Chapter 7

Rotational Motion and The Law of Gravity
1. Rotational Kinematics
2. Angular and Linear Quantities
3. Centripetal Acceleration and Force
5. Gravitational Potential Energy
The Radian

- What is a Radian?
- Conversions

\[
\theta = 1 \text{ rad} \approx 53.1^\circ
\]
Angular Displacement and Rigid Body

- Definition
- What is a Rigid body?
- What is Angular Displacement?
- How do I calculate it?
- What are the SI units?
Average Angular Speed

- What is angular speed?
- How do I represent it?
- How do I calculate it?
- What are its SI units?
- How do I differentiate between Instantaneous and Average values?
- What sign convention do I use?
Average Angular Acceleration

- What is angular acceleration?
- How do I represent it?
- How do I calculate it?
- What are the SI units?
- What sign convention do I follow?
- What is the difference between average and instantaneous values?
### Analogies Between Linear and Rotational Motion

<table>
<thead>
<tr>
<th>Linear Motion with $a$ Constant</th>
<th>Rotational Motion about a Fixed Axis with $\alpha$ Constant (Variables: $\theta$ and $\omega$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Variables: $x$ and $v$)</td>
<td></td>
</tr>
<tr>
<td>$v = v_i + at$</td>
<td>$\omega = \omega_i + \alpha t$  [7.7]</td>
</tr>
<tr>
<td>$\Delta x = v_i t + \frac{1}{2} at^2$</td>
<td>$\Delta \theta = \omega_i t + \frac{1}{2} \alpha t^2$  [7.8]</td>
</tr>
<tr>
<td>$v^2 = v_i^2 + 2a\Delta x$</td>
<td>$\omega^2 = \omega_i^2 + 2\alpha \Delta \theta$  [7.9]</td>
</tr>
</tbody>
</table>
Relationship Between Angular and Linear Quantities
Example

1. A wheel is turning with an angular velocity of 2.0 rad/s at \( t=0 \) and angular acceleration 3.5 rad/s\(^2\). Find the number of revolutions the wheel has turned in 2 seconds.
Centripetal Acceleration

- What is centripetal acceleration?
- How do I calculate it?
- How do I relate centripetal acceleration with angular velocity?
- What do we mean by total acceleration?
Vector Nature of Angular Quantities

- How do I find the direction of Angular displacement, velocity and acceleration?
Velocity Directions, Example
Acceleration Directions

- Two rules to remember?
Example – centripetal acceleration

1. A test car moves at a constant speed of 10m/s round a circular road of radius 50 m. Find the car's centripetal acceleration and angular speed.
Example – centripetal acceleration

1. A pulsar is a celestial object that emits light in short bursts. A pulsar in the Crab Nebula flashes at a rate of 30 times/s. Suppose the light pulses are caused by the rotation of a spherical object that emits light from a pair of diametrically opposed “flashlights” on its equator. What is the maximum radius of the pulsar if no part of its surface can move faster than the speed of light (3.00 x 108 m/s)?
Application: Level Curves
Application: Banked Curves
Application: The rotor

1. In a popular amusement park ride, a rotating cylinder of radius 3.00 m is set in rotation at an angular speed of 5.00 rad/s, as in Figure P7.51. The floor then drops away, leaving the riders suspended against the wall in a vertical position. What minimum coefficient of friction between a rider's clothing and the wall is needed to keep the rider from slipping? (Hint: Recall that the magnitude of the maximum force of static friction is equal to $\mu_s n$, where $n$ is the normal force—in this case, the force causing the centripetal acceleration.)
Forces in Accelerating Reference Frames
Example - Forces in Accelerating Reference Frames

1. An air puck of mass 0.25 kg is tied to a string and allowed to revolve in a circle of radius 1.0 m on a frictionless horizontal table. The other end of the string passes through a hole in the center of the table, and a mass of 1.0 kg is tied to it (Fig. P7.25). The suspended mass remains in equilibrium while the puck on the tabletop revolves. (a) What is the tension in the string? (b) What is the horizontal force acting on the puck? (c) What is the speed of the puck?
Newton’s Law of Universal Gravitation

- What is it?
- How do I calculate it?
- What is $G$?
- Newton’s Laws
- Gauss Law
Gravitation Constant

- Determined experimentally
- Henry Cavendish
  - 1798
- The light beam and mirror serve to amplify the motion
Applications of Universal Gravitation

**TABLE 7.1**

<table>
<thead>
<tr>
<th>Altitude (km)$^a$</th>
<th>$g$ (m/s$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 000</td>
<td>7.33</td>
</tr>
<tr>
<td>2 000</td>
<td>5.68</td>
</tr>
<tr>
<td>3 000</td>
<td>4.53</td>
</tr>
<tr>
<td>4 000</td>
<td>3.70</td>
</tr>
<tr>
<td>5 000</td>
<td>3.08</td>
</tr>
<tr>
<td>6 000</td>
<td>2.60</td>
</tr>
<tr>
<td>7 000</td>
<td>2.23</td>
</tr>
<tr>
<td>8 000</td>
<td>1.93</td>
</tr>
<tr>
<td>9 000</td>
<td>1.69</td>
</tr>
<tr>
<td>10 000</td>
<td>1.40</td>
</tr>
<tr>
<td>50 000</td>
<td>0.13</td>
</tr>
</tbody>
</table>

$^a$All figures are distances above Earth’s surface.
Gravitational Potential Energy

\[ r = R_E + h \]
Escape Speeds

**TABLE 7.2**

<table>
<thead>
<tr>
<th>Planet</th>
<th>$v_e$ (km/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>4.3</td>
</tr>
<tr>
<td>Venus</td>
<td>10.3</td>
</tr>
<tr>
<td>Earth</td>
<td>11.2</td>
</tr>
<tr>
<td>Moon</td>
<td>2.3</td>
</tr>
<tr>
<td>Mars</td>
<td>5.0</td>
</tr>
<tr>
<td>Jupiter</td>
<td>60.0</td>
</tr>
<tr>
<td>Saturn</td>
<td>36.0</td>
</tr>
<tr>
<td>Uranus</td>
<td>22.0</td>
</tr>
<tr>
<td>Neptune</td>
<td>24.0</td>
</tr>
<tr>
<td>Pluto</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Example – Geosynchronous Orbit

1.
Example – Mass of Earth

1.
Example – Roller Coaster

1.
Example – Law of Gravity

1. A 600-kg satellite is in a circular orbit about Earth at a height above Earth equal to Earth’s mean radius. Find (a) the satellite’s orbital speed, (b) the period of its revolution, and (c) the gravitational force acting on it.