WHAT IS CLASSICAL MECHANICS ANYHOW?

It is important to keep in mind that Classical Mechanics is a system for modelling physical systems. This much we can say for certain and it is the attitude that I want you have as you learn to use it. In building models we identify objects whose behaviour we want to be able to describe and predict. The primary objects in the models constructed using Classical Mechanics are called PARTICLES. So, what is a particle? Some people will tell you that a particle is a "point" object with no size that can move around from place to place. Actually, in Classical Mechanics, this is not the case. A PARTICLE in Classical Mechanics is any physical system where WE DON'T CARE or can't resolve what its internal structure is (if any!). Of course the word PARTICLE evokes images in our minds of a point like object. A point-object cannot have any internal structure because there simply is no inside to it and this means that (aside from possibly merging with or emerging from other particles) the only interesting aspect of its behaviour is how it moves. The cool thing is that on a sufficiently large scale anything looks like a point. A car, a person, an atom, a star, a cluster of galaxies, they all look like points if we just "zoom out" to a large enough spatial scale. If we are only concerned with predicting the motion of the "particle" on such a scale then we will build a model with this object represented as a moving point. If, on the other hand, we can resolve the object into smaller pieces and actually care how they move with respect to one another then we would build another model where we identify the "particles" as these smaller pieces; again, where we don't care about any internal structure that might or might not exist inside these littler things. What is the object of the game? ***The object of the game is to describe and predict the motion of the particles we identify in the model we are using.***

Wait a minute! Which model should I use to describe my original "particle"? The one where it is modelled as a single thing or as lots of little things? The answer is that it doesn't matter. Both models will give exactly the same results for the motion of the larger "particle" due to a symmetry that is a big part of the internal consistency of the theory. As you might expect, the model with more parts will almost always be more complicated so generally we choose to identify the "particles" in the model with the real objects whose motion we actually care about. If I were to throw you off a cliff and wanted to predict when and where you would hit the bottom I would model you as a particle. If I cared what part of you would hit the bottom first then I would use a more complex model that captured the details of your anatomy. Often we do both! ***We start with the simplest model possible, make sure we understand that, and then deal with the more complicated and informative one later.*** This allows us a powerful check on very complicated models for they must agree in the aggregate with simpler models that are easier to construct and understand. Historically this feature has made it possible to systematically refine and IMPROVE models of particular systems when new details become apparent.

So the object of our game is to be able to predict how the particles we identify in our model are going to move. This begs the question ***"What controls the motion of particles?"*** Before we can address this question in a quantitative way we must first make a quantitative model of motion itself, starting with a quantitative description of position. Since we seem to only be able to make quantitative measurements of the distances BETWEEN OBJECTS, we build a description based on FRAMES OF REFERENCE. The idea is that we always have in mind a collection of objects to refer the motion of our particles to. As a practical matter in everyday applications we typically use a collection of reference objects fixed on the surface of the earth. We then employ a system of measurement, geometry, and calculus to describe the motion of particles with respect to our reference objects. The very first part of the course is concerned with developing this system. [There is a lot of deep physics in the implications that follow from our choice of reference frame; some of them were beyond Newton's apparent capacity to deal with. These questions waited hundreds of years to be addressed by Einstein and others. We will revisit some of these questions at the end of our course when we study Relativity.] Using this scheme to obtain a quantitative description of motion we find three particularly interesting quantities associated with the motion of an object (they are all related by Calculus): **position, velocity, and acceleration.** It turns out that all three of these quantities have size and direction and are modelled as **VECTOR** quantities. This description of motion has its own name; it is called **Kinematics** and understanding it is the first major goal of the course. ***The internal consistency of this description of motion guarantees that if one knows that acceleration of a particle moment-to-moment over a period of time and also the initial position and velocity of the particle then it is possible to figure out where and with what velocity the particle moves throughout the same period.***

Understanding these kinematics' quantities associated with motion will put us in a position to understand all the details of Newton's answer to the question "What controls the motion of particles?" but the broad answer is that **INTERACTIONS with other particles, an environment of external influences, is what controls the motion of each particle.** The theory holds that only EXTERNAL INFLUENCES, as embodied in the interactions between particles, control the motion of each and every particle. Much more precisely, the quantitative aspect of the motion that is instantaneously controlled by these interactions is the Acceleration of a particle. What do interactions cause? They cause acceleration. No interaction means no acceleration. "Ok", you say, but what exactly is an "interaction"? The idea here is that any PAIR of particles can enter into an interaction. When this occurs each particle is subjected to a "push" which has size and direction. It is a fundamental, implicit tenant of Mechanics that **all interactions occur PAIR WISE and are SYMMETRIC in the sense that when any two particles interact the pushes they experience are equal in size and opposite in direction at each instant.** [On closer examination, many students have an intuitive problem with this idea. Get over it.] This SYMMETRY principle is so important that it is promoted to the status of a law, Newton's Third Law to put a name to it. As you might guess, the "push" that a particle is subjected to during an interaction is known as a FORCE and it, like acceleration, can be represented as a VECTOR quantity because it has size and direction. In Newton's picture of interacting particles, the motion of any single particle is controlled by its environment through these interactions. The influence of each interaction on the particle being represented by a force vector. Ok, OK, but how does this control the motion of the particle? The answer is first, all the influences combine in a simple way into one big influence. **The rule of combination is known as the principle of superposition and mathematically the rule is exquisitely simple and completely independent of which particular particles or types of interactions are involved. The forces (influences) combine by simple Vector addition.** [This is the real reason we choose to model forces as vector quantities.] The idea is that each force is a vector and they combine in the simplest possible way: you just add them up! What you get, of course is one "big" vector, often called the "net" force. Sometimes the forces on a particle add up to ZERO and you get no effect (acceleration); sometimes they do not cancel and acceleration is the result!! ***"Well fine, they all add up. But precisely how much acceleration results from this one big combined "push"?"*** The answer is that it depends on an INTRINSIC property of every particle called its MASS (or inertia in the old language). The idea is that the net (i.e. TOTAL) force is a vector and the acceleration is a vector and they point in the same direction and their sizes are related by a proportionality constant called the MASS which is an intrinsic property of the particle that determines how much of the response (acceleration) results from a particular total force (combined influence). The law is known as Newton's 2nd Law: Sum of the Forces (Influences) = MASS times Acceleration (Effect). The bigger the mass the less the effect of these pushes. So that is the basic scheme.

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