Coupled pendulum experiment report

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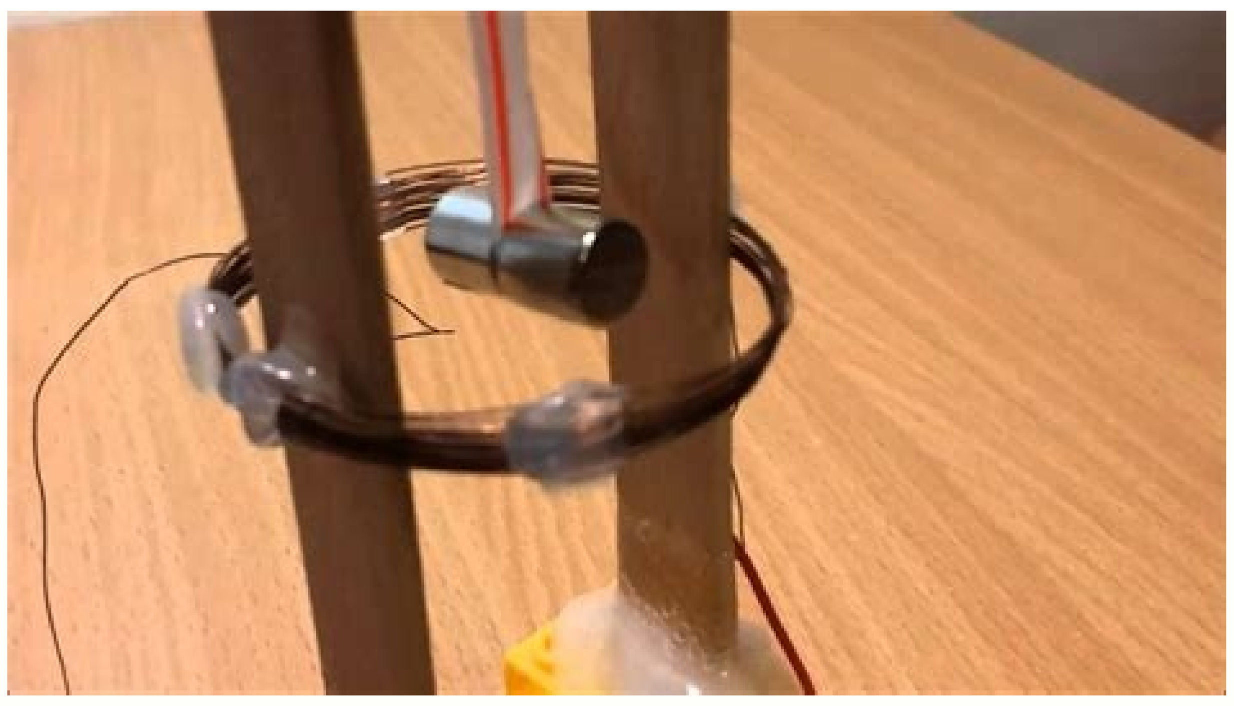
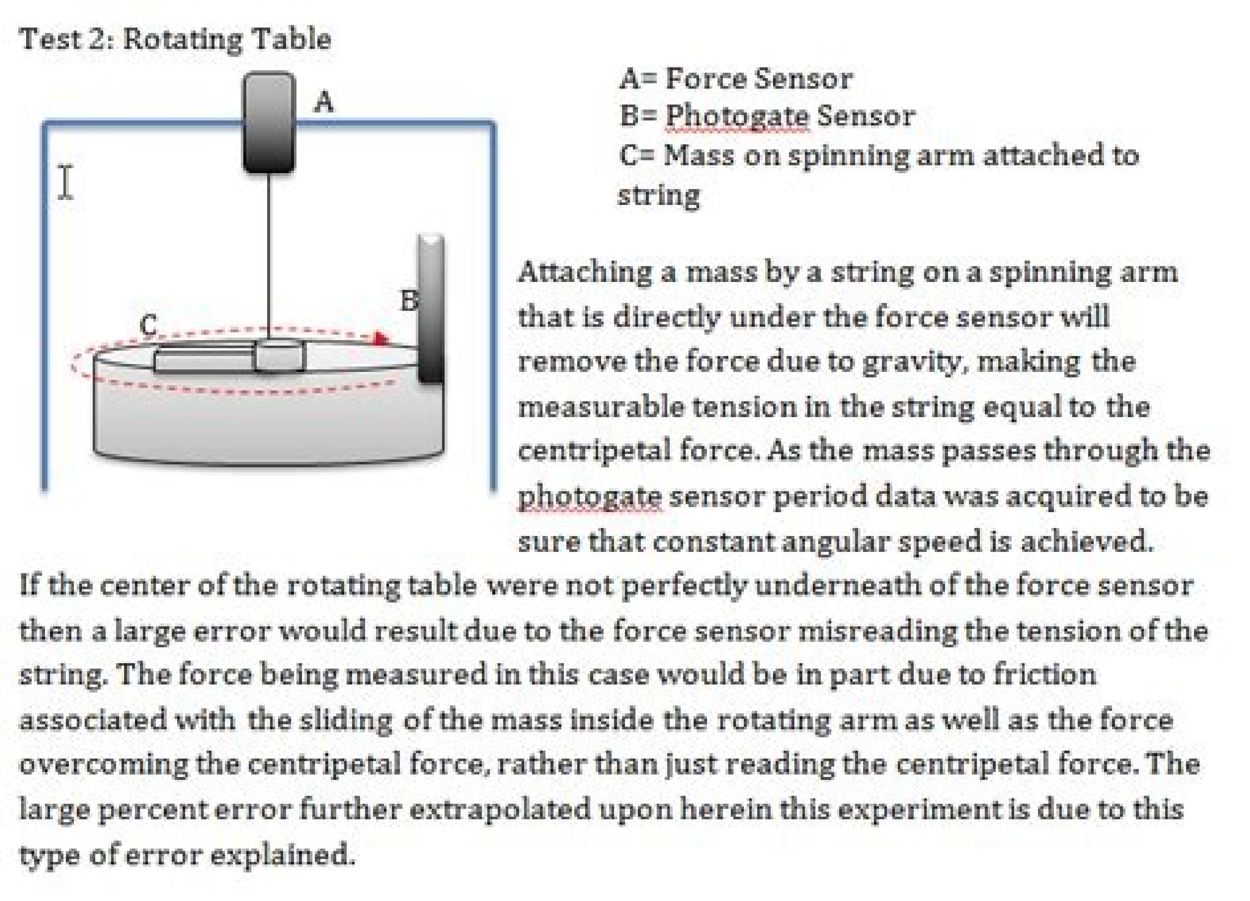


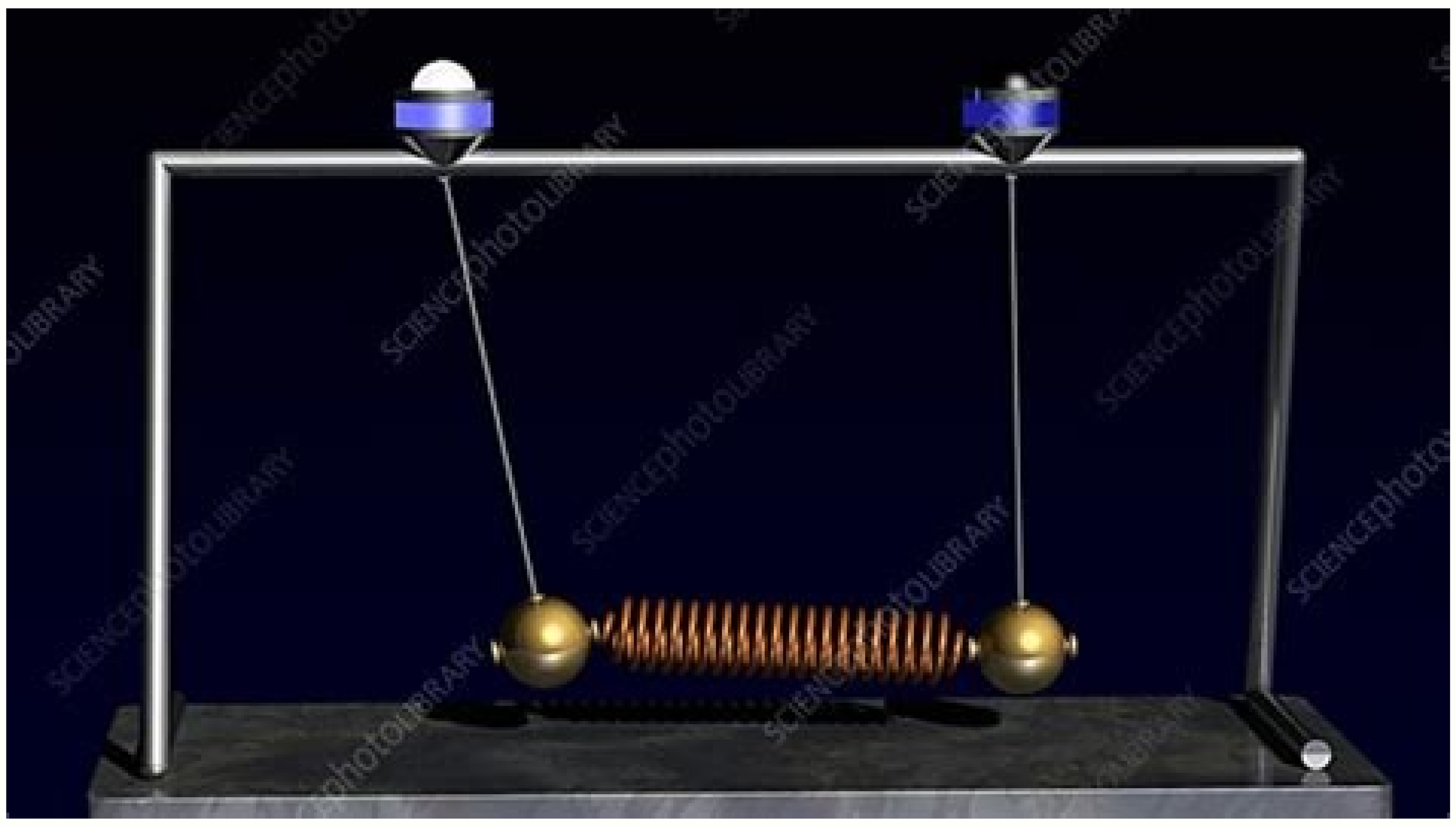


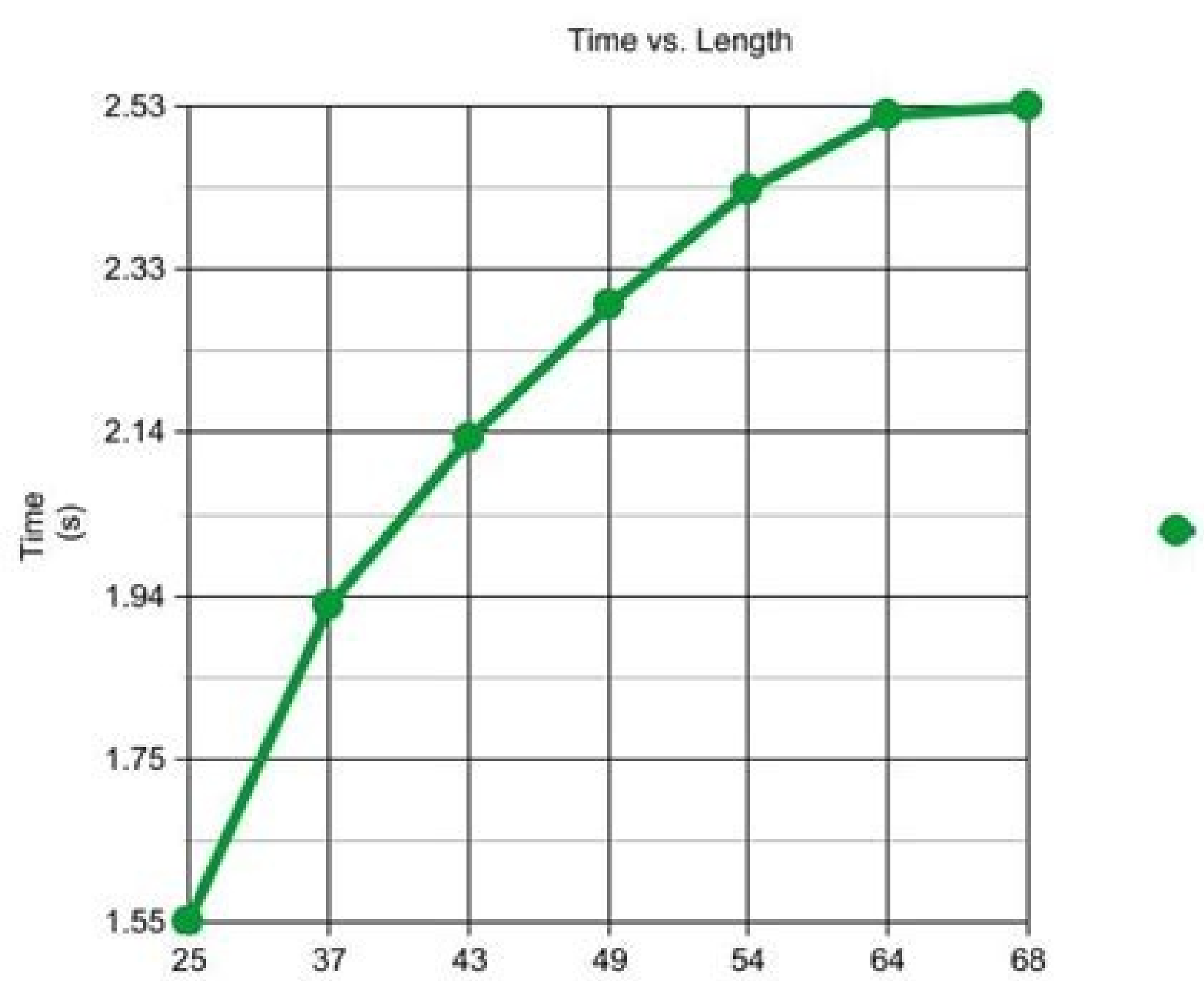
Test 2: Rotating Table

A= Force Sensor
B= Photogate Sensor
C= Mass on spinning arm attached to string

Attaching a mass by a string on a spinning arm that is directly under the force sensor will remove the force due to gravity, making the measurable tension in the string equal to the centripetal force. As the mass passes through the photogate sensor period data was acquired to be sure that constant angular speed is achieved.

If the center of the rotating table were not perfectly underneath of the force sensor then a large error would result due to the force sensor misreading the tension of the string. The force being measured in this case would be in part due to friction associated with the sliding of the mass inside the rotating arm as well as the force overcoming the centripetal force, rather than just reading the centripetal force. The large percent error further extrapolated upon herein this experiment is due to this type of error explained.





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Pendulum with another pendulum attached to its endThis article includes a list of general references, but it lacks sufficient corresponding inline citations. Please help to improve this article by introducing more precise citations. (June 2013) (Learn how and when to remove this template message) A double pendulum consists of two pendulums attached end to end. In physics and mathematics, in the area of dynamical systems, a double pendulum is a pendulum with another pendulum attached to its end, forming a simple physical system that exhibits rich dynamic behavior with a strong sensitivity to initial conditions.[1] The motion of a double pendulum is governed by a set of coupled ordinary differential equations and is chaotic. Analysis and interpretation Several variants of the double pendulum may be considered; the two limbs may be of equal or unequal lengths and masses, they may be simple pendulums or compound pendulums (also called complex pendulums) and the motion may be in three dimensions or restricted to the vertical plane. In the following analysis, the limbs are taken to be identical compound pendulums of length l and mass m, and the motion is restricted to two dimensions. Double compound pendulum Motion of the double compound pendulum (from numerical integration of the equations of motion) Trajectories of a double pendulum In a compound pendulum, the mass is distributed along its length. If the mass is evenly distributed, then the center of mass of each limb is at its midpoint, and the limb has a moment of inertia of I = 1/12ml2 about that point. It is convenient to use the angles between each limb and the vertical as the generalized coordinates defining the configuration of the system. These angles are denoted θ1 and θ2. The position of the center of mass of each rod may be written in terms of these two coordinates. If the origin of the Cartesian coordinate system is taken to be at the point of suspension of the first pendulum, then the center of mass of this pendulum is at: x 1 = l 2 sin ⁡ θ 1 y 1 = − l 2 cos ⁡ θ 1 {\displaystyle {\begin{aligned}x_{1}&={\frac {l}{2}}\sin \theta _{1}\\y_{1}&=-{\frac {l}{2}}\cos \theta _{1}\end{aligned}}} and the center of mass of the second pendulum is at x 2 = l (sin ⁡ θ 1 + 1 2 sin ⁡ θ 2) y 2 = − l (cos ⁡ θ 1 + 1 2 cos ⁡ θ 2) {\displaystyle {\begin{aligned}x_{2}&=l\left(\sin \theta _{1}+{\tfrac {1}{2}}\sin \theta _{2}\right)\\y_{2}&=-l\left(\cos \theta _{1}+{\tfrac {1}{2}}\cos \theta _{2}\right)\end{aligned}}} This is enough information to write out the Lagrangian. Lagrangian The Lagrangian is L = kinetic energy − potential energy = 1 2 m (v 1 2 + v 2 2) + 1 2 I (θ ˙ 1 2 + θ ˙ 2 2) − m g (y 1 + y 2) = 1 2 m (x ˙ 1 2 + y ˙ 1 2 + x ˙ 2 2 + y ˙ 2 2) + 1 2 I (θ ˙ 1 2 + θ ˙ 2 2) − m g (y 1 + y 2) {\displaystyle {\begin{aligned}L&={\text{kinetic energy}}-{\text{potential energy}}\\&={\tfrac {1}{2}}m\left(v_{1}^{2}+v_{2}^{2}\right)+{\tfrac {1}{2}}I\left({{\dot {\theta }}_{1}}^{2}+{{\dot {\theta }}_{2}}^{2}\right)-mg\left(y_{1}+y_{2}\right)\\&={\tfrac {1}{2}}m\left({{\dot {x}}_{1}}^{2}+{{\dot {y}}_{1}}^{2}+{{\dot {x}}_{2}}^{2}+{{\dot {y}}_{2}}^{2}\right)+{\tfrac {1}{2}}I\left({{\dot {\theta }}_{1}}^{2}+{{\dot {\theta }}_{2}}^{2}\right)-mg\left(y_{1}+y_{2}\right)\end{aligned}}} The first term is the linear kinetic energy of the center of mass of the bodies and the second term is the rotational kinetic energy around the center of mass of each rod. The last term is the potential energy of the bodies in a uniform gravitational field. The dot-notation indicates the time derivative of the variable in question. Substituting the coordinates above and rearranging the equation gives L = 1 6 m l 2 (θ ˙ 2 2 + 4 θ ˙ 1 2 + 3 θ ˙ 1 θ ˙ 2 cos ⁡ (θ 1 − θ 2)) + 1 2 m g l (3 cos ⁡ θ 1 + cos ⁡ θ 2) . {\displaystyle L={\tfrac {1}{6}}ml^{2}\left({{\dot {\theta }}_{2}}^{2}+4{{\dot {\theta }}_{1}}^{2}+3{{\dot {\theta }}_{1}}{{\dot {\theta }}_{2}}\cos(\theta _{1}-\theta _{2})\right)+{\tfrac {1}{2}}mgl\left(3\cos \theta _{1}+\cos \theta _{2}\right).} There is only one conserved quantity (the energy), and no conserved momenta. The two generalized momenta may be written as p θ 1 = ∂ L ∂ θ ˙ 1 = 1 6 m l 2 (8 θ ˙ 1 + 3 θ ˙ 2 cos ⁡ (θ 1 − θ 2)) p θ 2 = ∂ L ∂ θ ˙ 2 = 1 6 m l 2 (2 θ ˙ 2 + 3 θ ˙ 1 cos ⁡ (θ 1 − θ 2)) . {\displaystyle {\begin{aligned}p_{\theta _{1}}&={\frac {\partial L}{\partial {{\dot {\theta }}_{1}}}}={\tfrac {1}{6}}ml^{2}\left(8{{\dot {\theta }}_{1}}+3{{\dot {\theta }}_{2}}\cos(\theta _{1}-\theta _{2})\right)\\p_{\theta _{2}}&={\frac {\partial L}{\partial {{\dot {\theta }}_{2}}}}={\tfrac {1}{6}}ml^{2}\left(2{{\dot {\theta }}_{2}}+3{{\dot {\theta }}_{1}}\cos(\theta _{1}-\theta _{2})\right).\end{aligned}}} These expressions may be inverted to get θ ˙ 1 = 6 m l 2 2 p θ 1 − 3 cos ⁡ (θ 1 − θ 2) p θ 2 16 − 9 cos 2 ⁡ (θ 1 − θ 2) θ ˙ 2 = 6 m l 2 8 p θ 2 − 3 cos ⁡ (θ 1 − θ 2) p θ 1 16 − 9 cos 2 ⁡ (θ 1 − θ 2) . {\displaystyle {\begin{aligned}{{\dot {\theta }}_{1}}&={\frac {6}{ml^{2}}}{\frac {2p_{\theta _{1}}-3\cos(\theta _{1}-\theta _{2})p_{\theta _{2}}}{16-9\cos ^{2}(\theta _{1}-\theta _{2})}}\\{{\dot {\theta }}_{2}}&={\frac {6}{ml^{2}}}{\frac {8p_{\theta _{2}}-3\cos(\theta _{1}-\theta _{2})p_{\theta _{1}}}{16-9\cos ^{2}(\theta _{1}-\theta _{2})}}.\end{aligned}}} The remaining equations of motion are written as p ˙ θ 1 = ∂ L ∂ θ 1 = − 1 2 m l 2 (θ ˙ 1 θ ˙ 2 sin ⁡ (θ 1 − θ 2) + 3 g l sin ⁡ θ 1) p ˙ θ 2 = ∂ L ∂ θ 2 = − 1 2 m l 2 (− θ ˙ 1 θ ˙ 2 sin ⁡ (θ 1 − θ 2) + g l sin ⁡ θ 2) . {\displaystyle {\begin{aligned}{{\dot {p}}_{\theta _{1}}}&={\frac {\partial L}{\partial \theta _{1}}}=-{\tfrac {1}{2}}ml^{2}\left({{\dot {\theta }}_{1}}{{\dot {\theta }}_{2}}\sin(\theta _{1}-\theta _{2})+3{\frac {g}{l}}\sin \theta _{1}\right)\\{{\dot {p}}_{\theta _{2}}}&={\frac {\partial L}{\partial \theta _{2}}}=-{\tfrac {1}{2}}ml^{2}\left(-{{\dot {\theta }}_{1}}{{\dot {\theta }}_{2}}\sin(\theta _{1}-\theta _{2})+{\frac {g}{l}}\sin \theta _{2}\right).\end{aligned}}} These last four equations are explicit formulas for the time evolution of the system given its current state. It is not possible[citation needed] to go further and integrate these equations to an expression in closed form, to get formulas for θ1 and θ2 as functions of time. It is, however, possible to perform this integration numerically using the Runge Kutta method or similar techniques. Chaotic motion Graph of the time for the pendulum to flip over as a function of initial conditions Long exposure of double pendulum exhibiting chaotic motion (tracked with an LED) The double pendulum undergoes chaotic motion, and shows a sensitive dependence on initial conditions. The image to the right shows the amount of elapsed time before the pendulum flips over, as a function of initial position when released at rest. Here, the initial value of θ1 ranges along the x-direction from −3.14 to 3.14. The initial value θ2 ranges along the y-direction, from −3.14 to 3.14. The colour of each pixel indicates whether either pendulum flips within: l g {\displaystyle {\sqrt {\frac {l}{g}}}} (black) 10 l g {\displaystyle 10{\sqrt {\frac {l}{g}}}} (red) 100 l g {\displaystyle 100{\sqrt {\frac {l}{g}}}} (green) 1000 l g {\displaystyle 1000{\sqrt {\frac {l}{g}}}} (blue) or 10000 l g {\displaystyle 10000{\sqrt {\frac {l}{g}}}} (purple). Three double pendulums with near identical initial conditions diverge over time displaying the chaotic nature of the system. Initial conditions that do not lead to a flip within 10000 l g {\displaystyle 10000{\sqrt {\frac {l}{g}}}} are plotted white. The boundary of the central white region is defined in part by energy conservation with the following curve: 3 cos ⁡ θ 1 + cos ⁡ θ 2 = 2. {\displaystyle 3\cos \theta _{1}+\cos \theta _{2}=2.} Within the region defined by this curve, that is if 3 cos ⁡ θ 1 + cos ⁡ θ 2 > 2 , {\displaystyle 3\cos \theta _{1}+\cos \theta _{2}>2,} then it is energetically impossible for either pendulum to flip. Outside this region, the pendulum can flip, but it is a complex question to determine when it will flip. Similar behavior is observed for a double pendulum composed of two point masses rather than two rods with distributed mass.[2] The lack of a natural excitation frequency has led to the use of double pendulum systems in seismic resistance designs in buildings, where the building itself is the primary inverted pendulum, and a secondary mass is connected to complete the double pendulum. See also Double inverted pendulum Pendulum (mechanics) Mid-20th century physics textbooks use the term "double pendulum" to mean a single bob suspended from a string which is in turn suspended from a V-shaped string. This type of pendulum, which produces Lissajous curves, is now referred to as a Blackburn pendulum. Notes ^ Levien, R. B.; Tan, S. M. (1993). "Double Pendulum: An experiment in chaos". American Journal of Physics. 61 (11): 1038. Bibcode:1993AmJPh..61.1038L. doi:10.1119/1.17335. ^ Alex Small, Sample Final Project: One Signature of Chaos in the Double Pendulum, (2013). A report produced as an example for students. Includes a derivation of the equations of motion, and a comparison between the double pendulum with 2 point masses and the double pendulum with 2 rods. References Meirovitch, Leonard (1986). Elements of Vibration Analysis (2nd ed.). McGraw-Hill Science/Engineering/Math. ISBN 0-07-041342-8. Eric W. Weisstein, Double pendulum (2005), ScienceWorld (contains details of the complicated equations involved) and "Double Pendulum" by Rob Morris, Wolfram Demonstrations Project, 2007 (animations of those equations). Peter Lynch, Double Pendulum, (2001). (Java applet simulation.) Northwestern University, Double Pendulum, (Java applet simulation.) Theoretical High-Energy Astrophysics Group at UBC, Double pendulum, (2005). External links Animations and explanations of a double pendulum and a physical double pendulum (two square plates) by Mike Wheatland (Univ. Sydney) Interactive Open Source Physics JavaScript simulation with detailed equations double pendulum Interactive Javascript simulation of a double pendulum Double pendulum physics simulation from www.myphysicslab.com using open source JavaScript code Simulation, equations and explanation of Rott's pendulum Comparison videos of a double pendulum with the same initial starting conditions on YouTube Double Pendulum Simulator - An open source simulator written in C++ using the Qt toolkit. Online Java simulator of the Imaginary exhibition. Retrieved from " have attached a picture of the question. Thank you in advance! 17. This problem illustrates how the choice of method can dramatically affect the time it takes the computer to solve a differential eq...try this on matlab 1. Allow the user to select what ... Critical concerns that have been raised about personality theory by criminologists will be reviewed; first, concerns related to key propositions and policy implications will are considered and evaluated; secondly, criticism regarding methodological weaknesses in personality theory research will be reviewed.

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