**Newton's 1st Law** - If no force acts on a body then the body's velocity cannot change; i.e. the body cannot accelerate.

**Force** - A force causes a body to accelerate.

Frictionless Surface

A force of 1 Newton causes a mass of 1 kg to accelerate at 1 m/s².

**Newton's 2nd Law** \(\sum F = ma\)

The weight of a body = the gravitational force on the body.

\[W = mg\]

\[F_2 = ma\]

The cord does not shrink or elongate.
Systems of Units

<table>
<thead>
<tr>
<th>System</th>
<th>Force</th>
<th>Mass</th>
<th>Acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI</td>
<td>N</td>
<td>kg</td>
<td>m/s²</td>
</tr>
<tr>
<td>CGS</td>
<td>dyne</td>
<td>gn</td>
<td>cm/s²</td>
</tr>
<tr>
<td>British</td>
<td>lb</td>
<td>slug</td>
<td>ft/s²</td>
</tr>
</tbody>
</table>

FBD - Free Body Diagrams

\[ m = 5 \text{ kg} \]
\[ F = 7 \text{ N} \]
\[ a = \frac{7}{5} = 1.4 \text{ m/s}^2 \]

Action Reaction Pair (Third Law)

Newton's 3rd Law - When two bodies interact, the forces on the bodies from each other are always in magnitude and opposite in direction.

Example 1: Find the tension in the cords

\[ \sum F_x = 0 \quad T_2 \cos 30^\circ - T_1 \cos 15^\circ = 0 \]
\[ T_2 = \frac{0.966}{0.866} = 1.115 \quad T_1 \]

\[ 15^\circ \quad 30^\circ \]
\[ \Sigma F_y = 0 \quad T_1 \sin 15^\circ + T_2 \sin 30^\circ - 10 = 0 \]
\[ .259 \cdot 1.500 \]
\[ T_1 (.259 + .5 (1.155)) = 10 \]
\[ T_1 (.259 + .558) = 10 \]
\[ T_1 = \frac{10}{.817} = 12.24 \text{ N} \]
\[ T_2 = 12.24 (1.155) = 13.65 \text{ N} \]

**Example 2** Find the tension in the rope and the normal force

\[ T = 4g \sin 30^\circ = 0 \]
\[ T = 4 (9.8) (\frac{1}{2}) = 19.6 \text{ N} \]

\[ \Sigma F_y = 0 \quad +N - mg \cos 30^\circ = 0 \]
\[ N = mg \cos 30^\circ = 4 (9.8) (0.866) = 33.9 \text{ N} \]

**Example 3**

For Body 1
\[ \Sigma F_y = ma \]
\[ T = 4a \]
\[ T = 4(3.27) = 13.08 \text{ N} \]

For Body 2
\[ 2g - 4a = 2a \]
\[ a = \frac{2g}{6} = 3.27 m/s^2 \]
EXAMPLE 4 - FIND THE FORCE ON THE SCALE

\[ F = \text{force} \]

\[ F_y = \text{force}\]

3 possibilities:
- \( a = 0 \)
- \( a < 0 \)
- \( a > 0 \)

IF \( a = 0 \)
\[ F_y = m a_y \]
\[ F_y = 0 \]
\[ F = m g \]

IF \( a > 0 \)
\[ F_y = m a \]
\[ F_y = m a + m g \]
\[ a \uparrow \]

IF \( a < 0 \)
\[ F_y = -m a \]
\[ F_y = m (g - a) \]

IF \( g_i = 1 \alpha \)
\[ F_y = 0 \]

FREE FALL

EXAMPLE 5 - IF \( F = 12 \text{N} \) FIND THE TENSION & ACCELERATION

Since the cord has constant length:
\[ T = T_1 = T_2 \]
\[ a_1 = a_2 > a \]

Body 1
\[ \Sigma F = m a \]
\[ T = 3a \]
\[ 12 - T = 0.63g = a = 0.33T \]
\[ a = \frac{I - 0.33T}{2} \]

Body 2
\[ T = 4.6N \quad a = 1.53 \text{m/s}^2 \]
**Example 6 -** For the figure at the left

**Find the force between blocks**

**For Body 1**

\[ F_x = 0 \quad N_1 - 4g \cos 30 = 0 \]

\[ N_1 = 33.9 \]

\[ 2F_y = ma \quad 7 - F_y - N_1 \sin 30 = 4a \]

\[ 7 - F_y - 33.9(0.5) = 4a \]

**For Body 2**

\[ 2F_y = 0 \quad N_2 - 3g \cos 30 = 0 \]

\[ N_2 = 25.5 \]

\[ 2F_x = ma \quad F_x - N_2 \sin 30 = 3a \]

\[ F_x = 3a + 12.75 \]

\[ a = -3.25 \text{ m/s}^2 \quad F_x = 3.00 \text{ N} \]
**Example 7**

Given:

\[
\begin{align*}
  m_1 &= 2 \text{ kg} \\
  m_2 &= 1 \text{ kg} \\
  m_3 &= 3 \text{ kg}
\end{align*}
\]

Find: \( T_1, T_2 \) and \( \alpha \)

\[
\begin{align*}
  T_1 - 3g \sin 20 &= 2a \\
  T_2 - T_1 - 1g \sin 20 &= 1a \\
  3g - T_2 &= 3g
\end{align*}
\]

3 Equations, 3 unknowns:

\( T_1, T_2 \) and \( \alpha \)
1. 1 mi is equivalent to 1609 m so 55 mph is:

A) 15 m/s  
B) 25 m/s  
C) 66 m/s  
D) 88 m/s  
E) 1500 m/s

2. The vector \( \mathbf{V}_3 \) in the diagram is equal to:

![](image)

A) \( \mathbf{V}_1 - \mathbf{V}_2 \)  
B) \( \mathbf{V}_1 + \mathbf{V}_2 \)  
C) \( \mathbf{V}_2 - \mathbf{V}_1 \)  
D) \( \mathbf{V}_1 \cos \theta \)  
E) \( \mathbf{V}_1 / (\cos \theta) \)

3. A vector has a component of 10 in the +x direction, a component of 10 in the +y direction, and a component of 5 in the -z direction. The magnitude of this vector is:

A) zero  
B) 15  
C) 20  
D) 25  
E) 225
4. The average speed of a moving object during a given interval of time is always:

   A) its speed at any point
   B) the distance covered during the time interval divided by the time interval
   C) one-half its speed at the end of the interval
   D) its acceleration multiplied by the time interval
   E) one-half its acceleration multiplied by the time interval.

5. A car starts from Hither, goes 50 km in a straight line to Yon, immediately turns around, and returns to Hither. The time for this round trip is 2 hours. The average speed of the car for this round trip is:

   A) 0 km/h
   B) 50 km/h
   C) 100 km/h
   D) 200 km/h
   E) cannot be calculated without knowing the acceleration

6. An object with an initial velocity of 12 m/s west experiences a constant acceleration of 4 m/s² west for 3 seconds. During this time the object travels a distance of:

   A) 12 m
   B) 24 m
   C) 36 m
   D) 54 m
   E) 144 m

7. An object is thrown straight up from ground level with a speed of 50 m/s. If g = 10 m/s² its distance above ground level 6.0 s later is:

   A) 480 m
   B) 270 m
   C) none of these
   D) 0.00 m
   E) 330 m
8. The airplane shown is in level flight at an altitude of 0.50 km and a speed of 150 km/h. At what distance \( d \) should it release a heavy bomb to hit the target X? Take \( g = 10 \text{ m/s}^2 \).

A) 150 m  
B) 295 m  
C) 417 m  
D) 2550 m  
E) 15000 m

9. A large cannon is fired over level ground at an angle of 30° above the horizontal. The muzzle velocity is 980 m/s. Neglecting air resistance, the projectile will travel what horizontal distance before striking the ground?

A) 4300 m  
B) 8500 m  
C) 43,000 m  
D) 85,000 m  
E) 170,000 m
10. A dart is thrown horizontally toward X at 20 m/s as shown. It hits Y 0.1 s later. The distance XY is:

A) 2 m  
B) 1 m  
C) 0.5 m  
D) 0.1 m  
E) 0.05 m

11. A stone is tied to a 0.50 m string and whirled at a constant speed of 4.0 m/s in a vertical circle. Its acceleration in m/s² at the top of the circle is:

A) 9.8, up  
B) 9.8, down  
C) 8.0, down  
D) 32, up  
E) 32, down
12. Two forces, one with a magnitude of 3 N and the other with a magnitude of 5 N, are applied to an object. For which orientations of the forces is the magnitude of the acceleration of the object the least?

A) IV  
B) V  
C) I  
D) II  
E) III

13. A 700-kg elevator accelerates downward at 3.0 m/s². The force exerted by the cable on the elevator is:

A) 2.1 kN, up  
B) 2.1 kN, down  
C) 4.8 kN, up  
D) 4.8 kN, down  
E) 9.0 kN, up

14. A 150 lb man stands on a spring scale in an elevator that is accelerating upward at 16 ft/s². The scale will read (in lbs):

A) 300  
B) 225  
C) 175  
D) 150  
E) 75
15. When a 40-N force, parallel to the incline and directed up the incline, is applied to a crate on a frictionless incline that is 30° above the horizontal, the acceleration of the crate is 2.0 m/s² up the incline. The mass of the crate is:

A) 3.8 kg
B) 4.1 kg
C) 5.8 kg
D) 6.2 kg
E) 10 kg
Answer Key

1. B
2. C
3. B
4. B
5. B
6. D
7. C
8. C
9. D
10. E
11. E
12. C
13. C
14. B
15. C