

L3 Physics: Questions for 1.2 (Mechanics, rotation)

Majority taken from Knight chap. 8, 12.

1. A 1350 kg car drives around a flat 150 m diameter circular track at 20 m s^{-1} . What is the magnitude and direction of the net force on the car? What causes this force?
2. A car drives over the top of a circular-section hill with a radius of 50 m. Draw a force diagram, and calculate the maximum speed the car can drive without taking flight.
3. A new car is tested on a 200 m diameter circular track. If the car speeds up at a steady 1.5 m s^{-1} , how long after starting is its centripetal acceleration equal to the tangential acceleration?
4. A 300 g ball and a 600 g ball are connected by a 40 cm rigid massless rod. The structure rotates about its centre of mass at 100 rev min^{-1} . What is its rotational kinetic energy?
5. A ball of radius R is placed at a height of 30 cm on a 15° slope. It is released and rolls without slipping to the bottom. From what height should a circular hoop of radius R be released in order to equal the ball's speed at the bottom?
6. A steel beam is 5 m long and has a mass of 400 kg. It extends horizontally from the point to which it has been bolted to the framework of a building. A construction worker of mass 100 kg, unworried about health and safety regulations, stands on the end of the beam. What is the total torque about the bolt due to the worker and the beam?
7. A 2.0 kg, 30 cm diameter disc is spinning at 300 rev min^{-1} . How much friction force must a brake apply to the rim to bring the disc to a halt in 3.0 s?
8. A 200 g toy car is placed on a narrow 60 cm diameter track (mass of track ring 1.0 kg, massless interior) that is free to rotate on a frictionless vertical axis. When the car is started, it soon reaches a steady speed of 0.75 m s^{-1} relative to the track. At this point, what is the track's angular velocity in rpm?
9. A flywheel is a large, massive wheel used to store energy. They can be spun up slowly, then the wheel's energy can be released quickly to accomplish a task that demands high power. An industrial flywheel has diameter 1.5 m and mass 250 kg. It has maximum angular velocity $1200 \text{ rev min}^{-1}$.
 - (a) A motor spins up the flywheel with a constant torque of 50 N m. How long does it take for the wheel to reach maximum speed?
 - (b) How much energy is stored in the flywheel?
 - (c) The flywheel is disconnected from the motor and connected to a machine to which it will deliver energy. Half the energy stored in the flywheel is delivered in 2.0 s. What is the average power delivered to the machine?
 - (d) How much torque does the flywheel exert on the machine?
10. A piece of modern sculpture consists of an 8.0 m long, 150 kg stainless steel bar passing diametrically through a 50 kg copper sphere. The centre of the sphere is 2.0 m from the end of the bar. To be mounted for display, the bar is oriented vertically with the copper sphere at the lower end, then tilted 35° from the vertical and held in place by one horizontal steel cable attached to the bar 2.0 m from the top end. What is the tension in the cable?
11. [Difficult] If a vertical cylinder of some liquid rotates about its axis, the surface forms a smooth curve. Assuming that the water moves as a unit (i.e. all the water moves with the same angular velocity), show that the shape of the surface is a parabola described by the equation

$$z = \frac{\omega^2}{2g} r^2. \quad (1)$$

[Hint: Each particle of water on the surface is subject to only two forces: gravity, and the normal force due to the water underneath it. The normal force, as always, acts perpendicular to the surface.]