1. THE ACTION PRINCIPLES IN MECHANICS pdf

1: classical mechanics - Why the Principle of Least Action? - Physics Stack Exchange

1. The Action Principles in Mechanics 5 The difference between li and lio acting on t, Xi(t) and Xi(t) is expressed by the identity d li = lio + lit dt. () So far we have obtained.

The rest is commentary. You just get used to them. A rational person will immediately get it in one go because there is a straight-forward rigorous proof to the claim that the ball will go tangentially. Developing an intuition for things based on your experience and not based on rigorous proofs is adopting a religion and not doing actual mathematical science. One thing left unsaid by Newton is conservation of energy. Elastic processes are more fundamental than inelastic ones. But energy conservation is only part of the story. Suppose you have a bunch of masses connected by springs, and one of them is attached to a double-pendulum. You could theoretically have energy conservation in such a system by having all the energy leak out of the masses on the springs and go into the double pendulum. Perhaps every frictionless motion of the springs eventually settles all the energy into a single mode. How could the pendulum move around and not set the springs vibrating! But the solutions do not exhibit such phenomena, and there must be a reason why. This intuition tells you that a perfect frictionless mechanical system is more than energy-conserving, it must conserve some notion of "motion-volume", so that if you alter the initial state by a certain amount, the final state should alter the same way. This principle is the principle of conservation of phase-space volume, or the conservation of information. If all the motion got concentrated into one mode, the information about where everything was would have to get absurdly compressed into a tiny region of the phase space, the space of all possible motions. So you need to understand what type of law will give a law of conservation of information. There are two paths to go down, and both lead to the same structure, but from two different points of view, local in time and global in time. One path is Hamiltonian: This formulation clearly separates between reversible and irreversible dynamics, because it only works for reversible. It also explains the fundamental mathematical structure behind reversible classical mechanics, the symplectic geometry. The volume of symplectic geometry gives the precise law of information conservation, and further, the geometrical structure of systems with multiperiodic solutions, the integrable systems, is made clear. But this point of view is centered on a time-slicing it describes things going from one instant of time to another. This is not playing very nice with relativity. So you also want to think about the solution globally, and consider the space of all solutions as the phase space. The initial position and velocities are good coordinates, and intuitive ones, because they determine the future. But if you want a global picture, you want coordinates which are symmetric between the final and initial state, since the dynamics are reversible. An explicit revesible description should treat the initial time and final time symmetrically. So you can use the initial positions and final positions, which also, generically, away from certain bad choices, determine the motion. For these types of coordinates on phase space, you give the dynamical law as a condition on the trajectory between the intial and final positions. The condition should not be stated as a differential equation, because such a description is unnatural for boundary conditions of this sort. But when you have an action principle, you determine the trajectory by extremizing the action between the end points, you automatically have a notion of phase space volume, which is intuitive the phase space volume is defined by the change in the action of extremal trajectories with respect to changes in the initial velocities. This volume is the same as for the changes of the extremal trajectories with respect to changes in the final velocities. This is a straightforward consequence of the equivalence of Lagrangian and Hamiltonian formulation. The full justification for both principles comes only with quantum mechanics. There you learn that the least action principle is a geometric optics Fermat principle for matter waves, and it is saying that the trajectories are perpendicular to constant-phase lines. But historically, the Lagrangian formulation was recognized to be more fundamental a century before Hamilton conjectured that classical mechanics was a wave mechanics, and this was many decades before Schrodinger. Still, with our modern point of view, it does not hurt to learn the quantum version of these formulations first, and it certainly provides a more solid motivation than the heuristic considerations I gave above.

1. THE ACTION PRINCIPLES IN MECHANICS pdf

2: Principle of least action - Wikipedia

4 1. Principle of Least Action A New Way of Looking at Things Newtonian Mechanics Let's start simple. Consider a single particle at position r (t), acted upon by a force F.

The Hamilton principle is nowadays the most used. More than one true trajectory may satisfy the given constraints of fixed end-positions and travel time see Section 3. In Section 7 we mention generalized action principles with relaxed end-position constraints. Some smoothness restrictions are also often imposed on the trial trajectories. In all cases the solutions for the true trajectories and orbits can be obtained directly from the Hamilton and Maupertuis variational principles see Section 8 , or from the solution of the corresponding Euler-Lagrange differential equations see Section 3 which are equivalent to the variational principles. Systems with velocity-dependent forces require special treatment. Dissipative nonconservative systems are discussed in Section 4. Magnetic and relativistic systems are discussed by Jackson , and in Section 9 below. For conservative systems the two principles 2 and 4 are related by a Legendre transformation, as discussed in Section 6. An appealing feature of the action principles is their brevity and elegance in expressing the laws of motion. They are valid for any choice of coordinates i. They generate covariant equations of motion Section 3 , but they also supply an alternative and direct route to finding true trajectories which bypasses equations of motion; this route can be implemented analytically as an approximation scheme Section 8 , or numerically to give essentially exact trajectories Beck et al. Action principles transcend classical particle and rigid body mechanics and extend naturally to other branches of physics such as continuum mechanics Section 11 , relativistic mechanics Section 9 , quantum mechanics Section 10 , and field theory Section 11 , and thus play a unifying role. Unifying the various laws of physics with the help of action principles has been an ongoing activity for centuries, not always successful, e. The action principles have occasionally assisted in developing new laws of physics see comments at the end of Section 9. The Hamilton and Maupertuis principles are not applicable, however, if the system is nonholonomic, and usually not if the system is dissipative Section 4. History Various aspects of the extensive history of action principles and variational principles in general are discussed in the historical references at the end of this article. The original formulation of Maupertuis was vague and it is the reformulation due to Euler and Lagrange that is described above. Today we recognize that a principle of least action is partly conventional changing the sign in the definition of the action leaves the equations of motion intact but changes the principle to one of greatest action , that in general action is least only for sufficiently short trajectories Section 5 , that the principle is not valid for all force laws Section 4 , and, when valid, it is a mathematical consequence of the equations of motion. No a priori physical argument requires a principle of least or stationary action in classical mechanics, but the classical principle is a consequence of quantum mechanical variational principles in the classical limit Section Quantum mechanics itself can be based on postulates of action principles Section 10 , and in new fields one often simply postulates an action principle. At the end of Section 9 we briefly discuss the history of the role of action principles in establishing new laws of physics, and at the end of the preceding section we mention the long history of using action principles in attempting to unify the various laws of physics. As with Maupertuis, unifying the treatments of geometric optics and mechanics motivated Hamilton. These form the basis of modern Hamiltonian mechanics Goldstein et al. This last result was given implicitly by Hamilton in his papers and somewhat more explicitly by Jacobi in his lectures Clebsch The various versions of quantum mechanics all developed from corresponding classical mechanics results of Hamilton, i. Over the years, and even recently, a number of reformulations and generalizations of the basic Maupertuis and Hamilton action principles have been given see Gray et al. In Section 7 we discuss several of the most recent generalizations. Euler-Lagrange Equations Using standard calculus of variations techniques one can carry out the first-order variation of the action, set the result to zero as in 2 or 4 , and thereby derive differential equations for the true trajectory, called the Euler-Lagrange equations, which are equivalent to the variational principles. For particle systems these equations reduce to the standard Newton equations of motion if one chooses Cartesian coordinates in an inertial frame. In practice, one usually has initial conditions in mind, where the solution is unique, and selects the appropriate solution of the corresponding boundary value problem, or imposes the initial conditions directly on the solution of the Euler-Lagrange equation of motion. Another system exhibiting multiple solutions under space-time boundary condition constraints is the quartic oscillator, discussed in Sections 5 and 8. Additional true trajectories with higher energies also satisfy the boundary conditions. If we throw the ball twice, in the same vertical plane, with two different angles of elevation of the initial velocity, say one with 45 degrees and the other with 75 degrees, but the same initial speed, the two parabolic spatial paths will recross at some point in the plane, call it R. We see in these examples of multiple solutions the roles of the differing constraints in the Hamilton and Maupertuis principles. In the Maupertuis principle example, the opposite is true: Restrictions to Holonomic and Nondissipative Systems The action principles 2 and 4 are restricted to holonomic systems, i. Simple examples of holonomic and nonholonomic systems are a particle confined to a spherical surface, and a wheel confined to rolling without slipping on a horizontal plane, respectively. Attempts to extend the usual action principles to nonholonomic systems have been controversial and ultimately unsuccessful Papastavridis In essence, the Lagrange multipliers relax the constraints, with one multiplier for each constraint relaxed. In the literature e. The usual action principles are valid for this type of velocity-dependent constraint. The Dirac-type constraints are implemented by the method of Lagrange multipliers. In Section 7 we use Lagrange multipliers to relax the fundamental constraints of the Hamilton and Maupertuis principles. In general, the action principles do not apply to dissipative systems, i. More generally, the question of whether a Lagrangian and corresponding action principle exist for a particular dynamical system, given the equations of motion and the nature of the forces acting on the system, is referred to as the "inverse problem of the calculus of variations" Santilli Additional freedom of choice will also often exist. By putting additional conditions on the Lagrangian we can narrow down the choice. Thus for the free particle in one dimension, using an inertial frame of reference and by requiring the Lagrangian function to be invariant under Galilean transformations, i. In this review we restrict ourselves to the most common case where the Lagrangian depends on the coordinates and their first derivatives, but when higher derivatives occur in the Lagrangian the Euler-Lagrange equation generalizes in a natural way Fox, As an example, in considering the vibrational motion of elastic continuum systems Section 11 such as beams and plates, the standard Lagrangian contains spatial second derivatives, and the corresponding Euler-Lagrange equation of motion contains spatial fourth derivatives Reddy, For this particular oscillator the kinetic focus occurs approximately at a fraction 0. From Gray and Taylor As defined in Section 1, action is never a local maximum, as we shall discuss. In relativistic mechanics see Section 9 two sign conventions for the action have been employed, and whether the action is never a maximum or never a minimum depends on which convention is used. In our convention it is never a minimum. Establishing the existence of a kinetic focus using this criterion is discussed by Fox An equivalent and more intuitive definition of a kinetic focus can be given. Based on this definition a simple prescription for finding the kinetic focus can be derived Gray and Taylor , i. This is the first kinetic focus, usually called simply the kinetic focus. Subsequent kinetic foci may exist but we will not be concerned with them. The other trajectories shown in Figure 1 have their own kinetic foci, i. For the purpose of determining the true trajectories, the nature of the stationary action minimum or saddle point is usually not of interest. However, there are situations where this is of interest, such as investigating whether a trajectory is stable or unstable Papastavridis , and in semiclassical mechanics where the phase of the propagator Section 10 depends on the true classical trajectory action and its stationary nature; the latter dependence is expressed in terms of the number of kinetic foci occurring between the end-points of the true trajectory Schulman In general relativity kinetic foci play a key role in establishing the Hawking-Penrose singularity theorems for the gravitational field Wald Kinetic foci are also of importance in electron and particle beam optics. Finally, in seeking stationary action trajectories numerically Basile and Gray , Beck et al. If a minimum is being sought, comparison of the action at successive stages of the calculation gives an indication of the error in the trajectory at a given stage since the action should approach the minimum value monotonically from above as the trajectory is refined. The error sensitivity is, unfortunately, not particularly good, as, due the stationarity of the action, the error in the action is of second order in the error of the trajectory. Thus a relatively large error in the trajectory can produce a small error in the action. Relation of Hamilton and Maupertuis Principles For conservative time-invariant systems the Hamilton and Maupertuis principles are related by a Legendre transformation Gray et al. The two action principles are thus equivalent for conservative systems, and related by a Legendre transformation whereby one changes between energy and time as independent constraint parameters. The existence in mechanics of two actions and two corresponding variational principles which determine the true trajectories, with a Legendre transformation between them, is analogous to the situation in thermodynamics Gray et al. There, as established by Gibbs, one introduces two free energies related by a Legendre transformation, i. Generalizations We again restrict the discussion to time-invariant conservative systems. It is possible to derive additional generalized principles Gray et al. A word on notation may be appropriate in this regard: As we shall see in the next section and in Section 10, the alternative formulations of the action principles we have considered, particularly the reciprocal Maupertuis principle, have advantages when using action principles to solve practical problems, and also in making the connection to quantum variational principles. We note that reciprocal variational principles are common in geometry and in thermodynamics see Gray et al. Practical Use of Action Principles Just as in quantum mechanics, variational principles can be used directly to solve a dynamics problem, without employing the equations of motion. This is termed the direct variational or Rayleigh-Ritz method. The solution may be exact in simple cases or essentially exact using numerical methods , or approximate and analytic using a restricted and simple set of trial trajectories. We illustrate the approximation method with a simple example and refer the reader elsewhere for other pedagogical examples and more complicated examples dealing with research problems Gray et al. We wish to estimate this dependence. The frequency increases with amplitude, confirming what is seen in Fig. This problem is simple enough that the exact solution can be found in terms of an elliptic integral Gray et al. These methods are widely used in quantum mechanics Epstein , Adhikari , classical continuum mechanics Reddy , and classical field theory Milton and Schwinger They are also used in mathematics to prove the existence of solutions of differential Euler-Lagrange equations Dacorogna Relativistic Systems The Hamilton and Maupertuis principles, and the generalizations discussed above in Section 7, can be made relativistic and put in either Lorentz covariant or noncovariant forms Gray et al. The Hamilton principle is thus gauge invariant. Specific examples, such as an electron in a uniform magnetic field, are discussed in the references Gray et al. As discussed below, the equations for the field Maxwell equations can also be derived from an action principle. Action principles are important also in general relativity. The proper time is stationary, here a maximum, for the true trajectory which is straight in a Lorentz frame compared to the proper time for all virtual trajectories. The principle of stationary proper time, or maximal aging, is also valid in general relativity for the motion of a test particle in a gravitational field Taylor and Wheeler ; for "short" true trajectories the proper time is a maximum, and for "long" true trajectories "long" and "short" trajectories are defined in Section 5 the proper time is a saddle point Misner et al. The corresponding Euler-Lagrange equation of motion is the relativistic geodesic equation. In general relativity the Einstein gravitational field equations can also be derived from an action principle, using the so-called Einstein-Hilbert action Landau and Lifshitz , Misner et al. General relativity is perhaps the first, and still the best, example of a field where new laws of physics were derived heuristically from action principles, since Einstein and Hilbert were both motivated by action principles, at least partly, in establishing the field equations, and the principle of stationary proper time was used to obtain the equation of motion of a test particle in a gravitational field. A second example is modern Yang-Mills type gauge field theory.

1. THE ACTION PRINCIPLES IN MECHANICS pdf

3: Action (physics) - Wikipedia

In physics, action is an attribute of the dynamics of a physical system from which the equations of motion of the system can be derived. It is a mathematical functional which takes the trajectory, also called path or history, of the system as its argument and has a real number as its result.

First, however, the nurse needs to understand and practice proper body mechanics himself or herself. People clients and nurses alike differ in weight, size, and ability to move. It is important to provide safety for both the nurse and the client. This means applying mechanical principles of movement to the human body. Principles of Body Mechanics The laws of physics govern all movement. From these laws we derive the general principles of body mechanics Box In other words, some ways of moving and carrying objects are more effective than others. Principles underlying proper body mechanics involve three major factors: This means that approximately half the body weight is distributed above this area, half below it, when thinking of the body divided horizontally. In addition, half the body weight is to each side, when thinking of the body divided vertically. When lifting an object, bend at the knees and hips and keep the back straight. By doing so, the center of gravity remains over the feet, giving extra stability. It is thus easier to maintain balance Fig. The wider the base of support, the more stable the object, within limits see Fig. The feet must not be too wide apart, as this would cause instability. The feet are spread sidewise when lifting, to give side-to-side stability. Basic Principles of Body Mechanics 1. It is easier to pull, push, or roll an object than it is to lift it. The movement should be smooth and continuous, rather than jerky. Often less energy or force is required to keep an object moving than it is to start and stop it. It takes less effort to lift an object if the nurse works as close to it as possible. Use the strong leg and arm muscles as much as possible. Use back muscles, which are not as strong, as little as possible. The nurse rocks backward or forward on the feet and with his or her body as a force for pulling or pushing. B By increasing the distance between his feet and lowering his body toward the ground, the person has increased ability to maintain side-to-side balance. His right foot is slightly in front of the left, for back-to-front stability. One foot is placed slightly in front of the other for back-to-front stability. The weight is distributed evenly between both feet. The knees are flexed slightly, to absorb jolts. The feet are moved to turn the object being moved. It is important not to twist the body. Line of Gravity Draw an imaginary vertical up and down line through the top of the head, the center of gravity, and the base of support. This becomes the line of gravity, or the gravital plane Fig. This is the direction of gravitational pull from the top of the head to the feet. For highest efficiency, this line should be straight from the top of the head to the base of support, with equal weight on each side. Therefore, if a person stands with the back straight and the head erect, the line of gravity will be approximately through the center of the body, and proper body mechanics will be in place. Body Alignment When lifting, walking, or performing any body activity, proper body alignment is essential to maintain balance. Stretching the body as tall as possible produces proper alignment. This can be accomplished through proper posture see Fig. When standing, the weight is slightly forward and is supported on the outside part of the feet. Again, the head is erect, the back is straight, and the abdomen is tucked in. Remember that the client in bed should be in approximately the same position as if he or she were standing [Fig. Alignment in bed should be approximately the same as when standing. A Proper body alignment for a person lying on the back supine. B Proper body alignment for a person lying on the side lateral. C Proper body alignment for a person lying on the stomach in bed prone. A small pillow or folded towel should be placed under the shoulder toward which the head is turned. Clients may be reluctant to move or may stay in bed unnecessarily. This immobility can contribute to a number of disorders, among which are pressure ulcers, blood clots, constipation, muscle weakness and atrophy, pneumonia, joint deformities, and mental disorders. By assisting clients to maintain or regain mobility, you promote self-care practices and help to prevent these complications Fig. It is important to practice good body mechanics when lifting and moving clients. In this way, the nurse prevents injury to self and client Fig. Nursing Care Guidelines gives tips on positioning clients for their maximum comfort. It is important to explain to the client why his or her position is being changed and how it will be done. If he or she can help, explain how. Sometimes turning the client is such an important part of treatment that the provider specifies how often to do it. This consideration is especially important for older or immobile clients. Some conditions do not permit turning the client, such as fractures that require traction appliances. In other conditions, such as unstabilized spinal injuries, turning may be harmful. In most other conditions, turning is helpful and encouraged. In some situations, the client is turned only to wash or rub the back; to assess skin condition, wounds, or dressings; or to change the bed linens. Some clients may not be allowed or able to turn at all and must remain in a supine position. If this is the case, and the client is physically able, the nurse may ask him or her to pull up slightly on the overhead trapeze to provide back care and other interventions as needed. If the client is able to help move himself or herself, explain what he or she can do and why it is important. Encourage the client to help as much as possible. Key Concept It is important to give meticulous skin care to the person who must remain on his or her back. If the person can pull up off the bed, the nurse can wash and gently massage the back with the hand held flat. This helps to prevent skin breakdown. In other situations, a special bed is often used see Chap. Special beds operate in different ways to relieve pressure and provide back support. Although not commonly used, in some cases, the client who cannot turn is placed in a circle bed, which rotates the client from head to toe, or on a Stryker wedge turning frame, which rotates the client from side to side. More commonly, the client is placed in a rotating or oscillating bed e. Nursing Alert Be sure to request help from another person if the client is heavy or if you are unsure that you can move the person by yourself. It is also important to be sure you know how to use special equipment for moving and lifting clients before use. Positioning for Examinations and Treatments The client is sometimes helped into a special position as part of a treatment or examination. Many different positions are used for physical examinations, nursing treatments and tests, and to obtain specimens. Because nurses assist clients into some of these positions and will see other positions used, it is important to know how to assist the client and how to place the necessary drapes. The supine position may be modified by bending the knees and placing the feet flat on the bed. This position is also used for some portions of postural drainage, to help drain secretions from particular segments of the lungs. Two other, less commonly used positions are the modified standing position standing while bending over forward , and the position used for lumbar puncture. Special positioning is shown in Table Use long, strong muscles of arms and legs. Hold the object so the line of gravity falls within the base of support. Keep the back straight and the load close to the body. Ask for assistance, if necessary. The following measures are carried out before draping the client for examination: This helps the person feel more relaxed and helps the examiner to better palpate the area being examined. In some cases, a full bladder aids in the examination. Alignment is similar whether the client is standing or in bed. In some cases, a small pillow is provided. In addition, the nurse provides comfort to the client and answers questions.

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4: The Feynman Lectures on Physics Vol. II Ch. The Principle of Least Action

That's the relation between the principle of least action and quantum mechanics. The fact that quantum mechanics can be formulated in this way was discovered in by a student of that same teacher, Bader, I spoke of at the beginning of this lecture.

Every time the subject comes up, I work on it. In fact, when I began to prepare this lecture I found myself making more analyses on the thing. Instead of worrying about the lecture, I got involved in a new problem. The subject is thisâ€”the principle of least action. Bader told me the following: Suppose you have a particle in a gravitational field, for instance which starts somewhere and moves to some other point by free motionâ€”you throw it, and it goes up and comes down Fig. It goes from the original place to the final place in a certain amount of time. Now, you try a different motion. Suppose that to get from here to there, it went as shown in Fig. Then he said this: Now I take the kinetic energy minus the potential energy at every moment along the path and integrate that with respect to time from the initial time to the final time. But we could imagine some other motion that went very high and came up and down in some peculiar way Fig. We can calculate the kinetic energy minus the potential energy and integrate for such a path â€¦ or for any other path we want. The miracle is that the true path is the one for which that integral is least. First, suppose we take the case of a free particle for which there is no potential energy at all. Then the rule says that in going from one point to another in a given amount of time, the kinetic energy integral is least, so it must go at a uniform speed. Because if the particle were to go any other way, the velocities would be sometimes higher and sometimes lower than the average. You can do it several ways: You can accelerate like mad at the beginning and slow down with the brakes near the end, or you can go at a uniform speed, or you can go backwards for a while and then go forward, and so on. The thing is that the average speed has got to be, of course, the total distance that you have gone over the time. But if you do anything but go at a uniform speed, then sometimes you are going too fast and sometimes you are going too slow. Now the mean square of something that deviates around an average, as you know, is always greater than the square of the mean; so the kinetic energy integral would always be higher if you wobbled your velocity than if you went at a uniform velocity. So we see that the integral is a minimum if the velocity is a constant when there are no forces. The correct path is shown in Fig. That is because there is also the potential energy, and we must have the least difference of kinetic and potential energy on the average. Because the potential energy rises as we go up in space, we will get a lower difference if we can get as soon as possible up to where there is a high potential energy. Then we can take that potential away from the kinetic energy and get a lower average. So it is better to take a path which goes up and gets a lot of negative stuff from the potential energy Fig. So it turns out that the solution is some kind of balance between trying to get more potential energy with the least amount of extra kinetic energyâ€”trying to get the difference, kinetic minus the potential, as small as possible. So instead of leaving it as an interesting remark, I am going to horrify and disgust you with the complexities of life by proving that it is so. The kind of mathematical problem we will have is very difficult and a new kind. It is the kinetic energy, minus the potential energy, integrated over time. For each different possible path you get a different number for this action. Our mathematical problem is to find out for what curve that number is the least. You calculate the action and just differentiate to find the minimum. Ordinarily we just have a function of some variable, and we have to find the value of that variable where the function is least or most. For instance, we have a rod which has been heated in the middle and the heat is spread around. For each point on the rod we have a temperature, and we must find the point at which that temperature is largest. But now for each path in space we have a numberâ€”quite a different thingâ€”and we have to find the path in space for which the number is the minimum. That is a completely different branch of mathematics. It is not the ordinary calculus. In fact, it is called the calculus of variations. For example, the circle is usually defined as the locus of all points at a constant distance from a fixed point, but another way of defining a circle is this: Any other curve encloses less area for a given perimeter than the circle does. So if we give the problem: Here is the way we are going to do it. The idea is that we imagine that there is a true path and that any other curve we draw is a false path, so that if we calculate the action for the false path we will get a value that is bigger than if we calculate the action for the true path Fig. Find the true path. One way, of course, is to calculate the action for millions and millions of paths and look at which one is lowest. But we can do it better than that. When we have a quantity which has a minimumâ€”for instance, in an ordinary function like the temperatureâ€”one of the properties of the minimum is that if we go away from the minimum in the first order, the deviation of the function from its minimum value is only second order. At any place else on the curve, if we move a small distance the value of the function changes also in the first order. But at a minimum, a tiny motion away makes, in the first approximation, no difference Fig. If we have the true path, a curve which differs only a little bit from it will, in the first approximation, make no difference in the action. Any difference will be in the second approximation, if we really have a minimum. If there is a change in the first order when I deviate the curve a certain way, there is a change in the action that is proportional to the deviation. But then if the change is proportional to the deviation, reversing the sign of the deviation will make the action less. We would get the action to increase one way and to decrease the other way. It can differ in the second order, but in the first order the difference must be zero. With that condition, we have specified our mathematical problem. Here is a certain integral. You will see the great value of that in a minute. There are formulas that tell you how to do this in some cases without actually calculating, but they are not general enough to be worth bothering about; the best way is to calculate it out this way. I can do that by integrating by parts. It is always the same in every problem in which derivatives appear. Then I must have the integral from the rest of the integration by parts. The last term is brought down without change. In fact, if the integrated part does not disappear, you restate the principle, adding conditions to make sure it does! So the integrated term is zero. We collect the other terms together and obtain this: The action integral will be a minimum for the path that satisfies this complicated differential equation: The first term is the mass times acceleration, and the second is the derivative of the potential energy, which is the force. The fundamental principle was that for any first-order variation away from the optical path, the change in time was zero; it is the same story. In the first place, the thing can be done in three dimensions. And what about the path? The path is some general curve in space, which is not so easily drawn, but the idea is the same. Since only the first-order variation has to be zero, we can do the calculation by three successive shifts. We get one equation. Or, of course, in any order that you want. Anyway, you get three equations. I think that you can practically see that it is bound to work, but we will leave you to show for yourself that it will work for three dimensions. If you have, say, two particles with a force between them, so that there is a mutual potential energy, then you just add the kinetic energy of both particles and take the potential energy of the mutual interaction. And what do you vary? You vary the paths of both particles. Then, for two particles moving in three dimensions, there are six equations. But the principle of least action only works for conservative systemsâ€”where all forces can be gotten from a potential function. You know, however, that on a microscopic levelâ€”on the deepest level of physicsâ€—there are no nonconservative forces. Nonconservative forces, like friction, appear only because we neglect microscopic complicationsâ€—there are just too many particles to analyze. But the fundamental laws can be put in the form of a principle of least action. Suppose we ask what happens if the particle moves relativistically. Is there a corresponding principle of least action for the relativistic case? The formula in the case of relativity is the following: Of course, we are then including only electromagnetic forces. This action function gives the complete theory of relativistic motion of a single particle in an electromagnetic field. I will leave to the more ingenious of you the problem to demonstrate that this action formula does, in fact, give the correct equations of motion for relativity. The variations get much more complicated. But I will leave that for you to play with. The question of what the action should be for any particular case must be determined by some kind of trial and error. It is just the same problem as determining what are the laws of motion in the first place.

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5: Principle of least action - Scholarpedia

The principle of least action - or, more accurately, the principle of stationary action - is a variational principle that, when applied to the action of a mechanical system, can be used to obtain the equations of motion for that system. In relativity, a different action must be minimized or maximized.

The scientific revolution would change forever how people think about the universe. In his book, Copernicus pointed out that the calculations needed to predict the positions of the planets in the night sky would be somewhat simplified if the Sun , rather than the Earth, were taken to be the centre of the universe by which he meant what is now called the solar system. To the casual observer, the Earth certainly seems to be solidly at rest. Scholarly thought about the universe in the centuries before Copernicus was largely dominated by the philosophy of Plato and Aristotle. According to Aristotelian science, the Earth was the centre of the universe. The four elementsâ€”earth, water, air, and fireâ€”were naturally disposed in concentric spheres, with earth at the centre, surrounded respectively by water, air, and fire. Outside these were the crystal spheres on which the heavenly bodies rotated. Heavy, earthy objects fell because they sought their natural place. Smoke would rise through air, and bubbles through water for the same reason. These were natural motions. All other kinds of motion were violent motion and required a proximate cause. For example, an oxcart would not move without the help of an ox. When Copernicus displaced the Earth from the centre of the universe, he tore the heart out of Aristotelian mechanics, but he did not suggest how it might be replaced. Without suitable explanation, Copernicanism was a violation not only of Aristotelian philosophy but also of plain common sense. The solution to the problem was discovered by the Italian mathematician and scientist Galileo Galilei. Inventing experimental physics as he went along, Galileo studied the motion of balls rolling on inclined planes. He noticed that, if a ball rolled down one plane and up another, it would seek to regain its initial height above the ground, regardless of the inclines of the two planes. That meant, he reasoned, that, if the second plane were not inclined at all but were horizontal instead, the ball, unable to regain its original height, would keep rolling forever. From this observation he deduced that bodies do not need a proximate cause to stay in motion. Instead, a body moving in the horizontal direction would tend to stay in motion unless something interfered with it. Timing the rate of descent of the balls by means of precision water clocks and other ingenious contrivances and imagining what would happen if experiments could be carried out in the absence of air resistance, he deduced that freely falling bodies would be uniformly accelerated at a rate independent of their mass. Moreover, he understood that the motion of any projectile was the consequence of simultaneous and independent inertial motion in the horizontal direction and falling motion in the vertical direction. In his book Dialogues Concerning the Two New Sciences , Galileo wrote, It has been observed that missiles and projectiles describe a curved path of some sort; however, no one has pointed out the fact that this path is a parabola. But this and other facts, not few in number or less worth knowing, I have succeeded in proving. His studies fall into the branch of classical mechanics known as kinematics , or the description of motion. Although Galileo and others tried to formulate explanations of the causes of motion, the focus of the field termed dynamics , none would succeed before Newton. What he saw there, particularly the moons of Jupiter, either prompted or confirmed his embrace of the Copernican system. At the time, Copernicus had few other followers in Europe. Among those few, however, was the brilliant German astronomer and mathematician Johannes Kepler. Kepler devoted much of his scientific career to elucidating the Copernican system. Although Copernicus had put the Sun at the centre of the solar system, his astronomy was still rooted in the Platonic ideal of circular motion. Before Copernicus, astronomers had tried to account for the observed motions of heavenly bodies by imagining that they rotated on crystal spheres centred on the Earth. This picture worked well enough for the stars but not for the planets. This system of astronomy culminated with the Almagest of Ptolemy , who worked in Alexandria in the 2nd century ad. Kepler set out to find further simplifications that would help to establish the validity of the Copernican system. In the course of his investigations, Kepler discovered the three laws of planetary motion that are still named for him. This observation swept epicycles out of astronomy. His second law stated that, as the planet moved through its orbit , a line joining it to the Sun would sweep out equal areas in equal times. For Kepler, this law was merely a rule that helped him make precise calculations for his astronomical tables. Later, however, it would be understood to be a direct consequence of the law of conservation of angular momentum. In particular, the square of the period is proportional to the cube of the semimajor axis of its elliptical orbit. This observation would suggest to Newton the inverse-square law of universal gravitational attraction. Newton is thought to have made many of his great discoveries at the age of 23, when in â€”66 he retreated from the University of Cambridge to his Lincolnshire home to escape from the bubonic plague. However, he chose not to publish his results until the Principia emerged 20 years later. In the Principia, Newton set out his basic postulates concerning force, mass, and motion. In addition to these, he introduced the universal force of gravity , which, acting instantaneously through space, attracted every bit of matter in the universe to every other bit of matter, with a strength proportional to their masses and inversely proportional to the square of the distance between them. The way it worked is what is now referred to as classical mechanics. Fundamental concepts Units and dimensions Quantities have both dimensions, which are an expression of their fundamental nature, and units , which are chosen by convention to express magnitude or size. For example, a series of events have a certain duration in time. Time is the dimension of the duration. The duration might be expressed as 30 minutes or as half an hour. Minutes and hours are among the units in which time may be expressed. One can compare quantities of the same dimensions, even if they are expressed in different units an hour is longer than a minute. Quantities of different dimensions cannot be compared with one another. The fundamental dimensions used in mechanics are time, mass, and length. Symbolically, these are written as t, m, and l, respectively. The study of electromagnetism adds an additional fundamental dimension, electric charge , or q. Other quantities have dimensions compounded of these. Some quantities, such as temperature, have units but are not compounded of fundamental dimensions. Dimensionless numbers may be constructed as ratios of quantities having the same dimension. Dimensionless numbers have the advantage that they are always the same, regardless of what set of units is being used. Governments have traditionally been responsible for establishing and enforcing standard units for the sake of orderly commerce, navigation , science, and, of course, taxation. Today all such units are established by international treaty, revised every few years in light of scientific findings. They are based on the metric system , first adopted officially by France in Other units, such as those of the British engineering system , are still in use in some places, but these are now defined in terms of the SI units. The fundamental unit of length is the metre. By contrast, in the British system, units of length have a clear human bias: Each of these is today defined as some fraction or multiple of a metre one yard is nearly equal to one metre. Times longer than one second are expressed in the units seconds, minutes, hours, days, weeks, and years. The fundamental unit of time i. Units of mass are also defined in a way that is technically sound , but in common usage they are the subject of some confusion because they are easily confused with units of weight , which is a different physical quantity. Thus, the mass of a given object is the same everywhere, but its weight varies slightly if it is moved about the surface of the Earth, and it would change a great deal if it were moved to the surface of another planet. The kilogram is equal to 1, grams; 1 gram is the mass of 1 cubic centimetre of waterâ€”under appropriate conditions of temperature and pressure. Vectors The equations of mechanics are typically written in terms of Cartesian coordinates. At a certain time t, the position of a particle may be specified by giving its coordinates x t , y t , and z t in a particular Cartesian frame of reference. That is, both observers see the same particle executing the same motion and obeying the same laws, but they describe the situation with different equations. This awkward situation may be avoided by means of a mathematical construction called a vector. Although vectors are mathematically simple and extremely useful in discussing mechanics, they were not developed in their modern form until late in the 19th century, when J. Willard Gibbs and Oliver Heaviside of the United States and Britain, respectively each applied vector analysis in order to help express the new laws of electromagnetism proposed by James Clerk Maxwell. A vector is a quantity that has both magnitude and direction. It is typically represented symbolically by an arrow in the proper direction, whose length is proportional to the magnitude of the vector. Although a vector has magnitude and direction, it does not have position. A vector is not altered if it is displaced parallel to itself as long as its length is not changed. By contrast to a vector, an ordinary quantity having magnitude but not direction is known as a scalar.

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In printed works vectors are often represented by boldface letters such as A or X, and scalars are represented by lightface letters, A or X. The magnitude of a vector, denoted A , is itself a scalarâ€"i. Because vectors are different from ordinary i. Addition, subtraction, three kinds of multiplication, and differentiation will be discussed here. There is no mathematical operation that corresponds to division by a vector. The operation is performed by displacing B so that it begins where A ends, as shown in Figure 1A. C is then the vector that starts where A begins and ends where B ends. There do exist quantities having magnitude and direction that do not obey this requirement. An example is finite rotations in space. Two finite rotations of a body about different axes do not necessarily result in the same orientation if performed in the opposite order. The idea is illustrated in Figure 1B. A vector may be multiplied by a scalar. Thus, for example, the vector 2A has the same direction as A but is twice as long. If the scalar has dimensions, the resulting vector still has the same direction as the original one, but the two cannot be compared in magnitude. The vector v has been multiplied by the scalar t to give a new vector, s, which has the same direction as v but cannot be compared to v in magnitude a displacement of one metre is neither bigger nor smaller than a velocity of one metre per second.

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Basic principles for understanding sport mechanics Before we begin, we need to brush up on the mechanical principles that are fundamental to understanding sport mechanics. The following reference section provides an overview of the mechanical terms mass, weight, and inertia; linear and angular motion; and speed, velocity, and acceleration. Mass Mass simply means substance, or matter, and is typically measured with the units of pounds lb or kilograms kg. People often interchange mass with weight, but scientifically these terms mean two different things. If an object has substance and occupies space, it has mass. Mass is the quantity of matter that the object takes up. Weight, on the other hand, is this quantity of matter plus the influence of gravity or, more precisely, gravitational force. For example, someone with a mass of kg will have a force of weight measured in newtons, N of 1, N. So for coaches, athletes, and sport scientists, mass is the most common term we should use, and weight is the force this mass generates. We frequently talk of National Football League NFL linemen as being massive or having tremendous body mass, indicating that the athletes are enormous and have plenty of muscle, bones, fat, tissue, fluids, and other substances that make up their bodies. Athletes who want to perform well in their chosen events carefully monitor their body mass. They know that too much or too little mass can seriously affect their performance. For all of us, checking our body mass is a means of assessing our general health and fitness. When we get on a scale, the dial gives us a reading that we associate with the amount of body mass that we carry around. This is true, but what actually happens is a little more complex, as discussed next. The readout on the scale represents how much pull or attraction exists between the two. The earth pulls the athlete downward. So an athlete with more body mass compresses the springs to a greater extent than an athlete who has less body mass. As a result the needle on the scale moves farther around the dial. Inertia We use the word inertia in everyday life to characterize the behavior of people who are slow to commit themselves to action. Inertia means resistance to change. If we are looking at something moving, then the mass of the object will directly relate to the inertia. Naturally, the shot put is harder to get moving; so the greater the mass an object has, the more inertia it has too. We must also consider one more important characteristic of inertia. Once on the move, objects always want to move in a straight line. A giant lb kg athlete needs to exert great muscular force to get his body mass moving. Once moving in a particular direction, the athlete must again produce an immense amount of muscular force to stop or change direction. Athletes with less body mass have less inertia and therefore need to apply less force to get themselves going. There are many examples in everyday life of inertia at work. Oil tankers that cross our oceans have tremendous mass and inertia. They need powerful engines to get them going and huge distances to stop and to turn around. Consider Japanese sumo wrestlers or defensive and offensive linemen in American football. Just like the oil tanker, these athletes must apply tremendous force to get their body mass moving and then apply a huge amount of force to change direction or to maneuver the great masses of their opponents. Massive athletes tend to have a poorer strength-to-mass ratio than do smaller, less massive athletes; so they have a tougher time stopping, starting, and changing direction. An interesting example of inertia at work occurs when athletes are in flight. Consider two athletes who decide to bungee jump from a bridge. One athlete is twice as massive as the other. They step off the bridge at the same instant. Surprisingly, they accelerate toward the earth at approximately the same rate. Because the earth attracts the more massive bungee jumper twice as much, you might think that this athlete would accelerate downward twice as fast. But this same athlete has twice the inertia of the other thrill seeker and so resists being accelerated by gravity twice as much. In this situation, air resistance plays a negligible role, and the two athletes accelerate downward at approximately the same rate. Think of inertia as an enemy when an athlete wants to get moving. Once the athlete is on the move, inertia can become a friend because the second characteristic of inertia is that it wants to keep the athlete going. The difference between resting inertia and moving inertia causes athletes to expend much more energy at the start of a m dash than when sprinting in the middle of the race. The two characteristics of inertia, resistance to motion and then persistence in motion, are seen not only in linear situations in which objects and athletes move in a straight line, but also in rotary situations when objects such as bats and clubs are made to follow a circular pathway. As long as the athlete makes a baseball bat travel around in an arc, the bat will try to continue moving along this circular pathway. In linear movement, mass is synonymous with inertia. The more mass, the more inertia. This law also applies to rotary situations. But rotary inertia also called rotary resistance or moment of inertia involves more than just the mass of the object. We also need to know how the mass is distributed i. Chapter 4 will cover rotational movement. Linear and Angular Motion The movement of an object can be classified in three different ways. Movement can be linear in a straight line , angular in a circular or rotary fashion , or a mix of linear and angular, which we simply call general motion. In sport, a mix of linear and angular movement is most common. Linear motion describes a situation in which movement occurs in a straight line. Linear motion can also be called translation, but only if all parts of the object or the athlete move the same distance, in the same direction, and in the same time frame. For example, an athlete in the m sprint wants to travel the shortest distance from the start to the finish. The shortest distance is a straight line. Many terms are used to refer to angular motion. Coaches talk of athletes rotating, spinning, swinging, circling, turning, rolling, pirouetting, somersaulting, and twisting. All of these terms indicate that an object or an athlete is turning through an angle, or number of degrees. You can think of an axis as the axle of a wheel or the hinge on a door. The most visible rotary motion occurs in the arms and legs. The upper arm rotates at the shoulder joint, the lower arm at the elbow joint, and the hand at the wrist. The hip joint acts as an axis for the leg, the knee for the lower leg, and the ankle for the foot. Movements like walking and running depend on the rotary motion of each segment e. All human motion is best described as general motion, a combination of linear and angular motion. Even those sport skills that require an athlete to hold a set position involve various amounts of linear and angular motion. A gymnast balancing on a beam and the aerodynamic crouch position during the acceleration prior to takeoff in ski jumping are good examples. In maintaining balance on the beam, the gymnast still moves, however slightly. The ski jumper holding a crouched position attempts to reduce air resistance to a minimum and accelerate as much as possible prior to takeoff. Sliding down the inrun holding a crouched position is a good example of linear motion. But the athlete never fully maintains the same body position throughout, and the inrun is not straight throughout, so any motion that the ski jumper makes will be angular in character. Perhaps the most visible combination of angular and linear motion occurs in a wheelchair race. The motion of the wheels carries both the athlete and the chair along the track. Down the straightaway, the athlete and chair can be moving in a linear fashion. This combination of angular and linear motion is an example of general motion. Speed, Velocity, and Acceleration Just as the terms mass and weight are interchanged sometimes incorrectly , a similar situation occurs with speed and velocity. While both terms indicate how fast an object is traveling, with respect to time, they have subtle differences. Speed is a scalar measure indicating how fast an object is traveling, measured by dividing the length or distance traveled by the time; but speed does not quantify the direction of travel. Velocity, on the other hand, is the change in position divided by the time. If an elite sprinter runs m in 10 s, we know that the athlete has run a certain distance m, or And in running m on a straight track, since the direction of travel is in a straight and consistent line, the change in position is also m, so there is really no difference in calculating speed and calculating velocity in this instance. However, sometimes we need to know in which direction, as well as how fast, the object is traveling i. In these situations, velocity is the better term to use. For example, when kicking a ball, as the ball takes off we can look at how fast the ball is traveling in the horizontal direction, in the vertical direction, and the resultant of these two components. To measure how fast the ball travels in these planes, we measure velocity, not speed. The velocity that the sprinter averaged over a distance of m is A sprinter who averages The athlete then has to run faster somewhere else in the race to average Rates of acceleration vary dramatically from one athlete to another. Some athletes rocket out of the blocks and have tremendous acceleration over the first 40 m of a m race. Thereafter their rate of acceleration drops off, and close to the tape they may even decelerate. Athletes who raced against multiple Olympic champion Carl Lewis were well aware that he could still be accelerating at the 70 m mark in the m dash. His rate of acceleration may have been less than that of his opponents at the start of the race, but his acceleration continued longer. In the m event, the 50 m velocity measures for Michael Johnson as he broke the m world record in the time of It is possible for athletes to reduce their rate of acceleration and still increase velocity.

7: Body Mechanics and Positioning (Client Care) (Nursing) Part 1

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8: Sport Mechanics for Coaches, Third Edition: Basic principles for understanding sport mechanics

Mechanics: Mechanics, science concerned with the motion of bodies under the action of forces, including the special case in which a body remains at rest. Of first concern in the problem of motion are the forces that bodies exert on one another.

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