PYL127 -2020

Problem Set 1 – Basic Ideas

Range of applicability of Newtonan Mechanics

In each of the cases below, argue whether classical newtonian mechanics can be used with confidence, and if not what would be the dominant contributor to the dynamics. Prior to that, take card e to quantfify what you mean by confidence, vis -a vis Einsteinian and quantum corrections.

1. A freely falling body in earth's gravitational field
2. Acceleration of (i) electrons, (ii) protons and (iii) fully ionised Boron atoms by a tandem van de Graf accelerator which can produce an electric potential difference of 25 Mega Volts.
3. The electrons produced by the beta decay of neutrons: $n \to p + e^- + \bar{\nu}_e$ which are then subjected to a magnetic field of strength 1T.
4. Elelctrons in the innermost shell atoms of (i) Oxygen, ((ii) Germanium, and (iii) Gold
5. Atom/molecules on the surface of (i) the Sun and (ii) in the outer core of the Earth.
6. Hydrogen bond
7. Neutrons in a neutron star

Estimation of masses distances and times

Reason, or readup, methods of estimating the following. You are not allowed to travel long distances either on ground or fly.

1. Radius of the earth (First argue why the Earth should be finite)
2. Mass of the Earth
3. Height of a tall building (from the ground)
4. The Earth moon distance

5. The Earth Sun distance
6. Period of the Moon around the Earth (Indian astronomers, e.g, knew it upto a minute)
7. Angular sizes of the Sun and the Moon
8. Radii of the Sun and the Moon

Coordinate in a plane

1. Consider blique coordinate systems with angle α between the coordinate axes such that it can can take all values except $\frac{\pi}{2}$. Express the inner product between two position vectors suitably.
2. Also express their their cross product. Compare with your result for the inner product.
3. Repeat the exercise for (i) polar coordinates, (ii) parabolic coordinates, and (iii) elliptic coordinates.
4. Identify features which are different between the coordinate systems enumerated in the two sets above.
5. what do each of them have in common with rectangular coordinate systems.
6. *How would you construct the most general curvilinear orthogonal coordinate system.

Degrees of freedom

Identify the dimensions of the configuration space, momentum space and the phase space in each of the following examples:

1. A particle moving on a straight line along the x-axis
2. A particle constrained to move in the region $0 < x < \infty$
3. Two particles constrained to move inside and on a sphere of radius R
4. A rigid body free to move all over the space

5. A rigid body with whose centre of mass is a t a fixed distance from the origin
6. A pendulum with its end point fixed
7. A pendulum with its support that is free to move on a horizontal surface
8. A vibrating sitar string

Forces and their forms

1. Show that all strictly position dependent forces acting in one dimensions are necessarily conservative
2. Are the following forces conservative?
   $\vec{F} \propto (i) x^3 \hat{i}, \quad (ii)\ \vec{r}\exp(-r), \quad (iii)(x\hat{j} - y\hat{i}), (iv) \quad \vec{v}$. Is there something to be reconciled with the previous problem?
3. A body movinbg on a rough surface is generally assumed to experience a constant frictional force. Write the force in a vectorial form.
4. Consider a wheel rolling without slipping on a surface with only so called rolling friction (energy is conserved). How do you express that vectorially?
5. An aircraft flying in air experiences a frictional force proprtional to its kinetic energy. Write the expression for the force.

Constraints

1. A particle is constrained to move on the surface of a circle of radius R in the XY plane which is centered at the origin. Determine (i) its degree of freedom, and (ii) a set of corresponding coordinates. Pay due attention to the range.
2. Repeat the execise when the restriction is on the surface of the sphere.
3. . A dog held on a leash of length L by a person who is free to move in an area A. Set up a suitable coordinate system, and identify independent coordinates for this two body system. Ignore their physical dimensions.
4. A particle is constrained to moven inside a sphere of radius R_1 whose centre is in turn constrained to be at a constant distance L from a point in the XY plane. Set up a system of independent coordinates.