*Problem 1: Define geodesy as a science and describe concisely the three pillars of modern geodesy.*

Geodesy is the science of measuring the Earth's shape, gravity field, and rotation.

The “three pillars” of geodesy are the Earth's time-dependent geometric shape, gravitational field, and rotation.

Problem 2: What is a geodetic "reference system" and what a "reference frame"?

By Reference System it is meant the set of prescriptions and conventions together with the modeling required to define at any time a triad of axes.

By Reference Frame it is meant a practical realization with given fiducial directions agreeing with the concepts introduced in the Reference System.

Problem 3: What are the two fundamental global geodetic reference systems and what physical quantity links these two systems together? What are the two conventional systems accepted by IAG and IAU, and what are the corresponding most accurate reference frames? What organization maintains the systems and frames, and where are the conventions published?

The two fundamental global geodetic reference systems are celestial reference system and terrestrial reference system. The Earth rotation vector links the celestial and terrestrial reference system. The two conventional systems accepted by IAG and IAU are ICRS and ITRS. Their corresponding frames are ICRF and ITRF. They are maintained by IERS (International Earth Rotation and Reference Systems Service), which a service under the joint auspice of IAG and IAU, and for the ICRF, both organizations take responsibility. Today, IERS provides parameters related to Earth's rotation under the name of EOP.

Problem 4: For the International Terrestrial Reference Frame (ITRF):

1. How is the ITRF given and published?
2. How do reference coordinates for ITRF reference points change over time?
3. What is the general mathematical relationship between two versions of the ITRF?
4. How can the coordinates of a point in the two systems be compared?

The ITRS is realized through a reference frame specifying a set of coordinates for a network of stations. These coordinates are given as Cartesian equatorial coordinates triples 

For different realizations of the ITRS, transformations are given to convert coordinates from one ITRF to another. The basic transformation formula is a seven parameter similarity transformation, often denoted as Helmert Transformation. This is given by



where andare the coordinate vectors of the point in the unprimed and primed frame, and  is the vector describing the offset of the origin between the primed and unprimed system measured in scale units of the primed system.

For many applications, it is necessary to compare coordinates of a point determined at different epochs or to refer coordinates to a reference epoch different from the central epoch of observations. Within the same reference frame, this can be achieved by



where and  are the reference epoch and the central epoch of measurement, respectively, and and are the position and velocity vectors given in the relevant ITRF.

Problem 5: What are the mathematical shapes of the solid Earth that are related to the main phases in the development of geodesy since its beginning and what are the main parameters of these shapes that were the focus of research/observations in these phases?

The following table answers the question:

**Table 3.1:** The four main phases of geodesy reflecting transitions in our view on main features of the Earth's shape.

|  |  |  |
| --- | --- | --- |
| **Phase and duration** | **Key characteristics** | **General idea** |
| A: From 200 BC up to the middle of the 17th century | Radius of a spherical Earth | Simple geometrical form. |
| B: From the middle of the 17th century to the middle of the 19th century | Oblateness of a rotational ellipsoid | Geometrical form resulting from rotational dynamics. |
| C: From the middle of the 19th century to the middle of the 20th century | Geoid | Gravitational field in addition to a purely geometrical form. |
| D: Since the middle of the 20th century | Dynamics of the Earth's surface and relativistic models of the Earth system | Changes in the shape instead of mean shape; dynamical instead of static view. |

Problem 6: How is the geodetic reference ellipsoid for the Earth defined and what are the key parameters?

<http://en.wikipedia.org/wiki/Reference_ellipsoid>

Mathematically, reference ellipsoid is an oblate (flattened) spheroid with two different axes: An equatorial radius (the semi-major axis ), and a polar radius (the semi-minor axis ). The polar axis here is the same as the axis with the great moment of inertia and is approximately aligned with the rotational axis ( not the magnetic nor orbital pole). The geometric center is placed at the center of mass.

Key parameters are including equatorial axis , polar axis and inverse flattening.

Problem 7: What are the main endogenic and exogenic processes impacting the shape of the Earth from periods of sub-seconds to millions of years?

Endogenic processes:

Earthquakes - coseismic: Earthquakes cause significant “static”/permanent 3-d deformations within seconds to minutes.

Free Oscillations: Seismic Free Oscillations of the Earth deform the earth with periods from 53 minutes down to seconds and can last for several days.

Earthquakes - Post-seismic.

Plate tectonics: Plate tectonics induce secular changes in shape on the order of 10 cm/yr horizontally.

Exogenic processes:

Exogenic variations in Earth's shape include:

- Tides of the solid Earth caused by the tidal potential of moon, sun, and planets;

- Rotational perturbations caused by exchange of momentum between core and mantle, angular momentum exchange with atmosphere and ocean, external torque caused by tidal forces, ...;

- surface loading due to mass relocation on the Earth's surface.