Nonstandard Problems, Harvard Physics Circle

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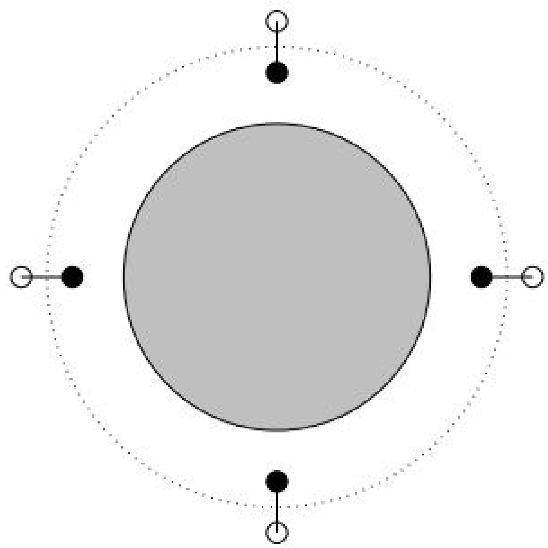
Problem 1. [F=ma 2013/17]



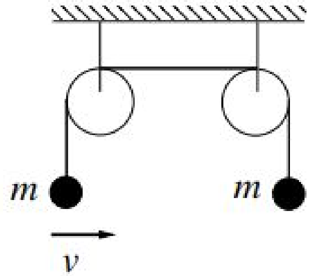
Two small, equal masses are attached by a lightweight rod. This object orbits a planet; the length of the rod is smaller than the radius of the orbit, but not negligible. The rod rotates about its axis in such a way that it remains vertical with respect to the planet.

- Is there a force in the rod? If so, is it tension or compression?
- Is the equilibrium stable, unstable, or neutral with respect to a small perturbation in the angle of the rod? (Assume this perturbation maintains the rate of rotation, so that in the co-rotating frame the rod is still stationary but at an angle to the vertical.)

Problem 2. [F=ma 2015/22] See the end of this document for problem statement.

Problem 3. [F=ma 2018 A/17] See the end of this document for problem statement.

Problem 4. [F=ma 2018 B/22] Two particles of mass m are connected by pulleys as shown.



The mass on the left is given a small horizontal velocity, and oscillates back and forth. The mass on the right

(A) remains at rest

(B) oscillates vertically, and with a net upward motion

(C) oscillates vertically, and with a net downward motion

(D) oscillates vertically, with no net motion

(E) oscillates horizontally, with no net motion

Problem 5. [F=ma 2018 B/24] A particle of mass m is placed at the center of a hemispherical shell of radius R and mass density σ, where σ has dimensions of kg/m^2. What is the gravitational force of the shell on the particle?

Problem 6. [F=ma 2018 B/7] A pendulum of length L oscillates inside a box. A person picks up the box and gently shakes it vertically with frequency ω and a fixed amplitude for a fixed time. To maximize the final amplitude of the pendulum, ω should satisfy

(A) $\omega = \sqrt{4g/L}$

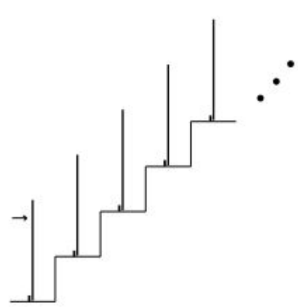
(B) $\omega = \sqrt{2g/L}$

(C) $\omega = \sqrt{g/L}$

(D) $\omega = \sqrt{g/4L}$

(E) there will be no significant effect on the pendulum amplitude for any value of ω

Problem 7. [NBPhO 2019/7]



David stands at the bottom of an infinite staircase with both step width and height being equal to d. The corner of each step is slightly rounded. In the middle of each step, there is initially an upright domino of length $\sqrt{5}d$ and negligible thickness. Behind the base of each domino, there is a small ridge that prevents it from sliding backward. David gives the first domino some initial angular velocity, and the dominoes start falling into each other. All collisions are perfectly inelastic, and there is no friction between two dominoes. David notices that after a while, all dominoes have equal initial angular velocity ω. Find ω.

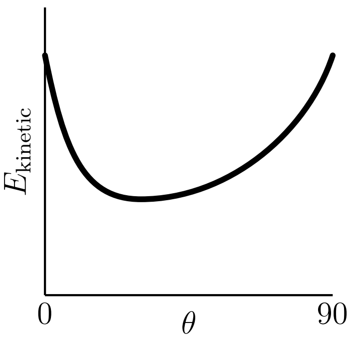
References

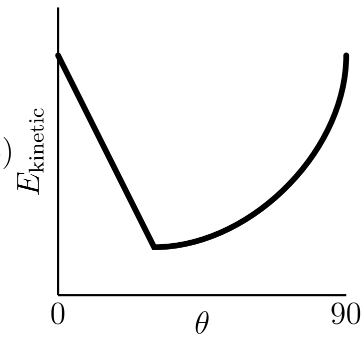
[M1] Morin, David J. *Problems and Solutions in Introductory Mechanics.*

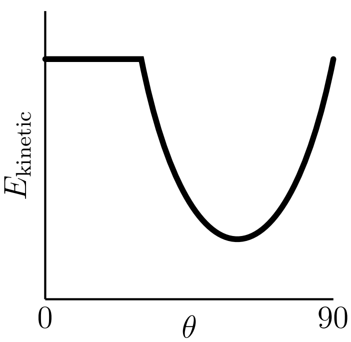
[M2] Morin, David J. *Introduction to Classical Mechanics: With Problems and Solutions.*

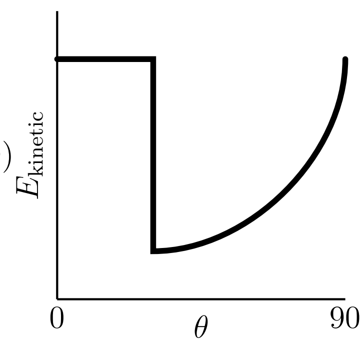
[PPP] Gnädig, Peter and Honyek Gyula and Riley, Ken. *200 Puzzling Physics Problems With Hints and Solutions.*

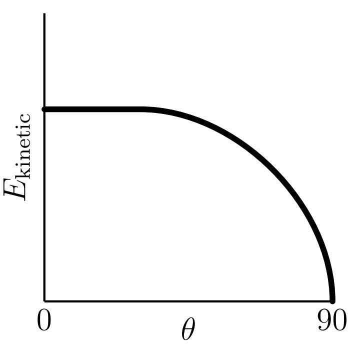
22. A solid ball is released from rest down inclines of various inclination angles θ but through a fixed vertical height h. The coefficient of static and kinetic friction are both equal to μ. Which of the following graphs best represents the total kinetic energy of the ball at the bottom of the incline as a function of the angle of the incline?

(A)


(B)


(C)


(D)


(E)


23. A 2.0 kg object falls from rest a distance of 5.0 meters onto a 6.0 kg object that is supported by a vertical massless spring with spring constant $k = 72$ N/m. The two objects stick together after the collision, which results in the mass/spring system oscillating. What is the maximum magnitude of the displacement of the 6.0 kg object from its original location before it is struck by the falling object?

(A) 0.27 m
(B) 1.1 m
(C) 2.5 m
(D) 2.8 m
(E) 3.1 m

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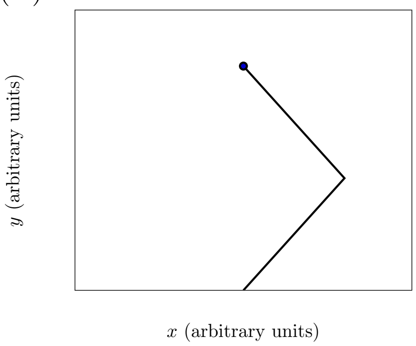
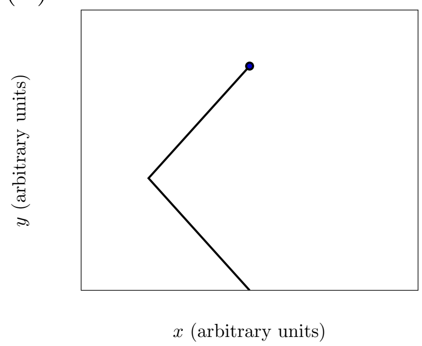
17. A stream of sand is dropped out of a helicopter initially moving at a constant speed v to the right. The helicopter suddenly turns and begins moving a constant speed v to the left. Neglecting air resistance on the sand, what is the shape of the stream of sand, as viewed from the ground? The black dot represents the helicopter.

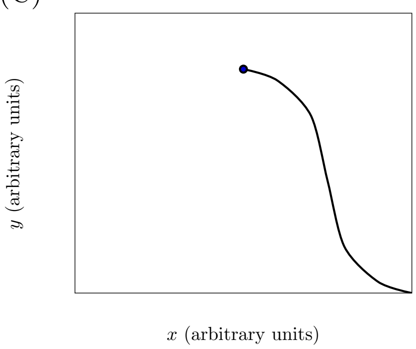
(A)



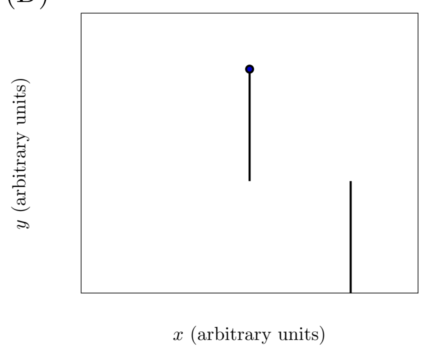
(B)



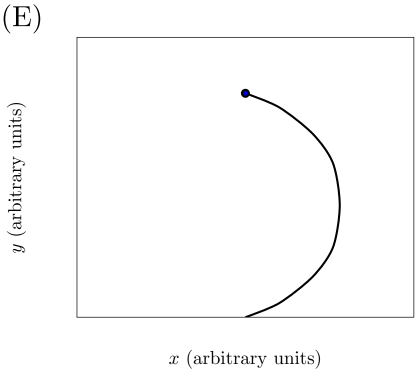
(C)



(D)



(E)



18. A mass m is attached to a thin rod of length ℓ so that it can freely spin in a vertical circle with period T. The difference in the tensions in the rod when the mass is at the top and the bottom of the circle is

(A) $6mg^2T^2/\ell$

(B) $4\pi mg^2T^2/\ell$

(C) $6mg$

(D) $\pi^2 m\ell/T^2$

(E) $4\pi m\ell/T^2$

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