REGIONAL CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION

Space and atmospheric science

Education curriculum

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REGIONAL CENTRES FOR SPACE SCIENCE AND TECHNOLOGY EDUCATION
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Preface

1. Thousands of years ago, on a small rocky planet orbiting a modest star in an ordinary spiral galaxy, our remote ancestors looked up and wondered about their place between Earth and sky. In the twenty-first century, people ask the same profound questions about how the universe began and evolved, how people got here, where they are going and whether they are alone in the universe. After only the blink of an eye in cosmic time, those questions are beginning to be answered. In the last 40 years, space probes and space observatories have played a central role in that process.

2. Space and atmospheric science missions and research are now generating news on a daily basis worldwide. They are responsible for programmes relating to astronomy, the solar system and the Sun and its interaction with Earth. Space and atmospheric science covers everything from the middle levels of Earth's atmosphere (about 60 kilometres up) to the edge of the universe billions of light years away. It may help to understand space and atmospheric science by considering the fields that are not involved, as follows:

(a) Earth science programmes are responsible for science relating to the Earth up to the middle levels of the atmosphere (about 60 kilometres up). They include topics like global warming and ozone depletion research;

(b) Human exploration and development in space is being addressed by manned spacecraft and space stations. Although space and atmospheric science may occasionally use spacecraft and space stations as carriers of space experiments, it is not the primary user of those vehicles and does not involve the management of them;

(c) Biological and physical research programmes are responsible for materials science and life science research done aboard spacecraft and space stations;

(d) Aerospace technology programmes work on technologies for better airplanes and future launch vehicles (rockets).

Contents

Explanatory notes

CCD	charged coupled device
CO_2	carbon dioxide
DIAL	differential-absorption lidar
f/#	a telescope of focal ratio f/# has an aperture equal to one #th of its focal length
GIS	geographic information system
GMRT/OSRT	Giant Metrewave Radio Telescope/Ooty Synthesis Radio Telescope
GPS	global positioning system
He-Ne	helium-neon
HF	high frequency
HI region	region of space where there is a large amount of ordinary hydrogen gas
IR	infrared
MCP	micro channel plate
MgF_2	magnesium florid
MST	mesosphere/stratosphere/troposphere
MUF	maximum usable frequency
RPA	retarding potential analyser
sporadic-E	E-region traces seen in an ionogram (mode of VHF propagation via the ionosphere that is of sporadic nature)
spread-F	diffused F-region trace seen in an ionogram (nighttime plasma instability phenomenon typical for the Earth's equatorial ionosphere)
TEC	total electron content
UV	ultra violet
VHF	very high frequency
VLBI	very long base interferometry
X-ray	electromagnetic radiation with wavelengths shorter than those of ultraviolet radiation but longer than those of gamma rays

Introduction

Space science and technology education can be pursued at the elementary, secondary and university levels. In spacefaring nations, elements of space science and technology have been introduced into science curricula at those levels. Such an innovation has not taken place in many developing countries, partly because the benefits of space science and technology have not been appreciated enough and partly because the facilities and resources for teaching science and technology at educational institutions are not yet well developed. Education in space science and technology in developed countries has become highly interactive; the World Wide Web and other information technologies have become useful tools in education programmes at all levels.

The incorporation of elements of space science and technology into university- level science curricula can serve a dual purpose for developed and developing countries. It can enable all countries to take advantage of the benefits inherent in the new technologies, which, in many cases, are spin-offs from space science and technology. It can revitalize the educational system, introduce the concepts of high technology in a non-esoteric fashion and help create national capacities in science and technology in general. In that regard, Lewis Pyenson emphasized in his recent work entitled *Servants of Nature*[1] that:

> "Both geographical decentralization and interdisciplinary innovation have become watchwords in academic science. Electronic information processing to some extent obviates the necessity for a scientist or scholar to reside at an ancient college of learning. Universities everywhere have adapted to new socioeconomic conditions by expanding curricula. They have always responded in this way, although never as quickly as their critics would like. Measured and deliberate innovation is one of academia's heavy burdens. It is also a great strength. Emerging fields of knowledge become new scientific disciplines only after they have found a secure place in universities. We look to universities for an authoritative word about the latest innovations. New scientific ideas emerge in a variety of settings, but they become the common heritage of humanity only when processed by an institution for advanced instruction like the modern university."

There are many challenges in the teaching of science at university level, both in developing and developed countries, but the challenges are of a higher magnitude in developing countries. The general problem confronting science education is the inability of students to see or experience the phenomena being taught, which often leads to an inability to learn basic principles and to see the relationship between two or more concepts and their practical relevance to problems in real life. Added to those problems are a lack of skills in the relevant aspects of mathematics and in problem-solving strategies. There are also language problems in countries in which science is not taught in the national language(s). Over the years, developed countries have overcome most of the basic problems, except perhaps a psychological problem, namely that students may consider science to be a difficult subject. In developing countries, however, basic problems linger, exacerbated by the fact that there are not enough academically and professionally well-trained teachers.

Establishment of the regional centres for space science and technology education

The General Assembly, in its resolution 45/72 of 11 December 1990, endorsed the recommendation of the Working Group of the Whole of the Scientific and Technical Subcommittee, as endorsed by the Committee on the Peaceful Uses of Outer Space, that the United Nations should lead, with the active support of its specialized agencies and other international organizations, an international effort to establish regional centres for space science and technology education in existing national/regional educational institutions in the developing countries (A/AC.105/456, annex II, para. 4 (n)).

The General Assembly, in its resolution 50/27 of 6 December 1995, paragraph 30, also endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space that those centres be established on the basis of affiliation to the United Nations as early as possible and that such affiliation would provide the centres with the necessary recognition and would strengthen the possibilities of attracting donors and of establishing academic relationships with national and international space-related institutions.

Regional centres have been established in India for Asia and the Pacific, in Morocco and Nigeria for Africa, in Brazil and Mexico for Latin America and the Caribbean and in Jordan for Western Asia, under the auspices of the Programme on Space Applications, implemented by the Office for Outer Space Affairs (A/AC.105/749). The objective of the centres is to enhance the capabilities of Member States, at the regional and international levels, in various disciplines of space science and technology that can advance their scientific, economic and social development. Each of the centres provides postgraduate education, research and application programmes with emphasis on remote sensing, satellite communications, satellite meteorology and space science for university educators and research and application scientists. All centres are implementing nine-month postgraduate courses (in remote sensing, satellite communications, meteorological satellite applications, and space and atmospheric sciences) based on model curricula that emanated from the United Nations/Spain Meeting of Experts on the Development of Education Curricula for the Regional Centres for Space Science and Technology Education, held in Granada, Spain, in 1995. Since 1995, these curricula (A/AC.105/649 and http://www.oosa.unvienna.org/SAP/centres/centres.htm) have been presented and discussed at regional and international educational meetings.

The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna in July 1999, recommended that collaboration should be established between the regional centres and other national, regional and international organizations to strengthen components of their education curricula.[2] In its resolution 54/68 of 6 December 1999, the General Assembly endorsed the resolution of UNISPACE III entitled “The Space Millennium: Vienna Declaration on Space and Human Development”, in which action was recommended to ensure sustainable funding mechanisms for the regional centres.[3]

United Nations Expert Meeting on the Regional Centres for Space Science and Technology Education: Status and Future Developments

The Office for Outer Space Affairs of the Secretariat organized, in cooperation with the European Space Agency (ESA), the United Nations Expert Meeting on the Regional Centres for Space Science and Technology Education: Status and Future Development in Frascati, Italy, from 3 to 7 September 2001. The Meeting was hosted by the ESA European Space Research Institute in Frascati.

The Meeting reviewed the status of establishment and operation of the regional centres with a view to enhancing cooperation between the centres. The main objective of the Meeting was to review and update curricula at the university level and across cultures in four areas: remote sensing, satellite meteorology, satellite communications and space science. The Meeting considered that education varied significantly between countries and even between institutions within the same country which led to differences in space science and technology education curricula in terms of course content and modes of presentation. The Meeting noted that the model curricula (A/AC.105/649) had contributed to resolving such problems.

The Meeting established five working groups to focus on the following specific topics and respective education curriculum: (a) management issues of the centres; (b) remote sensing; (c) satellite meteorology; (d) satellite communications; and (e) space science. The working groups drew on the knowledge and expertise of participants, thereby taking into account the results of previous nine-month postgraduate courses, particularly those organized since 1996 at the Centre for Space Science and Technology Education in Asia and the Pacific and since 1998 at the African Centre for Space Science and Technology—in French Language and the African Regional Centre for Space Science and Technology Education—in English Language.

The Meeting, through its working groups, updated the four education curricula and drew up course syllabuses that differ from most of those available in literature and on the World Wide Web. They are based on physics, mathematics and engineering as taught in many universities around the world. They are not tailored to any specific space-related project or mission that may have been or will be executed by any specific institution.

Curriculum on space and atmospheric science

The working group on space and atmospheric science, which was established during the United Nations Expert Meeting on the Regional Centres for Space Science and Technology Education: Status and Future Development reviewed and revised the curriculum for the third course (annex I), which commenced at the Centre for Space Science and Technology Education in Asia and the Pacific on 1 August 2002. The curricula for the second and first courses are shown in annexes II and III, respectively.

Purpose of the course and recommended topics

The working group felt that the course on space and atmospheric science should meet the need of developing countries to build a general capability in space science as a necessary support for infrastructure development. It should be suitable for: students with a background in physical sciences or engineering who wish to take up post-graduate study or other research in space science; university, college or secondary school teachers who require a good general knowledge of space science; engineers involved in space missions, either in the space or the ground segments; and administrators in any area of space activity.

The overall structure of the course should follow the same pattern as the other post-graduate courses, namely nine months of instruction involving a variety of teaching methods—lectures, tutorials, practical exercises, seminars etc.—and culminating in a pilot project of approximately two months' duration. This would be followed by a one-year research project, usually undertaken in the participant's home country and normally relevant to that country, during which period the students would have two supervisors, one from the regional centre and one from her/his home country. It was considered to be highly desirable for the pilot project to be the first phase of the one-year project, thus ensuring that the student returned home with at least some data, with suitable research training and with a working relationship with her/his supervisor from the centre. That would imply that even the pilot project would be selected in consultation with the supervisor in the home country.

The working group stressed that regional centres should have the freedom to use the teaching methods, selection criteria etc. that they preferred and that were appropriate for their region, particular conditions and expertise. The group recommended seven topics; an eighth topic, entitled "space geodesy", was also suggested and considered. The group felt that a suitable space and atmospheric science course would be expected to contain several (i.e. three to five) of the seven or eight topics, as decided by the centre giving the course. The curriculum could be interpreted flexibly and varied to suit a particular course design; the topics indicate in a general way the breadth and depth of study that would be expected. In some cases, for example spacecraft technology, the course designer might wish to include only some elements of a course, but the curriculum could provide a useful guide to what should be included. However, overall standards must be maintained fully at post-graduate level.

The eight topics are listed below. Instrumentation will normally be described as part of the appropriate topic.

1. Mathematics for space scientists and engineers

   As an introduction to the topic of mathematics for space scientists and engineers a refresher course could cover the following topics: algebra, geometry, trigonometry, linear algebra, calculus, ordinary differential equations, probability and statistics (Poisson and Gaussian distributions), introduction to numerical analysis, simple computer programming, basic knowledge of vector analysis. It may be desirable to make extensive use of examples taken from areas of space physics such as motion in a gravitational field, satellite orbits etc. Following the refresher course, the following courses could be held:

Statistics and data analysis: error analysis, time-series analysis, trends, Fourier analysis, effects of noise on data, fitting techniques, least squares, maximum likelihood, linear filtering methods, statistical tests of significance

Methods of numerical analysis: interpolation and extrapolation, finite difference methods, integration

Modelling: numerical solution of partial differential equations, development of a simple numerical model, practical use of numerical model

This list has deliberately been restricted in length, partly so that regional centres can, at their discretion, make additions appropriate to the other topics in space science that they are offering and partly in the expectation that students will be required to carry out short projects so that they develop real proficiency in mathematics.

2. Structure, composition, dynamics and evolution of planetary atmospheres

Atmospheres (including Earth's atmosphere)
Energy budget of planet Earth
Structure composition and dynamics of Earth's atmosphere
Solar radiation and effects of variability in Earth's atmosphere
Comparison with atmospheres of other planets
Long- and short-term evolution of the atmosphere
Regional climatology

3. Ionospheric physics

Structure and variability of Earth's ionosphere
Ionospheric techniques, especially space techniques
Ionospheric plasma dynamics
Optical emissions from the ionosphere
Ionospheres of the planets and their satellites
Ionosphere-atmosphere interactions
Radio communication through the ionosphere

4. Solar wind, magnetosphere and space weather

Solar activity and its effects
Magnetic fields of Earth and other planets
Magnetospheres of Earth and other planets
Interplanetary medium and space weather

5. Astronomy and astrophysics

Introduction to astronomy
Structure and evolution of stars and galaxies
Astronomical observations at all wavelengths
Cosmic rays
Basic cosmology

6. Basics of spacecraft design, construction and launch

Orbital dynamics and launch vehicles
Attitude measurement and control

Power generation and storage
Telemetry and command, data management
Mechanical design and testing
Thermal design and control
Payload design considerations
Materials for use in space systems

7. Space biology

Introduction to space biology
Overall physiological response to space flight
Radiation and radiobiology
Medical hazards in space operations
Living in space

8. Space geodesy

Coordinate systems: Earth-based, global and regional
Establishing coordinate systems from space-based observations
Global positioning system (GPS): theory and implementation
Geographic information system (GIS): theory and implementation
Scientific applications of space geodesy: continental drift, Earth-moon separation etc.

Review of recommendations of the Education Curriculum Review Committee

The Education Curriculum Review Committee, an ad hoc body established by the Centre for Space Science and Technology Education in Asia and the Pacific to prepare for the September 2001 meeting, suggested a revised curriculum for the third course. That curriculum, which was reviewed by the working group, was as follows:

Module/ submodule	*Topic*
1	Theoretical topics
1.1	Structure, composition and dynamics of planetary atmospheres
1.1.1	Structure of the Earth's atmosphere
1.1.2	Composition of the Earth's atmosphere
1.1.3	Dynamics of the Earth's atmosphere
1.1.4	Solar radiation and its effect on atmosphere
1.1.5	Atmospheres of planets and satellites
1.2	Ionospheric physics
1.2.1	Structure and variability of Earth's ionosphere
1.2.2	Ionospheric techniques: ground-based, rockets and satellites
1.2.3	Ionospheric plasma dynamics
1.2.4	Optical emissions
1.2.5	Ionospheres of other planets and satellites

Module/ submodule	*Topic*
2	Experiments
2.1	Surface monitoring of ozone
2.2	Radio sounding of ionosphere (ionosonde)
2.3	Langmuir probe for electron density measurements
2.4	Optical imaging of plasma depletions
2.5	Modelling experiment on neutral atmosphere
3	
3.1	Solar wind, magnetosphere and space weather
3.1.1	Elements of solar physics
3.1.2	Magnetic field of the Earth and other planets
3.1.3	Magnetosphere of the Earth and other planets
3.1.4	Interplanetary medium
3.1.5	Space weather
3.2	Astronomy and astrophysics
3.2.1	Introduction to astronomy
3.2.2	Astronomical instruments and observing techniques
3.2.3	Optical and near infrared (IR) studies of stars and galaxies
3.2.4	High-energy astrophysics
3.2.5	Radio astronomy studies
4	
4.1	Photometry of binary stars
4.2	Interferometric study of planetary nebulae
4.3	Radio pulsar studies using the Giant Metrewave Radio Telescope (GMRT)/Ooty Synthesis Radio Telescope (OSRT)
4.4	Measurement of temperature of outer planets using IR detectors
4.5	Study of the solar spectrum

The suggested evaluation procedure for the third course would be as follows:

	Points
Theory papers (4 papers x 300 points)	1,200
Practical exercises	
Participation in practical exercises (10 practical exercises x 45 points)	450
Examinations or practical exercises (2 examinations x 75 points)	150
Seminars (4 seminars x 75 points)	300
Pilot project	300
Total	2,400

Following the discussions in the working group, which suggested the introduction of a fifth topic on spacecraft design, construction and launch (see para. 16, below), the evaluation procedure was revised as shown in annex I, paragraph 3.

Revised curriculum for the third course on space and atmospheric science

Recommendations for the structure of the third course

The third course will have the following five modules:

1. Theory
2. Experiments
3. Theory
4. Experiments
5. Pilot project

More complete details of the syllabus to be followed, particularly for the theoretical models, are given in annex I.

Suggested changes in the syllabus from the second course

The total contact hours for instruction through lectures and through experiments were 300 hours each in the second course (see annex II). The major changes recommended in the allocation of hours are discussed below.

Changes in theoretical topics

In the second course, 50 hours were devoted to astronomy and astrophysics. In the revised curriculum, this number should be increased to 60 hours and 33 additional hours should also be devoted to planetary physics, as follows:

	Hours
Atmospheres of planets and satellites	12
Ionospheres of other planets and satellites	8
Magnetic field of the Earth and other planets	6
Magnetosphere of the Earth and other plants	7
Total	33

Thus, 43 additional hours would be added to the topic of astronomy and astrophysics and planetary physics in the suggested syllabus.

In the second course, 50 hours were devoted to optical and laboratory studies of space processes. In the revised syllabus for the third course, the number should be reduced to 8 hours and included under the topic isonospheric propagation and measurement techniques.

In the second course, 50 hours were devoted to modelling of climate, neutral atmosphere, radiative effects of aerosols, ionosphere and numerical simulation of plasma bubbles. In the revised syllabus for the third course, this number should be reduced to about 15 in the form of a modelling experiment on atmosphere/ionosphere in module 4.

In addition, it is suggested that 59 hours should be devoted to a new topic on basics of spacecraft design and launch.

Thus, the general outline of the theoretical models is as follows:

Module/ submodule	*Topic*
1	
1.1	Structure, composition and dynamics of planetary atmospheres
1.1.1	Basic concepts of the Earth's atmosphere
1.1.2	Dynamics of the Earth's atmosphere
1.1.3	Solar radiation and its effect on atmosphere
1.1.4	Atmospheres of planets and satellites
1.2	Ionospheric physics
1.2.1	Structure and variability of the Earth's ionosphere
1.2.2	Ionospheric propagation and measurement techniques
1.2.3	Ionospheric plasma dynamics
1.2.4	Airglow emissions
1.2.5	Ionospheres of other planets and satellites
3	
3.1	Solar wind, magnetosphere and space weather
3.1.1	Elements of solar physics
3.1.2	Magnetic field of the Earth and other planets
3.1.3	Magnetosphere of the Earth and other planets
3.1.4	Space weather
3.1.5	Measurement techniques for solar and geomagnetic parameters
3.2	Astronomy and astrophysics
3.2.1	Introduction to astronomy and astrophysics
3.2.2	Astronomical instruments and observing techniques
3.2.3	Optical and near IR studies of stars and galaxies
3.2.4	High-energy astrophysics
3.2.5	Radio astronomy
3.3	Basics of spacecraft design, construction and launch
3.3.1	Orbital dynamics, control and guidance
3.3.2	Power generation and storage
3.3.3	Telemetry and telecommand
3.3.4	Mechanical, thermal and payload design aspects
3.3.5	Space system materials

Changes in experiments

There were a total of 12 experiments in the second course (see annex II). Of those, the following experiments should be discontinued:

Slit function of a monochromator
Absorption spectroscopy to determine column density
Measurement of the Earth's magnetic field by proton precession magnetometer
Interferometry of ionospheric airglow
Measurement of fluorescence of Rodamine dye

The following new experiments are suggested:

Photometry of binary stars
Interferometric study of planetary nebulae
Modelling experiment on atmosphere/ionosphere
Radio pulsar studies using GMRT/OSRT
Study of solar spectrum

Schedule for course activities

The nine-month course will consist of 200 six-hour days, totalling 1,200 hours. Those hours will be allocated as follows:

Activity and schedule	*Hours*	*Percentage of total time*
Theoretical lectures: 5 topics, 60 hours per topic; 3 lectures every day from 0900 to 1000, 1040 to 1150 and 1150 to 1300 hours	300	25
Practical exercises: 12 practical exercises; Monday, Tuesday and Wednesday from 1430 to 1730 hours	180	15
Library work: every Friday from 1430 to 1730 hours	60	5
Tutorials and seminars: every Thursday from 1430 to 1530 hours	60	5
Field visits: 5 six-day weeks (in two sessions); 6 hours/day	180	15
Examinations (including preparation time)	120	10
Project work (10 five-day weeks; 6 hours/day)	300	25
Total	1,200	100

Notes

[1] L. Pyenson and S. Sheets-Pyenson, *Servants of Nature: a History of Scientific Institution, Enterprises, and Sensibilities* (New York, W. W. Norton and Company, 1999).

[2] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. II, sect. G, para. 220.

[3] Ibid., chap. I, resolution 1, para. 1 (e) (ii). The Declaration is also available on the home page of the Office for Outer Space Affairs (http://www.oosa.unvienna.org).

Annex I

Specifications for the curriculum of the third course

Details of the theoretical topics are as follows:

Module/ submodule	*Topic and hours*
1	
1.1	Structure, composition and dynamics of planetary atmospheres (60 hours)
1.1.1	Basic concepts of the Earth's atmosphere (12 hours)
	Atmospheric nomenclature, hydrostatic equations, scale height, geopotential height; chemical concepts of the atmosphere; thermodynamic considerations, elementary chemical kinetics; composition and chemistry of middle atmosphere and thermosphere; thermal balance in the thermosphere; modelling of neutral atmosphere
1.1.2	Dynamics of the Earth's atmosphere (16 hours)
	Equation of motion of neutral atmosphere; thermal wind equation; elements of planetary waves; internal gravity waves and atmospheric tides; fundamental description of atmospheric dynamics and effects of dynamics on chemical species; lidar technique
1.1.3	Solar radiation and its effect on atmosphere (20 hours)
	Solar radiation at the top of the atmosphere, attenuation of solar radiation in the atmosphere, radiative transfer, thermal effects of radiation, photochemical effects of radiation, modelling of radiative effects of aerosols
1.1.4	Atmospheres of planets and satellites (12 hours)
	Inner and outer planets; atmospheric structure and composition of the Moon, Jupiter, Mars, Venus and Saturn and their important satellites
1.2	Ionospheric physics (60 hours)
1.2.1	Structure and variability of the Earth's ionosphere (12 hours)
	Introduction to ionosphere; photochemical processes; Chapman's theory of photoionization; production of ionospheric layers; loss reactions and chemistry of ionospheric regions; morphology of the ionosphere
1.2.2	Ionospheric propagation and measurement techniques (16 hours)
	Effect of ionosphere on radio wave propagation; refraction, dispersion and polarization; magneto-ionic theory; critical frequency and virtual height; oblique propagation and maximum usable frequency; ground-based techniques—ionosonde; radars; scintillations and total electron content (TEC), photometers, imagers and interferometers, ionospheric absorption; rocket- and satellite-borne techniques—Langmuir probe, electric field probe, retarding potential analysers, mass spectrometers, magnetometers, vapour release, satellite drag for neutral density
1.2.3	Ionospheric plasma dynamics (16 hours)
	Basic fluid equations; steady state ionospheric plasma motions owing to applied forces; generation of electric fields; electric field mapping; collision frequencies; electrical conductivity; plasma diffusion; ionospheric dynamo; equatorial electrojet; ionospheric modelling
1.2.4	Airglow (8 hours)
	Nightglow; dayglow; twilight glow; aurora; applications of airglow measurements for ionospheric dynamics and composition
1.2.5	Ionospheres of other planets and satellites (8 hours)
	Ionospheres of Mars, Venus and Jupiter

Module/ submodule	*Topic and hours*
3	
3.1	Solar wind, magnetosphere and space weather (60 hours)
3.1.1	Elements of solar physics (6 hours)
	Structure and composition of the Sun; the Sun as a source of radiation; sunspots and solar cycles; solar flares
3.1.2	Magnetic field of the Earth and other planets (12 hours)
	Models for generation of geomagnetic fields; secular variations of geomagnetic fields; international geomagnetic reference fields; local elements of geomagnetic fields; determinations of geomagnetic coordinates of stations; diurnal variation of geomagnetic fields; magnetic fields of other planets
3.1.3	Magnetosphere of the Earth and other planets (14 hours)
	Solar wind and its characteristics; interplanetary magnetic field and sector structure; formation of geomagnetic cavity, magnetopause; magnetosheath and bow shock; polar cusp and magnetotail; plasma sphere and Van Allen radiation belts; magnetosphere of other planets
3.1.4	Space weather (16 hours)
	Geomagnetic storms, sub-storms and current systems; coronal mass ejections; modification of the Earth's magnetosphere during magnetic disturbances and its implications; effect of magnetic disturbance on high, mid, and low latitudes
3.1.5	Measurement techniques for solar and geomagnetic parameters (12 hours)
	Optical techniques for solar parameters; radio techniques for solar parameters; X-ray techniques for solar parameters; techniques for magnetic measurements
3.2	Astronomy and astrophysics (60 hours)
3.2.1	Introduction to astronomy and astrophysics (18 hours)
	Basic parameters in astronomical observations (magnitude scale, coordinate systems), stellar classification, Hertzsprung-Russell diagram, Saha equation, Jean's criteria for stellar formation, stellar evolution, galaxy classification, cosmology
3.2.2	Astronomical instruments and observation techniques (12 hours)
	Telescopes: f/# (a telescope of focal ratio f/# has an aperture equal to one #th of its focal length), plate scale, types of telescopes, seeing conditions, diffraction limited resolution; photometers: spectrometers (interferometers, gratings), imaging detectors (microchannel plate (MPC), charged couple device (CCD) and IR arrays), high angular resolution techniques (speckle, lunar occultation, adaptive optics)
3.2.3	Optical and near IR studies of stars and galaxies (12 hours)
	Spectral energy distribution (in optical and IR bands) in stars, rotation of stars, study of binary stars, gaseous nebulae, extinction curve of interstellar matter, dust, rotation curves of galaxies, spectral energy distribution, colour-colour studies (imaging of galaxies in different bands)
3.2.4	High-energy astronomy (6 hours)
	Atmospheric transmission, detection techniques for X-rays and gamma rays, X-ray telescopes, imaging and spectroscopy, radiation processes, accretion disks in black holes and X-ray binaries, active galactic nuclei
3.2.5	Radio astronomy (12 hours)
	Radio telescopes, aperture synthesis, interplanetary scintillation (IPS) techniques, very long base interferometry (VLBI), pulsars, radio galaxies, distribution of HI gas in galaxies, radiation mechanisms
3.3	Spacecraft design, construction and launch (details to be determined)

The revised practical modules are as follows:

Module/ submodule	*Topic*
2	
2.1	Operation of Langmuir probe
2.2	Ionospheric sounding using an ionosonde
2.3	Surface monitoring of ozone
2.4	Optical imaging of plasma depletions
4	
4.1	Photometry of binary stars
4.2	Interferometric study of planetary nebulae or measurement of temperature of outer planets using IR detectors
4.3	Mass of suspended particles using quartz crystal microbalances
4.4	Optical depth measurement using filter photometers
4.5	Modelling experiment on atmosphere/ionosphere
4.6	Characterization of interference filters
4.7	Radio pulsar studies using GMRT/OSRT
4.8	Study of solar spectrum

The evaluation of students will be based on their performance in theory, practical exercises, seminars and pilot projects. Students will have to present one seminar in each of the five theoretical topics. The allocation of points in theory, practical exercises, seminars and pilot projects will be as follows:

	Points
Theory (5 topics, 100 points each) as follows:	
Written exam (3 hours), 80 points per topic	400
Class tests by each lecturer, 20 points per topic	100
Subtotal	500
Experiments:	
Examinations (including orals)	80
Continuous assessment, dedication and discipline	120
Subtotal	300
Seminars (5 presentations, 20 points each)	100
Pilot project	200
Total	1,000

The grades will be given as follows:

A+ or distinction	750 points or more	(75 per cent or more)
A or first class	600 to 749 points	(less than 75 per cent to 60 per cent)
B or pass class	500 to 599 points	(less than 60 per cent to 50 per cent)

Annex II

Revised curriculum for the second course

The second post-graduate course in Space and Atmospheric Science was held at the Centre for Space Science and Technology Education in Asia and the Pacific from 1 August 2000 to 30 April 2001. The first course was organized in two phases: phase I (six months), which was conducted at the regional centre and phase II (six months), which was conducted in the home country of the participants. For the second course, the duration of phase I was increased to 9 months at the centre and of phase II to 12 months in the home country. After the successful completion of both stages, all the eligible participants were to be assessed by a host-country university of the regional centre for the award of a Masters in Technology degree in space science. Changes in the curriculum vis-à-vis the first course are outlined below.

Changes in the number of hours in the curriculum after the first course

Table 1 shows the differences between the first four modules in the first and second course, using the titles of modules and submodules for the first course.

Table 1
Comparison of modules/submodules in the first and second courses

		Number of hours	
Module/ submodule	*Topic*	*First course*	*Second course*
1[a]			
1.1	Structure and composition of neutral atmosphere	40	50
1.2	Plasma aspects of Earth's environment	40	50
1.3	Astronomy and astrophysics	40	50
	Subtotal	**120**	**150**
2[b]			
2.1	Measurement of mass of suspended particles	20	25
2.2	Measurement of Earth's magnetic field by proton precession magnetometer	20	25
2.3	Absorption spectrometry to determine column density of minor constituents of the atmosphere	20	25
2.4	Measurement of methane concentration in air samples	20	25
2.5	Low-current measurement using Langmuir probe	20	25
	Additional hours in second course	___	25
	Subtotal	**100**	**150**
3[a]			
3.1	Ionospheric physics and radio wave propagation	40	50
3.2	Optical and laboratory studies of space processes	40	50
3.3	Modelling of atmospheric processes	40	50
	Subtotal	**120**	**150**

Module/ submodule	Topic	Number of hours: First course	Number of hours: Second course
4[b]			
4.1	Characterization of interference filters	20	25
4.2	Interferometry using a Fabry Perot interferometer	20	25
4.3	Optical imaging/filter photometry	20	25
4.4	Use of dye in dye lasers	20	25
4.5	Ionospheric sounding using an ionosonde	20	25
	Additional hours in second course	___	50
	Subtotal	**100**	**175**
	Total	**440**	**625**

[a]The number of hours in the first course was insufficient because there was too little time for (a) discussions during the lectures and (b) explaining the mistakes made by students in written examinations.

[b]The number of hours in the first course was insufficient because the available time was inadequate for reading, preparing, demonstrations, observations, repetitions, checking and writing about experiments.

No attention was given to pilot projects in the first course owing to (a) shortage of time and (b) lack of knowledge about possible experiments in the home country of participants. This resulted in the following problems:

(a) Finalization of the pilot project was delayed;

(b) The availability of data to participants was delayed;

(c) Participation and interaction with the supervisor appointed by the regional centre was too little to be of any significance;

(d) The occasional change of supervisors in the home countries of participants.

In view of the above, two months were exclusively devoted to the pilot project in the second course.

Syllabus followed in the second course

Table 2 shows the syllabus followed in the second course, with details of the theoretical topics covered in modules 1 and 3.

Table 2
Syllabus followed in the second course

Module/ submodule	Topic	Number of hours
1		
1.1	Structure, composition and dynamics of the neutral atmosphere	50
1.1.1	Structure, composition, hydrostatic equilibrium, scale height thermodynamics	
1.1.2	Solar radiation, its transfer through the atmosphere, aerosols and radiative effects of aerosols	

Module/ submodule	*Topic*	*Number of hours*
1.1.3	Atmospheric dynamics, large-scale motions, tides' gravity waves and turbulence	
1.1.4	Greenhouse gases and trace gases: their chemistry and measuring techniques and global warming	
1.1.5	Satellite measurement of neutral parameters	
1.2	Plasma aspects of Earth's environment	50
1.2.1	Geomagnetism, global electric circuit	
1.2.2	Plasma physics	
1.2.3	Magnetospheric processes and solar wind, solar activity	
1.2.4	In-situ measurements of plasma parameters	
1.2.5	Ionospheric irregularities	
1.3	Astronomy and astrophysics	50
1.3.1	Basic astronomy (planetary, stellar and extragalactic)	
1.3.2	Gamma-ray, X-ray and UV astronomy	
1.3.3	Optical, IR and far IR astronomy	
1.3.4	Millimeter wave, radio and solar astronomy	
1.3.5	Recent advances in astronomical detection techniques	
2		
2.1	Measurement of mass of suspended particles	25
2.2	Surface monitoring of minor constituents	25
2.3	Determination of the slit function of a monochromator using a helium-neon (He-Ne) laser as light source	25
2.4	Ionospheric sounding using an ionosonde	25
2.5	Low-current measurement using Langmuir probe	25
2.6	Optical imaging of plasma depletions	25
3		
3.1	Ionospheric physics and radiowave propagation	
3.1.1	Formation and structure of the ionosphere	
3.1.2	Theory of ionospheric radio propagation	
3.1.3	Radio sounding of the ionosphere (ionosonde, HF Doppler, meteor wind radar, spaced receiver technique, total electron content)	
3.1.4	Ionosphere scintillations, tomography and GPS systems	
3.1.5	Ionospheric radars (VHF backscatter radar, incoherent scatter radar and MST radar)	
3.2	Optical and laboratory studies of space processes	
3.2.1	Basic optics	
3.2.2	Photometers and images	
3.2.3	Spectral imaging of the atmosphere	
3.2.4	Laser sounding of the atmosphere	
3.2.5	Laboratory astrophysics	
3.3	Modelling of atmospheric processes	
3.3.1	Climate modelling	
3.3.2	Modelling of the neutral atmosphere	

Module/ submodule	*Topic*	*Number of hours*
3.3.3	Modelling of radiative effects of aerosol	
3.3.4	Modelling of ionosphere	
3.3.5	Numerical simulation of plasma bubbles	
4		
4.1	Absorption spectrometry to determine column density of minor constituents	25
4.2	Filter photometer for optical depth measurement	25
4.3	Measurement of Earth's magnetic field by proton precession magnetometer	25
4.4	Interferometry using a Fabry-Perot interferometer	25
4.5	Measurement of transmission of MgF_2 window	25
4.6	Characterization of interference filters	25
5	Pilot project	[a]

[a]Two months.

Module 5, a pilot project of two months' duration, was conducted at the completion of the four modules. Because many of the participants did not have a clear-cut idea of what was feasible as a one-year home project in their countries, the pilot project at the regional centre initiated the foundation of that project. The pilot project was undertaken in consultation with the supervisors in the regional centre's host country as well as in the home country. The purpose of the two-month module was to allow participants to work under the guidance of a regional centre host-country supervisor and get (a) guidance on the course of action to be pursued at home; (b) all the necessary experimental data, if required; and (c) the necessary software tools etc.

Evaluation procedure followed in the second course

Modules 1 and 3 (theory)

Faculty members taught each subsection of the modules. At the end of their lectures, all faculty members gave a one-hour class test. The average of all the class tests was calculated for each subsection. For each of the subsections, each participant was required to give one seminar, which was evaluated by a committee of faculty members. Finally, for each of the subsections, a three-hour written examination was conducted. The allocation of points was as follows:

	Points
Three-hour written test	125
One-hour class test (average of five tests)	50
Seminar	25
Total	200

The total for modules 1 and 3, with 200 points per topic and six topics was 1,200 points.

Modules 2 and 4 (practical)

Points were given for completing practical exercises in the 12 topics under modules 2 and 4 and one practical exercise was chosen in each module for practical examination and evaluation. The allocation of points was as follows:

	Points
Points for completing 12 practical exercises in modules 2 and 4 (40 points each)	480
Practical examination in one practical exercise each in modules 2 and 4 (60 points each)	120
Total	600

The total for the course was 2,400 points and grades were given based on a percentage of the points received as follows:

A+ or distinction	75 per cent or more
A or first class	Less than 75 per cent to 60 per cent
B or pass class	Less than 60 per cent to 50 per cent

One-year project

After completing the stage I at the regional centre, all participants are expected to complete a one-year project in their home country under the supervision of a supervisor in that country with regular communication with the regional centre's home-country supervisor. After completion of the one-year project work, each participant is expected to write a thesis, which must be approved and signed by both the supervisors as well as the candidate. The thesis is sent for evaluation to a supervisor appointed by the regional centre. After obtaining approval from that supervisor, the thesis is sent to the host-country university for consideration for the award of a Masters in Technology degree in space physics for those who are eligible.

Annex III

Curriculum for the first course

The first Post-Graduate Course in Space and Atmospheric Science was held at the Centre for Space Science and Technology Education in Asia and the Pacific from 1 June to 30 November 1998.

Table
Syllabus followed in the first course

Phase and module	*Title (duration)*	*Number of lectures*
I	First semester (three months)	
I.1	Atmospheric science	60
I.2	Ionosphere and solar terrestrial interaction	60
	Project work and laboratory work Visit to astronomical observatory (two weeks) Exams	
	Second semester (three months)	
I.3	Instrumentation, techniques and data processing	75
I.4	Modelling	50
II	Project work in home country of participant (six months)	

The detailed course content of the theoretical portion of the course was as follows:

Module 1: Atmosphere

Structure and composition, hydrostatic equilibrium, scale heights, thermodynamics, solar radiation and its transfer through atmosphere, aerosols and radiation

Atmospheric electricity, global electric circuit

Atmospheric dynamics, large-scale motions, tides, gravity waves, and turbulence

Ozone, trace gases and chemistry, methods of measurements, ozone depletion; concentration of carbon dioxide (CO_2) and other greenhouse gases, global warming, long-term changes in atmosphere due to anthropogenic changes

Module 2: Ionosphere and solar terrestrial interaction

Basic plasma physics

The sun, solar radiation, solar activity, solar wind, geomagnetism, magnetosphere

Photoabsorption and photoionization, formation of ionospheric layers, magneto-ionic theory, radio propagation in ionosphere, radio sounding, maximum usable frequency (MUF) and high frequency (HF) radio link calculations, features of ionosphere at low latitudes, equatorial electrojet, equatorial sporadic-E and equatorial spread-F

Solar flares, geomagnetic storm and effects in the ionosphere, magnetosphere-ionosphere coupling

Radio propagation through ionosphere, Faraday rotation, differential phase and group delay measurements, ionospheric tomography, radiowave scintillations

Radiowave scattering processes, coherent and incoherent backscatter radars

Probe theory, probe characteristics, in-situ measurements, airglow emissions, principles of optical measurements, optical aeronomy

High-energy astronomy, X-ray astronomy, X-ray sources, detection techniques; gamma-ray astronomy, sources, telescope and detectors in space, ground-based Cerenkov telescopes and very high energy gamma-ray astronomy; engineering trends and recent advances in detection techniques

Space biology

Module 3: Instrumentation techniques and data processing

Radio sounding: ionosondes, HF Doppler technique, spaced receiver technique

Radio beacon methods for electron content, tomography and scintillation studies

Radars for atmospheric and ionospheric studies, coherent backscatter radar, incoherent backscatter radar, meteor radar and mesosphere/stratosphere/troposphere (MST) radar

In-situ probes and artificial modification experiments, Langmuir probe, double probe, retarding potential analyser (RPA), magnetometer, mass spectrometer, and chemical release experiments; balloon-borne conductivity, ion density and electric field probes for stratosphere

Optical aeronomy experiments, photometers, spectrometers, imaging camera for day and night airglow emissions

Lidar techniques, principle and application, aerosol lidar, Rayleigh lidar, Doppler lidars and differential-absorption lidars (DIALs)

Instrumentation for atmospheric chemistry and aerosol studies, Dobson absorption spectroscopy, cryosampler, gas chromatography, sun photometer, aerosol sampler, remote sensing techniques

Techniques for laboratory measurements, instrumentation for laboratory experiments on photoabsorption and photoionization

Instrumentation for astronomical observations, telescopes, polarimetry, high resolution and spectrophotometry and spectroscopy, array detectors

Module 4: Modelling

Ocean-atmosphere and land-atmosphere interaction, past climate studies

Tropospheric and stratospheric ozone chemistry, aerosol-solar radiation interaction

Continuity equation, ionospheric models, numerical simulation studies, ionospheric scintillations, planetary atmospheres

For the experimental portion of the course, 8 of the following 11 experiments should be carried out:

1. Characterization of interference filters
2. Interferometry using a Fabry Perot interferometer
3. Measurements of mass of suspended particles
4. Measurements of Earth’s magnetic field with a proton precession magnetometer
5. Argon mini arc light source
6. Use of dye in dye lasers
7. Absorption spectrometry to determine column density of minor constituents of the atmosphere
8. Measurements of methane concentration in air samples
9. Principle of operation of an ionosonde
10. Low-current measurements using a Langmuir probe
11. Optical imaging/filter photometry

Annex IV

Recommended teaching material

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