solid state and low-temperature physics; magnetic resonance.

**Phillips**, Peter R., Ph.D., Stanford, 1961. Biomedical physics; general relativity and gravitation; astrophysics.

**Scandrett**, John H., Ph.D., Wisconsin, 1963. Biomedical physics; computer applications.

**Shrauner**, J. Ely, Ph.D., Chicago, 1963. Theoretical physics; elementary particle theory; high-energy physics.

**Sundfors**, Ronald K., Cornell, 1963. Ultrasonic studies of solids; acoustic magnetic resonance.

### Adjunct Professors

**Anderson**, Charles H., Ph.D., Harvard, 1962. Biophysics; signal processing; machine vision.

**Dixit**, Vijai V., Ph.D., Purdue, 1972. Theoretical physics.

**Elson**, Elliott L., Ph.D., Stanford, 1966. Molecular biophysics.

**Falster**, Robert, Ph.D., Stanford, 1983. Electronic materials.

**Khodel**, Victor A., Ph.D., Moscow Engineering & Physics Institute, 1965. Theoretical physics.

**Malik**, Fazley Bary, Ph.D., Goettingen, 1958. Theoretical physics.

**Mandula**, Jeffrey E., Ph.D., Harvard, 1966. Theoretical physics; particle physics; mathematical physics.

**Rigden**, John S., Ph.D., Johns Hopkins, 1960. History of science; molecular physics.

**Ristig**, Manfred L., Ph.D., Cologne, 1966. Many-body theory; condensed matter theory.

**Wickline**, Samuel A., M.D., Hawaii, 1980. Cardiology; ultrasonics; biophysics.

**Yablonskiy**, Dmitriy A., Ph.D., Ukrainian Academy of Sciences, 1972. Magnetic resonance; medical and health physics.

### Adjunct Associate Professors

**Christian**, Eric R., Ph.D., Caltech, 1989. Cosmic rays; high-energy astrophysics.

**Comer**, Gregory L., Ph.D., University of North Carolina, 1990. General relativity; astrophysics.

**Conturo**, Thomas E., Ph.D., M.D., Vanderbilt, 1989. Magnetic resonance imaging.

**Fraundorf**, Philip B., Ph.D., Washington (St. Louis), 1980. Space physics; solid state physics; statistical physics.

**Kalyanaraman**, Ramki, Ph.D., North Carolina State, 1998. Experimental materials science and solid state physics.

**Kovacs**, Sandor J., Jr., Ph.D., M.D., Caltech, 1977. Cardiovascular bio-physics; non-linear dynamics.

**Redmount**, Ian H., Ph.D., Caltech, 1984. General relativity, astrophysics.

### Adjunct Assistant Professors

**Culver**, Joseph P., Ph.D., University of Pennsylvania, 1997. Biomedical physics; diffuse optical tomography.

**Leopold**, Mary M., Ph.D., Washington (St. Louis), 1985. Optical response theory; electro-optics; mathematical physics.

- Sept, David S., Ph.D., Alberta, 1997. Theoretical biophysics; soft condensed matter physics.
- Woods, Jason C., Ph.D., Washington University (St. Louis), 2002. Biophysics; applied physics; hyperpolarized-gas MRI.

## RESEARCH SPECIALTIES AND STAFF

### Theoretical

- Applied Physics. Acoustic radiation, hydrodynamics, Mpemba effects, plasma physics. Katz.
- Astrophysics. Ultradense matter, neutron stars and quark stars; superfluidity and color superconductivity in compact stars; high-energy astrophysics and astroparticle physics. Alford, Clark, Cowsik, Dickhoff, Ferrer, Katz, Khodel.
- Biophysics. Force generation in biological systems; self-assembly of biopolymer networks; protein-protein interactions; neural networks; computational neuroscience; cardiovascular physiology and biophysics; nonlinear dynamics. Anderson, Carlsson, Clark, Kovacs, Sept.
- Condensed Matter Physics. Quantum fluids; strongly correlated electron systems; metal-insulator transitions; non-Fermi liquids; quantum critically; superconductivity; spin systems; quantum Hall effect; one-dimensional systems; soft condensed matter; magnetism; topological order; transition metal oxides; amorphous and complex ordered structures; glass transition; electronic structure; orbital order; statistical mechanics; mesoscopic physics; optimization and network problems; cold atom physics, excitonic effects. Clark, Dickhoff, Khodel, Nussinov, Seidel, Yang.
- Elementary Particles and Fields. Perturbation theory; quantum chromodynamics; Non-Abelian gauge theories and confinement; quark matter; lattice gauge theory; color superconductivity; PT-symmetric theories; semiclassical approximations. Alford, Bender, Bernard, Ferrer, Ogilvie.
- Low Temperature Physics. Many-body theory of helium liquids. Clark, Dickhoff, Khodel.
- Materials Science/Metallurgy. Alloys; amorphous and defective solids; theory of fracture; nucleation theory, semiconducting nanostructure, graphane, photovoltaics. Carlsson, Kelton, Nussinov, Yang.
- Nuclear Physics. Many-body theory of nuclear matter and finite nuclei. Clark, Dickhoff, Khodel.
- Relativity. Gravitational radiation, black holes, tests of general relativity; numerical relativity; galactic dynamics, dark matter, cosmology. Cowsik, Ferrer, Suen, Will.
- Statistical and Thermal Physics. Statistical mechanics; phase transitions; statistical mechanics of solitons; renormalization group. Carlsson, Nussinov, Ogilvie, Seidel.
- Systems Science. Theory of quantum control systems. Clark.
- Other Computational Physics. Parallel computation; simulation; numerical analysis, first-principles calculations. Alford, Bender, Bernard, Carlsson, Clark, Dickhoff, Kelton, Miller, Nussinov, Ogilvie, Suen, Yang.

### Experimental

- Acoustics. Elastic and viscoelastic properties of media including hard and soft tissue; ultrasonic imaging and quantitative ultrasonic imaging and quantitative ultrasonic investigation of the cardiovascular system; characterization of bone and of osteoporosis. Kovacs, Holland, Miller, Wickline.
- Applied Physics. Quantitative analysis of images; nondestructive evaluation of composite materials; magnetic resonance imaging of materials; ultrasonic transducers. Conradi, Holland, Leopold, Miller.
- Astrophysics/Extraterrestrial Materials. Solid state, ion micro-

probe, noble gas mass spectrometric and electron microscope investigations of ancient stardust in meteorites and interplanetary dust; nucleosynthesis, stellar evolution, origin and evolution of the solar system including planetary atmospheres and organic molecules, early chronology from studies of (now) extinct isotopes. Amari, Bernatowicz, Floss, Hohenberg, Meshik, Zinner.

Biophysics. Elastic properties of tissue; cardiac mechanics; mechanisms of ultrasonic propagation in tissue; cardiac Doppler ultrasound; wave-guide properties of retinal cells; mechanics of biomembranes; brain imaging; pulmonary physiology; biophysics of neural computation; physics of single neurons; single-molecule imaging. Holland, Kovacs, Miller, Wang, Wessel, Wickline, Woods.

Dark Matter. Laboratory and astronomical searches for dark matter. Buckley, Cowsik.

High-Energy Astrophysics. Cosmic-ray elemental and isotopic composition and energy spectra, gamma-ray and x-ray astrophysics of galactic and extragalactic sources, observations from spacecraft and high-altitude balloons; astrophysics of the highest-energy galactic and extragalactic gamma-ray sources; observations with ground-based atmospheric Cherenkov detectors; correlated optical observations of high-energy astronomical transients; observations of very high energy neutrinos from high-altitude balloons over Antarctica. Binns, Buckley, Israel, Krawczynski.

Low-Temperature Physics. Phase transitions; absorbed films; ortho-para conversion in hydrogen; hydrogen on surfaces; pressure-induced superconductivity. Schilling.

Condensed Matter/Materials Physics. Hydrogen in metals and ionic and complex solids; nucleation and phase transitions in liquid and solids; synchrotron x-ray diffraction and thermophysical property measurements of equilibrium and non-equilibrium liquids; x-ray and electron microscopy studies of quasicrystalline phases; superconductivity and magnetism under extreme pressures; high-Tc superconductivity; pressure-induced insulator-to-metal transitions; elastic and viscoelastic properties of composites; nanocrystalline materials; thin film growth and characterization; wide and narrow-gap semiconductors; extraordinary magnetoresistance; physisorbed (two-dimensional) matter; nuclear magnetic resonance; photoluminescence and photoconductivity in conducting polymers; electron microscopy and inelastic electron scattering in solids; plasmons in simple metals and composites; magnetic properties of Kondo lattices and weak itinerant ferromagnets, tensile stress-dependent transport properties of narrow-gap semiconductors; 2D physics and magnetic frustration in layered double hydroxides. Conradi, Gibbons, Kelton, Leopold, Miller, Schilling, Solin.

Medical and Health Physics. Quantitative ultrasonics and ultrasonic imaging; quantitative cardiovascular physiology echocardiography; nuclear magnetic resonance imaging (MRO) and positron emission tomography (PET); MRI of lungs with hyperpolarized gas. Conradi, Conturo, Culver, Holland, Kovacs, Miller, Wickline, Woods, Yablonskiy.

Nuclear Physics. Heavy-ion reaction studies from near barrier to relativistic energies; reaction dynamics studied with particle-particle interferometry and atomic x-ray clocks; fragmentation cross sections of cosmic-ray nuclei on various targets; double beta decay; natural nuclear reactors. Binns, Israel, Krawczynski, Meshik, Sobotka.

Relativity and Gravitation. Tests of the equivalence principle; study of forces in the submillimeter domain, including Casimir forces, axion exchange, and violations of the inverse square law of gravitation. Cowsik.