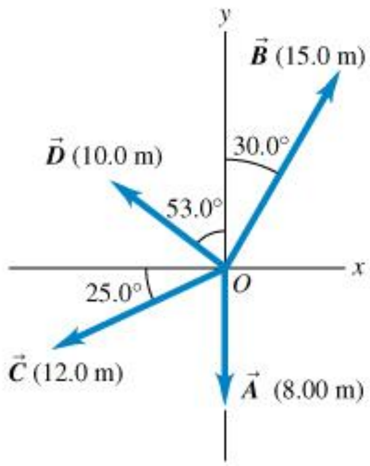
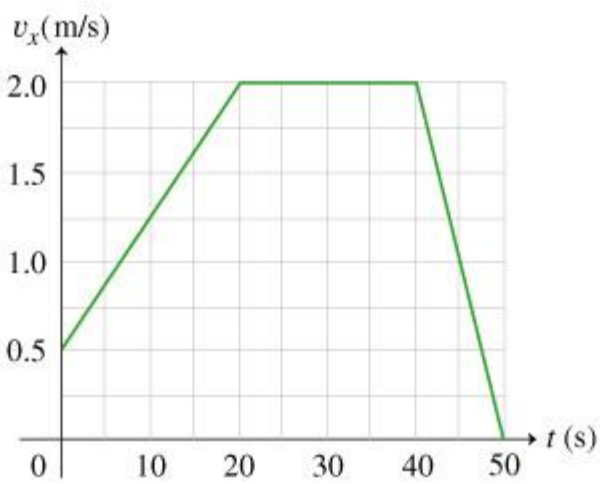
2425 review problems for final, 2009, Lianxi Ma

1. Write each vector in the figure in terms of the unit vectors $\hat{\imath}$ and $\hat{\jmath}$. Get the sum of all four vectors.



2. Here is a plot of velocity versus time for a particle that travels along a straight line with a varying velocity. Refer to this plot to answer the following questions.



(a) What is the initial velocity of the particle, v_0?

(b) What is the total distance Δx traveled by the particle?

(c) What is the average acceleration of the particle over the first 20.0 seconds?

(d) What is the instantaneous acceleration of the particle at t = 45.0 s.

3. A rocket, initially at rest on the ground, accelerates straight upward from rest with constant acceleration 44.1 m/s^2. The acceleration period lasts for time 5.00 s until the fuel is exhausted. After that, the rocket is in free fall. Find the maximum height reached by the rocket. Ignore air resistance.

4. A gymnast of mass 58.0 kg hangs from a vertical rope attached to the ceiling. You can ignore the weight of the rope and assume that the rope does not stretch.

(a) Calculate the tension T in the rope if the gymnast hangs motionless on the rope.

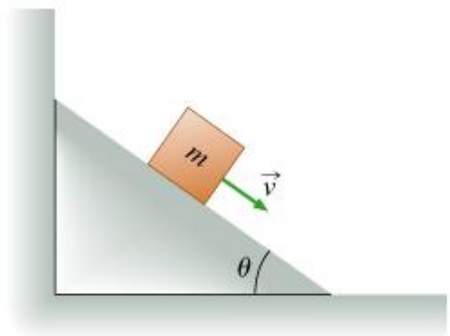
(b) Calculate the tension T in the rope if the gymnast climbs the rope at a constant rate.

(c) Calculate the tension T in the rope if the gymnast climbs up the rope with an upward acceleration of magnitude 0.700 m/s^2.

(d) Calculate the tension T in the rope if the gymnast slides down the rope with a downward acceleration of magnitude 0.700 m/s^2. (569 N, 569 N, 610 N, 528 N)

5. The position of a 2.75×10^5 N training helicopter under test is given by $\mathbf{r} = 0.020t^3\,\mathbf{i} + 2.2t\,\mathbf{j} - 0.060\,t^2\,\mathbf{k}$. (SI unit). Find the net force on the helicopter at t = 5.0 s. ($1.7\times10^4\,\mathbf{i} - 3.4\times10^3\,\mathbf{k}$ N).

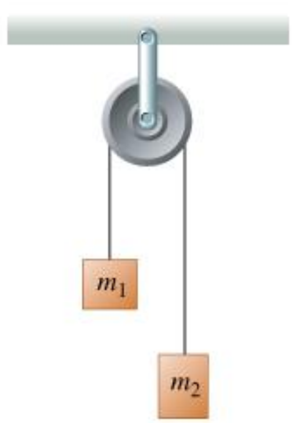
6. A wedge with an inclination of angle θ rests next to a wall. A block of mass m is sliding down the plane, as shown. There is no friction between the wedge and the block or between the wedge and the horizontal surface.



(a) Find the normal force. (mgcosθ)

(b) Find the magnitude, F_{net}, of the sum of all forces acting on the block. (mgsinθ)

7. An Atwood machine consists of two blocks (of masses m_1 and m_2) tied together with a massless rope that passes over a fixed, perfect (massless and frictionless) pulley.



(a) Derive general equations for acceleration a and tension T.

(b) Consider the special case when $m_1 = m_2$. (a = 0, $T = mg$)

(c) Consider the special case when m_2 = 0. ($a = m_1g$, T = 0)

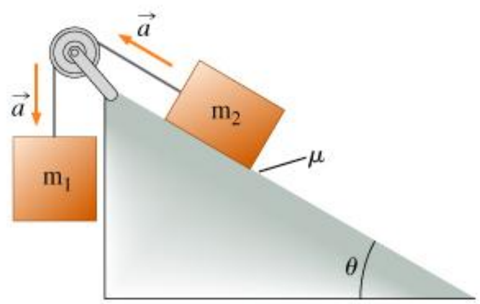
8. A block of mass m lies on a horizontal table. The coefficient of static friction between the block and the table is μ_s. The coefficient of kinetic friction is μ_k, with $\mu_k < \mu_s$. .

(a) Suppose you want to move the block, but you want to push it with the least force possible to get it moving. With what force **F** must you be pushing the block just before the block begins to move? ($\mu_s mg$)

(b) Suppose you push horizontally with half the force needed to just make the block move. What is the magnitude of the friction force? ($\mu_s mg/2$)

(c) Suppose you push horizontally with precisely enough force to make the block start to move, and you continue to apply the same amount of force even after it starts moving. Find the acceleration *a* of the block after it begins to move. ($(\mu_s-\mu_k)g$)

9. Block 1, of mass m_1, is connected over an ideal (massless and frictionless) pulley to block 2, of mass m_2, as shown. Assume that the blocks accelerate as shown with an acceleration of magnitude a and that the coefficient of kinetic friction between block 2 and the plane is μ.



Find the ratio of the masses m_1/m_2.

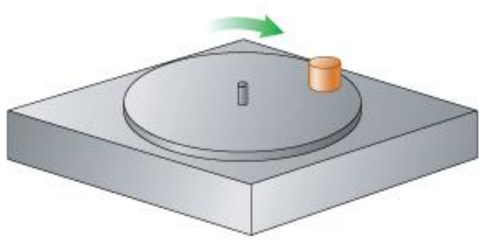
($(a+g\sin\theta+\mu g\cos\theta)/(g-a)$)

10. The radius of the earth's orbit around the sun (assumed to be circular) is 1.50×10^8 km, and the earth travels around this orbit in 365 days.

(a) What is the magnitude of the orbital velocity of the earth in m/s? (2.97×10^4 m/s)

(b) What is the radial acceleration of the earth toward the sun? (5.91×10^{-3} m/s^2).

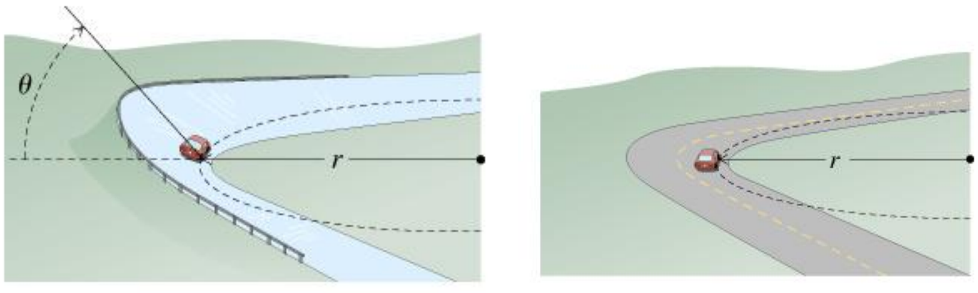
11. The small metal cylinder has a mass of 0.20 kg, the coefficient of static friction between the cylinder and the turntable is 0.080, and the cylinder is located 0.15 m from the center of the turntable.



What is the maximum speed that the cylinder can move along its circular path without slipping off the turntable? (0.34 m/s)

12. A car of mass $M = 1000$ kg traveling at 55.0 km/hour enters a banked turn covered with ice. The road is banked at an angle θ, and there is no friction between the road and the car's tires.

(a) What is the radius r of the turn if $\theta = 20.0°$ (assuming the car continues in uniform circular motion around the turn)? (65.4 m)



(b) Suppose that the curve is level ($\theta = 0$) and that the ice has melted, so that there is a coefficient of static friction μ between the road and the car's tires. What is μ_{min}, the minimum value of the coefficient of static friction between the tires and the road required to prevent the car from slipping? Assume that the car's speed is still 55.0 km/hour and that the radius of the curve is given by the value you found for r in Part A. (0.364)

13. A 12-pack of Omni-Cola (mass 4.30 kg) is initially at rest on a horizontal floor. It is then pushed in a straight line for 1.20 m by a trained dog who exerts a horizontal force with magnitude 36.0 N.

(A) Use the work-energy theorem to find the final speed of the 12-pack if there is no friction between the 12-pack and the floor.

(B) Use the work-energy theorem to find the final speed of the 12-pack if the coefficient of kinetic friction between the 12-pack and the floor is 0.30. (4.48 m/s, 3.60 m/s)

14. A bat strikes a 0.145-kg baseball. Just before impact, the ball is traveling horizontally to the right at 45.0 m/s, and it leaves the bat traveling to the left at an angle of 40° above horizontal with a speed of 60.0 m/s . The ball and bat are in contact for 1.85 ms. Find the horizontal component of the average force on the ball. Take the x-direction to be positive to the right.

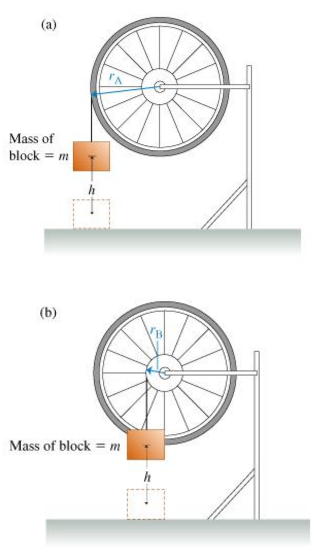
15. A particle of mass $m = 5.00$ kg is at rest at $t = 0$ s. A horizontal net force $F_{net}(t) = 6.00t^2 - 4.00t + 3.00$ (SI) is acting on the particle between $t = 0$ s and $t = 5.00$ s. Find the speed of the particle at $t = 5.00$ s. (43.0 m/s)

16. A hunter on a frozen, essentially frictionless pond uses a rifle that shoots 4.20 g bullets at 950 m/s. The mass of the hunter (including his gun) is 70.5 kg, and the hunter holds tight to the gun after firing it. (a) Find the recoil velocity of the hunter if he fires the rifle horizontally. (b) Find the recoil velocity of the hunter if he fires the rifle at 58.0° above the horizontal. (0.0566 m/s, 0.0300 m/s)

17. At time $t = 0$ a grinding wheel has an angular velocity of 21.0 rad/s. It has a constant angular acceleration of 25.0 rad/s^2 until a circuit breaker trips at time $t = 1.90$ s. From then on, the wheel turns through an angle of 430 rad as it coasts to a stop at constant angular deceleration. (a) Through what total angle did the wheel turn between $t = 0$ and the time it stopped? (b) At what time does the wheel stop? (515 rad, 14.5 s)

18. Two spherical shells have their mass uniformly distributed over the spherical surface. One of the shells has a diameter of 2 meters and a mass of 1 kilogram. The other shell has a diameter of 1 meter. What must the mass *m* of the 1-meter shell be for both shells to have the same moment of inertia about their centers of mass? (4 kg)

19. Consider a bicycle wheel that initially is not rotating. A block of mass *m* is attached to the wheel and is allowed to fall a distance *h*. Assume that the wheel has a moment of inertia *I* about its rotation axis.

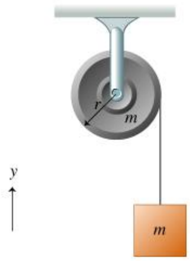


(a) Consider the case that the string tied to the block is attached to the outside of the wheel, at a radius r_A, find the angular speed of the wheel after the block has fallen a distance *h*, for this case.

(b) Now consider the case that the string tied to the block is wrapped around a smaller inside axle of the wheel of radius r_B. Find the angular speed of the wheel after the block has fallen a distance *h*, for this case.

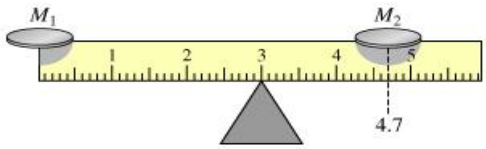
$\left(\sqrt{\frac{2mgh}{mr_A{}^2+I}}, \sqrt{\frac{2mgh}{mr_B{}^2+I}}\right)$

20. A string is wrapped around a uniform solid cylinder of radius *r*. The cylinder can rotate freely about its axis. The loose end of the string is attached to a block. The block and cylinder each have mass *m*.



Find the angular acceleration of the cylinder as the block descends. ($2g/3r$)

21. A ruler, balanced at its center point, has two coins placed on it, as shown in the figure. One coin, of mass $M_1 = 10$ g, is placed at the zero mark; the other, of unknown mass M_2, is placed at the 4.7 mark. The center of the ruler is at the 3.0 mark. The ruler is in equilibrium; it is perfectly balanced.

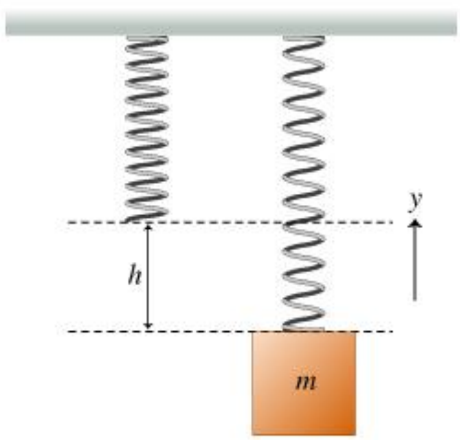


Find the mass M_2. (18 g)

22. A satellite used in a cellular telephone network has a mass of 2290 kg and is in a circular orbit at a height of 860 km above the surface of the earth. (a) What is the gravitational force on the satellite? (b) What fraction is this of the satellite's weight at the surface of the earth? (1.74×10^4 N, 0.777)

23. Find the escape velocity for an object of mass *m* that is initially at a distance *R* from the center of a planet of mass *M*. Ignore air resistance. [$(2GM/R)^{1/2}$]

24. A block of mass *m* is attached to the end of an ideal spring. Due to the weight of the block, the block remains at rest when the spring is stretched a distance *h* from its equilibrium length. The spring has an unknown spring constant *k*.



(a) What is the spring constant *k*?

(b) Suppose that the block gets bumped and undergoes a small vertical displacement. Find the resulting angular frequency of the block's oscillation about its equilibrium position.

(mg/h, $(g/h)^{1/2}$.

25. A simple pendulum consisting of a bob of mass *m* attached to a string of length *L* swings with a period *T*.

(A) If the bob's mass is doubled, approximately what will the pendulum's new period be? (*T*)

(B) If the pendulum is brought on the moon where the gravitational acceleration is about g/6, approximately what will its period now be? [$(6)^{1/2}$T].

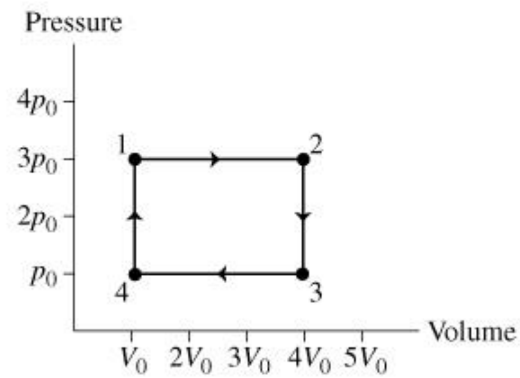
26. The diagram shows the pressure and volume of an ideal gas during one cycle of an engine. As the gas proceeds from state 1 to state 2, it is heated at constant pressure. It is then cooled at constant volume, until

it reaches state 3. The gas is then cooled at constant pressure to state 4. Finally, the gas is heated at constant volume until it returns to state 1.

(a) Find W_{12}, the work done by the gas as it expands from state 1 to state 2.

(b) Find W_{23}, the work done by the gas as it cools from state 2 to state 3.

(c) Find W_{34}, the work done by the gas as it is compressed from state 3 to state 4.



27. Two moles of an ideal gas are compressed in a cylinder at a constant temperature of 40.0 °C until the original pressure has tripled. Calculate the work done by the gas. (-5720 J)

28. Two moles of an ideal gas undergo a reversible isothermal expansion from $V_1$to V_2 at a temperature of T. What is the change in entropy of the gas? ($2R\ln(V_2/V_1)$).

29. A crate of fruit with a mass of 33.5 kg and a specific heat capacity of 3600 J/(kg K) slides 7.30 m down a ramp inclined at an angle of 35.3 degrees below the horizontal. (A) If the crate was at rest at the top of the incline and has a speed of 2.95 m/s at the bottom, how much work W_f was done on the crate by friction? (B) If an amount of heat equal to the magnitude of the work done by friction is absorbed by the crate of fruit and the fruit reaches a uniform final temperature, what is its temperature change ΔT? (-1240 J, 0.0103 °C)

30. An open container holds ice of mass 0.530 kg at a temperature of -17.9 °C. The mass of the container can be ignored. Heat is supplied to the container at the constant rate of 810 J/minute. The specific heat of ice to is 2100 J/(kg K) and the heat of fusion for ice is 334×10^3 J/kg . (A) How much time t_{melts} passes before the ice *starts* to melt? (B) From the time when the heating begins, how much time t_{rise} does it take before the temperature begins to rise above 0 °C? (24.6 min, 243 min.)