8.8 PROBLEMS

Problem 8.8.1. A block leaves a frictionless inclined surface horizontally after dropping off by a height h. Find the horizontal distance D where it will land on the floor in terms of h, H and g.

Ans: $D = 2\sqrt{hH}$

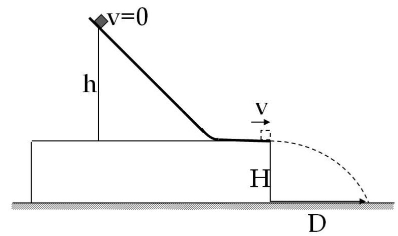


Figure 8.26: Problem 8.8.1.

Problem 8.8.2. A block of mass m after sliding down a frictionless incline strikes another block of mass M that is attached to a spring of spring constant k. The blocks stick together upon impact and travel together. (a) Find the compression of the spring in terms of m, M, h, g and k when the combination comes to rest. (b) The loss of kinetic energy as a result of the bonding of the two masses upon impact is stored in the so-called binding energy of the two masses. Calculate the binding energy.

Ans: (a) $\sqrt{\frac{2m^2gh}{k(m+M)}}$; (b) $\frac{mMgh}{m+M}$.

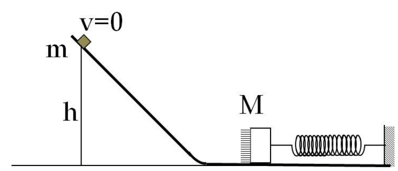


Figure 8.27: Problem 8.8.2.

Problem 8.8.3. A block of mass m slides in a frictionless track that bends in a circular arc and then straightens out. If the block is released from rest from an appropriate height h, the block will make it through the circular track without falling off; any less height and the block would not complete the circular path. Find the force that the block applies at positions marked A, B and C in terms of m, g, h and R.

Ans: (a)$F_A = 6mg$, $F_B = 3mg$, $F_C = 0$, (b) $h = 2.5R$.

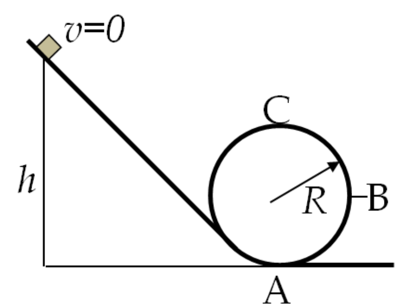


Figure 8.28: Problem 8.8.3.

Problem 8.8.4. A small block of mass m is sitting at the top of a sphere of radius R. When the block is moved infinitesimally to one side, it slides on the spherical surface up to a point when it leaves the spherical surface. Assuming no friction between the block and the surface of the sphere find the point at which the block will fall off the surface. You can specify the location of the place on the sphere by an angle a line from the center of the sphere to that point will make with the vertical line. Hint: The instant after the block is no longer in contact, there is no normal force on the block, but the speed of the block is same as it was when it left the surface.

Ans: $\cos^{-1}(2/3)$.

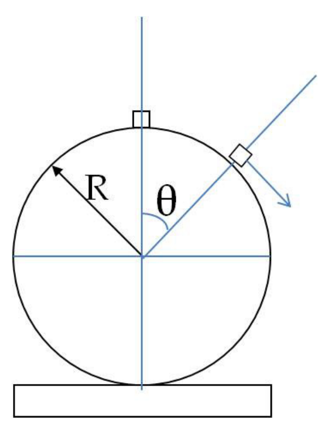
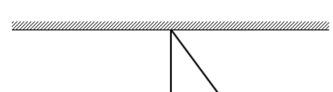


Figure 8.29: Problem 8.8.4.

Problem 8.8.5. Ballistic pendulum. A bullet of mass m is fired horizontally with speed v in a block of M that is hanging by a massless string of length L from the ceiling. After the impact the bullet is embedded in the block at its center and the two move together. Find the angle θ the string will make with the vertical when the bullet/block system comes to rest. Give your answer in terms of quantities given and g.



Ans: $\cos\theta = \left(1 - \frac{m^2v^2}{2gL(m+M)^2}\right)$.

Problem 8.8.6. A particle of mass m and speed v_0 collides head on with another particle of mass M and an unknown speed v. After the collision, particle m travels with speed $\frac{3}{4}v_0$ in the vertical direction to its original path and M moves at angle ϕ with respect to the original path of m but with an unknown speed v'. Find v and v' in terms of m, M, ϕ and v_0. Ans: $v = \left(\frac{mv}{M}\right)\left(1 - \frac{3}{4}\cot\phi\right)$; $v' = \frac{3mv}{4M}\mathrm{cosec}\,\phi$. Answer check: For $m = M$ and $\phi = 45°$, $v = v_0/4$ and $v' = (3\sqrt{2}/4)v_0$.

Problem 8.8.7. A ball bounces off the floor inelastically so that each bounce takes the ball to a lower height than the previous bounce. Eventually the ball comes to rest. (a) If the coefficient of restitution is 0.95, what is the speed of the ball immediately after the first bounce if it was dropped at rest from a height of 3 meters? (b) How long does it take for the ball to come to rest?

Ans: (a) 7.3 m/s; (b) 30.6 sec.

Problem 8.8.8. Two boys, Jack and Majid, want to compare powers of their muscles by pulling up a bucket of water of mass M hanging from a frictionless pulley. Each pulls on the cord with a constant force and measures the time for the bucket to rise by a height h meter. (a) Find an expression of the average power delivered in terms of force $\vec{F}$ applied, mass M of the bucket, height h, and the acceleration due to gravity g. (b) With what force the cord must be pulled so that an average 1 horse power can be supplied in raising the bucket by 2 meters?

Ans: (a) $F\sqrt{\frac{h}{2}\left(\frac{F}{M} - g\right)}$, (b) 217 N.

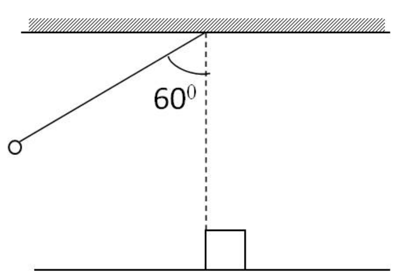


Figure 8.31: Problem 8.8.9.

Problem 8.8.9. A pendulum bob of mass 0.250 kg is hanging from a ceiling with a 150 cm long massless cord. When the pendulum is let go from rest at 60° from the vertical, it strikes a block of mass 0.500 kg when the pendulum is vertical. After the collision the block moves on a horizontal surface with decreasing speed due to the kinetic friction with the coefficient of kinetic friction equal to 0.2. If the collision between the pendulum bob and the block is elastic, find (a) the place the block comes to rest, and (b) the angle of maximum swing of the pendulum afterwards.

Problem 8.8.10. A ring of mass M and radius R has two metal beads, each of mass m and negligible radius. The beads can slide frictionlessly on the ring. The ring with the beads is hung from the ceiling with a string and the beads are brought at the top and released from rest. The beads then slide off on the two sides in a symmetric way, and when the beads reach a particular points on the ring, the ring tends to go up. Find this unique place and any conditions on the masses m and M for this phenomenon to occur.

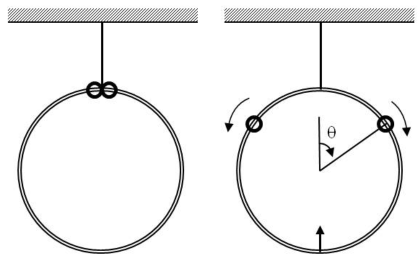


Figure 8.32: Problem 8.8.10.

Problem 8.8.11. A mysterious force acts on all particles along a particular line and always points towards a particular point (P) on the line. The magnitude of the force on a particle increases as the cube of the distance from that point, that is, $F \propto r^3$, if the distance from the P to the position of the particle is r. Let b be the proportionality constant, and write the magnitude of the force as $F = br^3$. Find the potential energy of a particle subjected to this force when the particle is at a distance D from P assuming the potential energy to be zero when the particle is at P.

Ans: $bD^4/4$.