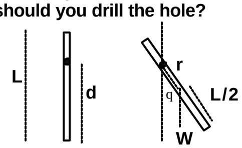
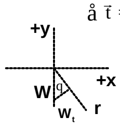
Problem from text: chap 14, 62

Your are given a meter stick and asked to drill a hole in it so when pivoted about the hole the period is a minimum. Where should you drill the hole?



Use dynamics to write the equation of motion

$$\sum \vec{\tau} = I\vec{\alpha}$$



$$\sum \vec{\tau} = rW_t = -rW\sin\theta$$

Torque is in
Angle is out

$$-rW\sin\theta = I\frac{d^2\theta}{dt^2}$$

Guess solution
$\theta = A\cos(2\pi ft + \phi)$

$$-rW\theta = I\frac{d^2\theta}{dt^2}$$

I from parallel axis theorem

You have volunteered to be a safety adviser for a charity circus. In an act that you are reviewing, one acrobat drops straight down from a platform while at the same time another one jumps straight up from a trampoline and catches the falling acrobat. What fraction of the distance between the platform and the trampoline will the catch take place if both acrobats have the same speed at the catch.

See solutions of quiz 1

Physics 1301

Understanding the Interactions of Objects
Interactions effect an object's motion

- Motion in perpendicular directions
  - Independent
- Coordinate system
- Vectors and their components
- Causality
  - The change of velocity of one object or system must be caused by an interaction with ANOTHER object or system.
- Describing Motion
  - Position
  - Time
  - Change
- Kinematics
  - Translational – center of mass
  - Rotational
  - Oscillations

Describe Interactions by Forces

- Contact
  - Friction
  - Normal
  - Tension
  - Spring
- Non-Contact
  - Gravitational

Describe Interactions by Conservation

- Energy
- Momentum
- Angular Momentum

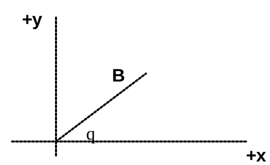
Tools:

Vectors

position	angle
velocity	angular momentum
acceleration	angular acceleration
Force	Torque
Momentum	Angular Momentum

Perpendicular Components are Independent

Define Coordinates with respect to Coordinate System



Mathematics:

- Organized Algebra
- Trig. for Components of Vectors
- Simple Geometry
- Calculus
  - Derivatives
  - Integrals
    - $\int dx$
    - $\int x\,dx$

Problem Solving:

Organized, logical and complete progression of your thought in writing

A person who knows as much physics as you should be able to read your solution and describe the problem.

Important Elements

- A picture
  - Clarifies situation
  - Defines symbols
- The question
  - It does not help to answer the wrong question.
- The approach
  - Gather you physics thoughts
- Diagrams
  - Simplify to the physics
  - Define quantities

Fundamental Principles

Equations you might use

Organized mathematical Development

Checking

- Units
- Reasonable
- Answered question

OVERVIEW:

Kinematics

Describe the motion of objects

Vectors

Perpendicular components are independent

Velocity

$$\vec{v} = \frac{d\vec{r}}{dt} \quad \text{means}$$

$$v_x = \frac{dx}{dt}$$

$$v_y = \frac{dy}{dt}$$

constant velocity when no net force.

If $\sum F_x = 0$ v_x = constant

If $\sum F_y = 0$ v_y = constant

Acceleration

$$\vec{a} = \frac{d\vec{v}}{dt} \quad \text{means}$$

$$a_x = \frac{dv_x}{dt}$$

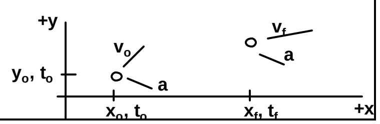
$$a_y = \frac{dv_y}{dt}$$

constant acceleration when there is a net force.

If $\sum F_x = \text{constant}$ a_x = constant

If $\sum F_y = \text{constant}$ a_y = constant

At every instant of its motion an object's motion is described by its velocity and acceleration



$$a_x = \frac{dv_x}{dt} \qquad a_y = \frac{dv_y}{dt}$$

$$v_x = \frac{dx}{dt} \qquad v_y = \frac{dy}{dt}$$

$$a_x = \frac{d^2x}{dt^2} \qquad v_y = \frac{d^2y}{dt^2}$$

If a_x is constant

$$a_x = \frac{d^2x}{dt^2} \quad \text{means}$$

$$x = \frac{1}{2}a_x(t - t_o)^2 + v_{ox}(t - t_o) + x_o$$

for any x,t

If a_x is constant

$$v_y = \frac{d^2y}{dt^2} \quad \text{means}$$

$$y = \frac{1}{2}a_y(t - t_o)^2 + v_{oy}(t - t_o) + y_o$$

for any y,t

Review Tools:

- Computer Quizzes
- Multiple Choice in Lab Book
- Problems in Competent Problem Solver
- Quizzes
- Group Problems
- Study Group
- TA's
- Me

Rigid Body Motion

Center of Mass

$$\vec{R} = \sum_i \frac{m_i \vec{r}_i}{m_i}$$

What point on an object actually moves with
acceleration and velocity
calculated with

Forces $\sum \vec{F} = m\vec{a}$

Conservation of momentum

$$(m\vec{v})_f - (m\vec{v})_i = \vec{p}_{input} - \vec{p}_{outpu}$$

$$\Delta\vec{p}_{transfer} = \vec{p}_{input} - \vec{p}_{output}$$

$$\vec{p}_{transfer} = \int \vec{F}dt$$

or any other calculation of the acceleration or velocity of an entire object
or other complex system

Reformulating Physics to More Easily Describ

Rotational Motion

Motion of an entire object
not just a point on that object

Every point on object rotates through the same angle in the same time.

Apply

Dynamics

$$\sum \vec{\tau} = I\vec{\alpha}$$

Conservation

$$(I\vec{\omega})_f - (I\vec{\omega})_i = \vec{L}_{input} - \vec{L}_{output}$$

$$\Delta\vec{L}_{transfer} = \vec{L}_{input} - \vec{L}_{output}$$

$$\vec{L}_{transfer} = \int \vec{\tau}dt$$

Define kinematics (Chap. 11 - Sec 1-5)

directions by right hand rule

angle

$$\theta = \frac{\text{arc length}}{\text{radius}}$$

$$\vec{\theta} \times \vec{r} = \vec{\ell}$$

angular velocity

$$\vec{\omega} = \frac{d\vec{\theta}}{dt}$$

$$\vec{\omega} \times \vec{r} = \vec{v}$$

angular acceleration

$$\vec{\alpha} = \frac{d\vec{\omega}}{dt}$$

$$\vec{\alpha} \times \vec{r} = \vec{a}$$

Define object

Rotational Inertia (or Moment of Inertia)

How an object responds
to an interaction - Rotation

Identify the axis of rotation

$$I = \int_{\text{over object}} r^2 dm$$

r is the position from the axis of rotation to the point of interaction

Useful Technique:

It is usually easiest to calculate I if the axis of rotation is the center of mass.

Use the <u>parallel</u> axis theorem to determine I for the axis of rotation you really want.

$I = I_{cm} + Mh^2$ (h is distance from the center of mass to the real axis of rotation)

Dynamics

$\sum \vec{F} = m\vec{a}$ Gives how the center of mass of an object responds to an interaction (translational motion)

$\sum \vec{\tau} = I\vec{\alpha}$ Gives how an object's rotation responds to an interaction (rotational motion)

Torques are caused by forces

$\vec{\tau} = \vec{r} \times \vec{F}$ direction by right hand rule

r is the position vector from the axis of rotation to the point of interaction

$\tau = rF_{\perp}$ use only the component of F perpendicular to r

Conservation of Energy

$$(E)_f - (E)_i = E_{input} - E_{output}$$

E_{system} = KE + PE + IE

inelastic collision means internal energy(IE) changes

$$\Delta E_{transfer} = E_{input} - E_{outpu}$$

Separate the kinetic energy into 2 parts

Translational kinetic energy - COM

$$\frac{1}{2}Mv_{cm}^2$$

Rotational kinetic energy

$$\frac{1}{2}I\omega^2$$

$$KE = \frac{1}{2}Mv_{cm}^2 + \frac{1}{2}I\omega^2$$

Energy transfer can be from torques

$$E_{transfer} = \int \vec{F} \cdot d\vec{r} + \int \vec{\tau} \cdot d\vec{\theta}$$

Conservation of Angular Momentum

Define

$\vec{L} = \vec{r} \times \vec{p}$ **or** $\vec{L} = I\vec{\omega}$

(these are really the same)

r is the position vector from the axis of rotation to the point on the object with momentum p.

$L = rp_{\perp}$ **use only component of p perpendicular to r**

Direction by right hand rule

Conservation

$$\left(\vec{L}\right)_f - \left(\vec{L}\right)_i = \vec{L}_{input} - \vec{L}_{output}$$

$$\Delta\vec{L}_{transfer} = \vec{L}_{input} - \vec{L}_{output}$$

$$\vec{L}_{transfer} = \int_0 \vec{\tau}\,dt$$

Oscillations

Application of Physics to Systems with Periodic Motion

Studied only special case of Periodic Motion

Simple Harmonic Motion

Position can be described by a cosine or a sine function which changes with time.

How to solve:

- **Write the equation of motion using**
  - **Dynamics**
  - **Conservation**
- **Guess a solution** $A\cos(2\pi f t + \phi)$
  - **f is the frequency of the motion**
- **Put solution into the equation of motion**
  - **Check to see if it is a solution**
  - **Frequency is determined**