10. The angular speed of an automobile engine is increased at a constant rate from 1200/rev/min to 3000 rev/min in 12 s.
a) What is its angular acceleration in revolutions per minute –squared?
b) How many revolutions does the engine make during this 12 s interval?

10. (a) We assume the sense of rotation is positive. Applying Eq. 10-12, we obtain

$$\omega = \omega_0 + \alpha t \quad \Rightarrow \quad \alpha = \frac{(3000 - 1200) \text{ rev/min}}{(12/60) \text{ min}} = 9.0 \times 10^3 \text{ rev/min}^2.$$

(b) And Eq. 10-15 gives

$$\theta = \frac{1}{2}(\omega_0 + \omega)t = \frac{1}{2}(1200 \text{ rev/min} + 3000 \text{ rev/min})\left(\frac{12}{60} \text{ min}\right) = 4.2 \times 10^2 \text{ rev.}$$

20. An astronaut is being tested in a centrifuge. The centrifuge has a radius of 10 m and, in starting, rotates according to $\theta = 0.3t^2$, where t is in seconds and θ is in radians. When t=5.0 second, what are the magnitudes of the astronaut's
a) Angular velocity,
b) Linear velocity,
c) Tangential acceleration, and
d) Radial acceleration?
20. (a) Using Eq. 10-6, the angular velocity at $t = 5.0$s is

$$\omega = \frac{d\theta}{dt}\bigg|_{t=5.0} = \frac{d}{dt} 0.30t^2\bigg|_{t=5.0} = 2(0.30)(5.0) = 3.0 \text{ rad/s.}$$

$v = \omega r = (3.0 \text{ rad/s})(10 \text{ m}) = 30 \text{ m/s.}$ (b) Eq. 10-18 gives the linear speed at $t = 5.0$s:

(c) The angular acceleration is, from Eq. 10-8,

$$\alpha = \frac{d\omega}{dt} = \frac{d}{dt}(0.60t) = 0.60 \text{ rad/s}^2.$$

Then, the tangential acceleration at $t = 5.0$s is, using Eq. 10-22,

$$a_t = r\alpha = (10 \text{ m}) \ 0.60 \text{ rad/s}^2 = 6.0 \text{ m/s}^2.$$

(d) The radial (centripetal) acceleration is given by Eq. 10-23:
$$a_r = \omega^2 r = \ 3.0 \text{ rad/s}^2 \ 10 \text{ m} = 90 \text{ m/s}^2.$$

55. In Fig. 10.45, block 1 has mass m1=460g, block 2 has mass m2=500g, and the pulley, which is mounted on a horizontal axle with negligible friction ahs radius R=5.0cm. When released from rest, block 2 falls 75.0cm in 5.00 s without the cord slipping on the pulley.
a) What is the magnitude of the acceleration of the blocks? What are (b) Tension T2 and (c) the tension T1 (d) what is the magnitude of the pulley's angular acceleration?
(e) What is its rotational inertia?

55. (a) We use constant acceleration kinematics. If down is taken to be positive and a is the acceleration of the heavier block m_2, then its coordinate is given by $y = \frac{1}{2}at^2$, so
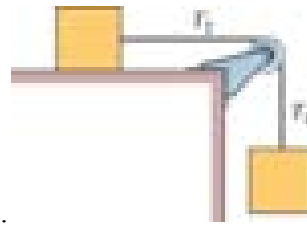
$$a = \frac{2y}{t^2} = \frac{2(0.750 \text{ m})}{(5.00 \text{ s})^2} = 6.00 \times 10^{-2} \text{ m/s}^2.$$

Block 1 has an acceleration of 6.00×10^{-2} m/s^2 upward.

(b) Newton's second law for block 2 is $m_2 g - T_2 = m_2 a$, where m_2 is its mass and T_2 is the tension force on the block. Thus,

$$T_2 = m_2(g-a) = (0.500 \text{ kg})(9.8 \text{ m/s}^2 - 6.00 \times 10^{-2} \text{ m/s}^2) = 4.87 \text{ N}.$$

(c) Newton's second law for block 1 is $m_1 g - T_1 = -m_1 a$, where T_1 is the tension force on the block. Thus,

$$T_1 = m_1(g+a) = (0.460 \text{ kg})(9.8 \text{ m/s}^2 + 6.00 \times 10^{-2} \text{ m/s}^2) = 4.54 \text{ N}.$$

(d) Since the cord does not slip on the pulley, the tangential acceleration of a point on the rim of the pulley must be the same as the acceleration of the blocks, so

$$\alpha = \frac{a}{R} = \frac{6.00 \times 10^{-2} \text{ m/s}^2}{5.00 \times 10^{-2} \text{ m}} = 1.20 \text{ rad/s}^2.$$

(e) The net torque acting on the pulley is $\tau = (T_2 - T_1)R$. Equating this to $I\alpha$ we solve for the rotational inertia:

$$I = \frac{(T_2 - T_1)R}{\alpha} = \frac{(4.87 \text{ N} - 4.54 \text{ N})(5.00 \times 10^{-2} \text{ m})}{1.20 \text{ rad/s}^2} = 1.38 \times 10^{-2} \text{ kg} \cdot \text{m}^2.$$

73. In Fig. 10-45, two blocks, of mass m1=400 g and m2=600g, are connected by a massless cord that is wrapped around a uniform disk of mass M=500g and radius R=12.0cm, The disk can rotate without friction about a fixed horizontal axis through its center; the cord cannot slip on the disk. The system is released from rest. Find 9a) the magnitude of the acceleration of the blocks, (b) the tension T1 into cord at the left and (c) the tension T2 in the cord at the right.

73. We choose positive coordinate directions (different choices for each item) so that each is accelerating positively, which will allow us to set $a_1 = a_2 = R\alpha$ (for simplicity, we denote this as a). Thus, we choose upward positive for m_1, downward positive for m_2 and (somewhat unconventionally) clockwise for positive sense of disk rotation. Applying Newton's second law to $m_1 m_2$ and (in the form of Eq. 10-45) to M, respectively, we arrive at the following three equations.
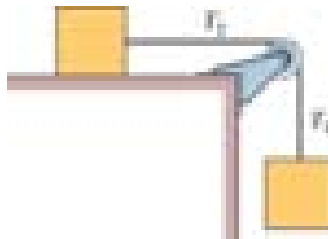
$$T_1 - m_1 g = m_1 a_1$$
$$m_2 g - T_2 = m_2 a_2$$
$$T_2 R - T_1 R = I\alpha$$

(a) The rotational inertia of the disk is $I = \frac{1}{2} MR^2$ (Table 10-2(c)), so we divide the third equation (above) by R, add them all, and use the earlier equality among accelerations — to obtain:

$$m_2 g - m_1 g = \left(m_1 + m_2 + \frac{1}{2} M \right) a$$

(b) Plugging back in to the first equation, we find

$$T_1 = \frac{29}{25} m_1 g = 4.55\,\text{N}$$

where it is important in this step to have the mass in SI units: $m_1 = 0.40$ kg.

(c) Similarly, with $m_2 = 0.60$ kg, we find

$$T_2 = \frac{5}{6} m_2 g = 4.94\,\text{N}.$$

59. A 32.0 kg wheel, essentially a thin hoop with radius 1.2m, is rotating at 280 rev/min. It must be brought to a stop in 15.0 s (a) how much work must be done to stop it? (b) What is the required average power?

59. The initial angular speed is $\omega = (280 \text{ rev/min})(2\pi/60) = 29.3$ rad/s.

(a) Since the rotational inertia is (Table 10-2(a)) $I = (32 \text{ kg})(1.2 \text{ m})^2 = 46.1 \text{ kg} \cdot \text{m}^2$, the work done is

$$W = \Delta K = 0 - \frac{1}{2} I \omega^2 = -\frac{1}{2}(46.1 \text{ kg} \cdot \text{m}^2)(29.3 \text{ rad/s})^2$$

which yields $|W| = 1.98 \times 10^4$ J.

(b) The average power (in absolute value) is therefore

$$|P| = \frac{|W|}{\Delta t} = \frac{19.8 \times 10^3}{15} = 1.32 \times 10^3 \text{ W}.$$

69. In Fig 10-49, two 6.20 kg blocks are connected by a massless string over a pulley of radius 2.4 cm and rotational inertia $7.40 \times 10^{-4} kg.m^2$. The string does not slip on the pulley; it is not know whether there is friction between the table and the sliding block; the pulley's axis is frictionless. When this system is released from rest, the pulley turns through 1.30 rad in 91.0ms and the acceleration of the blocks is constant. What are (a) the magnitude of the pulley's angular acceleration. (b) The magnitude of either block's acceleration, (c) string tension T1; and (d) string tension T2.

69. We choose positive coordinate directions (different choices for each item) so that each is accelerating positively, which will allow us to set $a_2 = a_1 = R\alpha$ (for simplicity, we denote this as a). Thus, we choose rightward positive for $m_2 = M$ (the block on the table), downward positive for $m_1 = M$ (the block at the end of the string) and (somewhat unconventionally) clockwise for positive sense of disk rotation. This means that we interpret θ given in the problem as a positive-valued quantity. Applying Newton's second law to m_1, m_2 and (in the form of Eq. 10-45) to M, respectively, we arrive at the following three equations (where we allow for the possibility of friction f_2 acting on m_2).

$$m_1 g - T_1 = m_1 a_1$$
$$T_2 - f_2 = m_2 a_2$$
$$T_1 R - T_2 R = I\alpha$$

(a) From Eq. 10-13 (with $\omega_0 = 0$) we find

$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2 \quad \Rightarrow \quad \alpha = \frac{2\theta}{t^2} = \frac{2(1.30 \text{ rad})}{(0.0910 \text{ s})^2} = 314 \text{ rad/s}^2.$$

(b) From the fact that $a = R\alpha$ (noted above), we obtain

$$a = \frac{2R\theta}{t^2} = \frac{2(0.024 \text{ m})(1.30 \text{ rad})}{(0.0910 \text{ s})^2} = 7.54 \text{ m/s}^2.$$

(c) From the first of the above equations, we find

$$T_1 = m_1 (g - a_1) = M\left(g - \frac{2R\theta}{t^2}\right) = (6.20 \text{ kg})\left(9.80 \text{ m/s}^2 - \frac{2(0.024 \text{ m})(1.30 \text{ rad})}{(0.0910 \text{ s})^2}\right)$$
$$= 14.0 \text{ N}.$$

(d) From the last of the above equations, we obtain the second tension:

$$T_2 = T_1 - \frac{I\alpha}{R} = M\left(g - \frac{2R\theta}{t^2}\right) - \frac{2I\theta}{Rt^2} = 14.0 \text{ N} - \frac{(7.40 \times 10^{-4} \text{ kg} \cdot \text{m}^2)(314 \text{ rad/s}^2)}{0.024 \text{ m}}$$
$$= 4.36 \text{ N}.$$

93. In Fig 10.56, a wheel of radius 0.20m is mounted on frictionless horizontal axle; a massless cord is wrapped around the wheel and attached to a 2.0 kg a box that slides on a frictionless surface inclined at angle $\theta = 20^o$ with the horizontal. The box accelerates down the surface at 2.0m/s2. What is the rotational l inertia of the wheel about the axle?

93. We choose positive coordinate directions so that each is accelerating positively, which will allow us to set $a_{box} = R\alpha$ (for simplicity, we denote this as a). Thus, we choose downhill positive for the $m = 2.0$ kg box and (as is conventional) counterclockwise for positive sense of wheel rotation. Applying Newton's second law to the box and (in the form of Eq. 10-45) to the wheel, respectively, we arrive at the following two equations (using θ as the incline angle 20°, not as the angular displacement of the wheel).

$$mg\sin\theta - T = ma$$
$$TR = I\alpha$$

Since the problem gives $a = 2.0$ m/s^2, the first equation gives the tension $T = m (g \sin \theta - a) = 2.7$ N. Plugging this and $R = 0.20$ m into the second equation (along with the fact that $\alpha = a/R$) we find the rotational inertia

$$I = TR^2/a = 0.054 \text{ kg} \cdot \text{m}^2.$$

87. A wheel of radius 0.2m is mounted on a frictionless horizontal axis. The rotational inertia of the wheel about his axis is 0.05 kg. m2. A mass less cord wrapped around the wheel is attached to a 2.0 kg block that slides on a horizontal frictionless surface. If a horizontal force of magnitude P=3.0 N is applied to the block as shown in Fig 10.54, what is the magnitude of the angular acceleration of the wheel? Assume the cord does not slip on the wheel.