"Ill-posed" mathematical problems are those in which the answers are so sensitive to the accuracy of the data that they have been considered unsolvable. Any errors in the data are magnified to produce absurd and unrealistic answers. But now a method for solving them has been developed by Joel N. Franklin, professor of applied mathematics, and a whole array of scientific and engineering problems have become amenable to solution.

What Franklin has done is to restate the ill-posed problem so that the correct answer does not depend so heavily on the precision of the data.

One person who has already found the method useful, Don Anderson, director of Caltech's seismological laboratory, explains that one can describe statistically the data errors and plausible solutions and include those estimations in the calculations of a set of unstable equations.

A graduate student working with Anderson, Tom Jordan, says that the data available about the changes of the properties of rocks with depth and increased pressures just don't give enough information to answer questions about the nature of the earth's interior. Franklin's theory lets them introduce new information—namely, educated guesses on what the properties will be.

The principal clues to the nature of the earth's interior are contained in the free oscillations of the earth caused by large earthquakes. If the structure of the earth were known, how it oscillates could be predicted. However, the geophysicists have to work the other way: They have the information about the free oscillations and want to determine the structure.

Their problem is to determine what the composition of the earth would be for it to oscillate as it does. The solution takes the form of a likely mathematical model of the earth, which is then tested in the computer to see if it oscillates the way the real earth does. If the computer shows the same oscillations, then the model is correct. If not, another model is made up and tested.

The computation job is immense. Billions of calculations are involved in what amounts to the solution of a system of linear equations.

The method is an extension of the prediction theory of Norbert Wiener and Norman Levinson. The general definition of ill-posed problems was first given in 1902 by French mathematician Jacques Hadamard, who regarded this class of problems as fundamentally beyond the practical reach of mathematics.

Old Data, New Answers—II

The earth's mantle is an 1,800-mile-thick layer of material between the crust and the core that has been thought to be uniform in composition. But, according to Don Anderson, director of Caltech's seismological laboratory, it is now clear that the earth is layered most of the way down, and there are about ten separate layers in the mantle. The mantle layering consists of changes in crystal structures in the rock, with some crystals changing shape two or three times as heat and pressure increase with depth. Also, the mantle has perhaps 20 percent more iron at greater depths than was thought, more silicates with depth, and more magnesium at shallower levels.

Anderson's work, which results from the application of the Franklin method described above, implies that the earth has undergone a series of differentiations. Anderson now thinks that the upper 250 miles of the mantle developed out of the lower part, much as the earth's crust differentiated out of the upper mantle. Anderson also says that mantle temperatures are considerably lower than supposed, ranging from about 1,800 degrees Fahrenheit near the top to 5,400 near the base.

The new work confirms the finding that the upper mantle, about 30 to 90 miles down, seems to be at least partly molten. This is the region believed to supply the magma for volcanoes and to form the "sea" on which huge plates of the crust float. Most earthquakes occur at the boundaries of the plates where they are colliding or pulling apart.

Anderson says the next step is to determine how the mantle's composition varies horizontally, and how it varies under the oceans and continents. Vari
tions down to 250 miles are known, but
the region below that is still a mystery.

Anderson is assisted in the work by
three graduate students. Thomas Jordan
is involved in the over-all mathematics;
Charles Sammis is working on atomic
theory of solids; and Bruce Julian is
examining the velocity of earthquake
waves with depth.

**Galactic Explosions**

What is the origin of the spiral arms of
galaxies? And of the peculiar S-shaped
pairs of streamers that some galaxies have
instead of spiral arms? Also of galactic
bridges, the streams of material linking
two or more galaxies?

Halton Arp of the Hale Observatories
has some answers, based on a study of
the unusual celestial objects pictured in
his *Atlas of Peculiar Galaxies*. In a recent
scientific paper, Arp suggests that titanic
explosions have ejected matter from such
galaxies. The ejected material leaves trails
of gas, dust, and stars; these appear as
spiral arms or S-shaped arms in galaxies
that are rotating. Occasionally they
appear as galactic bridges.

Arp, who earlier suggested that quasars
were shot out of galaxies, does not attempt
to explain why a galaxy, the largest unit
of matter known, would become unstable
enough to experience a king-sized
explosion. However, an explanation is
offered by Fred Hoyle, visiting associate
in physics at Caltech and Plumian
Professor of Astronomy and Experi-
mental Philosophy at Cambridge Uni-
versity in England. It is possible, he says, that
matter and antimatter are somehow
generated in equal amounts in the cores of
galaxies, with the matter being ejected and the
antimatter remaining in the core.

**Recoating the Mirror**

A delicate rebrightening operation
performed on the 200-inch mirror has
brought the Hale telescope on Palomar
Mountain back up to near-maximum
efficiency. A crew directed by Bruce Rule,
Caltech's chief engineer for the Hale
Observatories, dismantled the 14.5-ton
mirror, washed it, then coated it with
aluminum only 1/150,000 of an inch in
thickness.

The high-temperature coating process
was performed in a vacuum chamber at
the observatory using 360 tungsten fila-
ments to heat the aluminum until its
atoms boiled off and condensed on the
cold glass, forming a brilliantly reflective
surface.

It was the seventh aluminizing of the
200-inch mirror since it was installed in
1948; the last time the job was performed
was in 1960. This latest rebrightening is
expected to last for about nine years.

**Faster Solar Observing**

For the last 13 years the Hale Observa-
tories' 150-foot tower telescope at Mt.
Wilson has provided astronomers with
nearly all the magnetic observations that
are made of the sun. The telescope
produces regular daytime records of the
sun's shifting magnetic fields in the form
of maps (magnetograms), and also
records in pictures (dopplergrams) the
large-scale motions in the solar atmos-
phere. The instrument scans back and
forth across the sun, recording the
polarity and measuring the strength of the
magnetic fields with a magnetograph. At
any one time it can observe an area
1/10,000 of the sun's disk—a square
12,000 miles on a side.

At present it takes about an hour to
map the entire solar disk, but a new
system will cut this time to 15 to 20
minutes when it goes into operation next
fall. A computer and associated equip-
ment to improve the performance and
speed of the telescope are now being
assembled in the Astro-electronics Lab-
atory at Caltech under the supervision
of Edwin W. Dennison, staff member of
the Hale Observatories. The computer
will control and run the telescope as well
as collect and analyze the data.

The new instrumentation may make it
possible to learn whether there is any link
between sunspots and possible long-term
variations in the rotation of solar gases.
The improved telescope also will be better
able to measure and record the velocities
of the gases that rise and fall in the solar
atmosphere.

Magnetic observations of the sun are
useful in developing methods of fore-
casting outbursts of activity on the sun's
surface, such as solar flares. The speed
and sophistication of the new equipment
may well improve these forecasts, with
the possible practical application of
greater safety factors for astronauts, who
 can be endangered by high-speed atomic
particles while in space.

Funds for the improvements, to cost
$210,000, are being supplied by NASA
and the Air Force Cambridge Research
Laboratory.