three separators in series, each with 500 kV across a gap of 10 cm.

The new separator is basically a sensitive timing device: only those particles which cover a particular distance at the correct velocity can pass through—the others are intercepted. Before they reach the separator, all the particles have the same momentum, within one percent. Then the beam, consisting of pions and kaons, enters a loaded waveguide propagating a single mode of an electromagnetic wave. The particles are deflected through an angle α by the field, are then focused by a magnetic lens system, and then enter a second waveguide. Even though all the particles have the same momentum, the pions have greater velocity and so reach the next waveguide first. The system is adjusted so that the pions are in phase with the waves in the second guide. Hence the pions are again deflected through an angle α and emerge along the axis of the system. Meanwhile the kaons arrive out of phase, are deflected through α in the opposite direction, and emerge at an angle 2α with respect to the axis.

Thus a narrow beam of pions is produced. But it is kaons that one really wants, so a beam stopper is used to absorb the pions. The remaining kaons form a fan of angle 4α, which is collected into a kaon beam by a lens system, and the experimenters are then in business.

Each waveguide is fed as much as twenty megawatts of pulsed rf power from a klystron of the type used in radar equipment. It operates at 2855 Mc/sec, with a pulse length of eight microseconds and a repetition rate of one pulse per second. Since the rf system has such a short pulse length, this type of beam is mainly useful for bubble-chamber experiments.

When the separators began operating last winter they produced about a dozen K^- particles per burst, along with about half a dozen muons. Then it was time to use the bubble chamber; the intensity was deliberately reduced, and the photographs taken showed an average of seven kaons per burst, with only five or ten percent contamination from other strongly interacting particles.

If there are improvements in klystrons or if superconducting waveguides are developed, rf separators might prove to be useful in spark chamber or counter experiments as well.

The moon and its orbit

A new calculation of the moon's orbit, completed during the past year by W. J. Eckert, director of the IBM Watson Laboratory and professor of celestial mechanics at Columbia University, and H. F. Smith, Jr., a research associate at Watson Laboratory and a graduate student at Columbia, has predicted lunar positions with such precision that it has corrected a fluctuating error of 3/10 second per eighteen months in the astronomical time standard. The extreme accuracy of the calculation has also yielded a suggestion that the moon may be denser near the surface than it is in the center. The prediction rests on angular-momentum considerations necessary to explain a discrepancy of ten parts in seven million in the motion of the nodes of the lunar orbit.

The new calculation provides a 100-fold increase in the accuracy of the "main problem" of lunar theory, i.e., the description of the motion of the moon in response to gravitational forces of the earth-sun-moon system. (Effects of the other planets, and of the shapes of the earth and the moon, as well as relativistic effects, are added to the main problem as smaller corrections.)

The main problem presents a set of sixth-order nonlinear differential equations. The solution is attempted by substituting four-dimensional harmonic series, which go roughly to the tenth order, into the differential equations. Calculating out the series substitution results in 6000 residuals which must be used to determine corrections to the coefficients. The problem is further complicated by the fact that, of the four frequencies of the harmonic series, only two (angular motions of the sun and moon) are assumed as known, while the other two (precession of perigee and precession of nodes) must be found in the course of the calculation.

Six thousand variation equations with 600 unknowns are formed to connect the residuals with the corrections, and these yield a 6000 by 6000 matrix among whose 36 million elements the corrected coefficients are found. The corrected coefficients are then substituted back, and the calculation is carried forward again to yield a corrected result. The final solution in the Eckert-Smith procedure is accurate to ten significant figures.

The new solution to the main problem has exposed a significant error in the prediction of lunar motion contained in the tables of current ephemerides. One of the many fluctuations in the moon's orbital speed is an oscillation with a three-year cycle. Current lunar tables do not reflect the full effect of this cycle; their predictions were found to be 440 feet ahead of or behind the moon at the extremes of the cycle. Since the lunar orbital motion is used as the astronomical time standard, this circumstance contributed an error of ± 0.135 second in astronomical time determinations.

The suggestion about the distribution of mass within the moon rests on the calculation of the rate of rotation of the moon's orbital plane in space (precession of nodes), which is a sensitive indicator of forces acting on the moon. The nodes make about six revolutions (seven million seconds of arc) per century. After secondary corrections have been added to the contribution from the main problem, there still exists a discrepancy of about 25 seconds of arc between the observed and calculated motion of the nodes. If this contribution is attributed solely to the distribution of mass in the moon, it leads to the conclusion that the moon has a very high moment of inertia about its axis, i.e., that there is a concentration of dense material near the moon's surface. If the moon were homogeneous, 10 of the 25 seconds discrepancy would remain unaccounted for; if it had a heavy core like the earth, twelve seconds would remain unexplained.

Disagreement over the lunar mass distribution has gone on for a long time. In 1908, E. W. Brown, whose lunar computations have been standard for forty years, assumed that the lunar mass distribution was analogous to the earth's. This led him to the conclusion that the earth was more oblate than contemporary geodetic observations showed. The greater accuracy of present geodetic determinations, however, rules out his adjustment. Lately, the discrepancies were attributed to uncertainties in the solution of the main problem. The new computation now eliminates this factor from the controversy.

A description of the Eckert-Smith computation was presented at the International Astronomical Union Symposium 25, held last summer in Thessaloniki. A full account of the work will appear in the Astronomical Papers of the *American Ephemeris and Nautical Almanac.*

Cosmic rays

Atomic Energy of Canada Limited has dispatched a transport van loaded with cosmic-ray detectors on a 10 000-mile tour that began March 27 at Chalk River, Ontario, and will end June 18 at Acapulco, Mexico. Taking advantage of the present period of low solar interference, the program will undertake comparative studies and an intercalibration of the varying equipment at permanent ground stations in North America. The van will also stop at 200-mile intervals to measure the latitude effects on cosmic-ray penetration arising from the earth's magnetic field.

The project is directed by Hugh Carmichael, head of the General Physics Branch of AECL's Chalk River Nuclear Laboratories.

Penn magnet lab

A high-field magnet laboratory has been organized at the University of Pennsylvania and is now engaged in the construction of its equipment which is scheduled to begin operation by the beginning of 1966. The magnet laboratory is under the technical direction of Elias Burstein and is organized as part of the University's Laboratory for Research on the Structure of Matter, which is supported by the University, by industrial donors, and by the Advanced Research Projects Agency. Although primarily intended for use by faculty and students of the University of Pennsylvania, the facilities of the magnet laboratory will be made available also to visitors from other universities, to staff of ARPA-sponsored industrial projects, and to the staffs of industrial sponsors of the LRSM.

Although the new laboratory has provision for five magnet stations, only two magnets are being built at first. They are low-impedance, air-core solenoids of the type developed by Francis Bitter, designed for three-megawatt continuous operation at 10 000 amperes and 300 volts. One will have a $1\frac{1}{8}$-inch bore for fields up to 150 kG; the other will have a $4\frac{1}{8}$-inch bore for fields up to 90 kG. For the future a one-inch-bore pulsed magnet to produce fields up to 240 kG for periods up to a minute and a one-inch-bore, radial-access solenoid for up to 90 kG are planned.

The windings of the solenoids will be composed of approximately 500 copper disks with a sixteen-inch outside diameter. Each plate contains a radial cut so that it can become a segment of a continuous winding of half the 500 turns in series. The plates are so arranged that they form two continuous windings laid in contact with one another, one winding being advanced a partial turn with respect to the other.

The hole configuration for cooling lines is similar to that used by the Naval Research Laboratory. Holes in adjacent rows are arranged so as to form the corners of approximately equilateral triangles. The sides of the triangles vary inversely with the radius to compensate for greater current density near the center of the solenoid. Thus the maximum conductor temperatures will be approximately equal at all points on the winding plate.

According to Professor Burstein, the Magnet Laboratory will provide more than a fivefold increase in field intensity over that normally available in materials-science laboratories. The availability of fields in the 100-kG range will extend the range of materials which can be investigated and will also make possible the investigation of phenomena which would not otherwise be feasible.