Forces

Force: -physical property which causes masses to accelerate (change of speed or direction)
-a push or pull
-vector possessing both a magnitude and a direction and adds according to the Parallelogram Law
-the Resultant force is defined by Newton's Second Law as:

resultant force is proportional to linear acceleration

or *vice versa*

linear acceleration is proportional to resultant force

-with a consistent system of units, such as the metric system, the resultant force ($\underline{F}$) is defined:

$$\underline{\boldsymbol{F}} = m\,\underline{\boldsymbol{a}}$$

Where m = mass in kilograms
$\underline{a}$ = linear acceleration in m/s^2
$\underline{\boldsymbol{F}}$ = resultant force in newtons

and 1 newton = 1 N = 1 $kg.m/s^2$
-a newton is the force required to accelerate a one kilogram mass at the rate of one metre per second squared

Types of Forces:

External forces are environmental forces which act on the body or the forces exerted by other objects which come into contact with the body.

Examples are:

-gravitational forces especially the earth's
-frictional forces of surfaces and fluids
-ground reaction forces (includes friction)
-drag (viscous) forces of air or water
-impact forces of objects
-springs (poles, cables, springboards)
-buoyant force of water

Internal forces are forces that originate within the body (also terminate within the body). Sum of all internal forces within any body is always equal to zero (vector).

Examples are:

-muscle forces (through tendons)
-bone-on-bone forces (including cartilage)
-ligamentous forces
-joint capsular forces and skin
-fluid (viscous) forces

In addition to the **Cartesian** and **polar (2D) or spherical (3D) coordinate** systems two other systems are often used to simplify analysis.

Normal and Tangential Forces:

When considering the reaction force of a surface the component of the force that is at right angles to the plane of the surface is the **normal force**. The **tangential force** is the component of force parallel to the surface and is mainly due to friction.

Examples are:

-ground reaction forces in locomotion
-sliding down an incline

Radial and Transverse Forces:

When considering objects in curvilinear motion, the **radial force** is the component of force in the direction of the radius of curvature. The **transverse force** is the component of force which is at right angles to the radial force.

Examples are:

-hammer or discus thrower
-velodrome racing
-running a curved or banked track

Gravitational Force and Weight:

The gravitational force between most objects and the body are too small to be of any consequence. The force of gravity between the body and the earth is called weight.

$$\underline{W} = \underline{F}_g = -mg\underline{k}$$

where, $\underline{W}$ = weight in newtons

$\underline{F}_g$ = gravitational force in newtons

m = mass in kilograms

g = acceleration due to gravity $= 9.81 \text{ m/s}^2$

k = unit vector

For conversion with American units use:

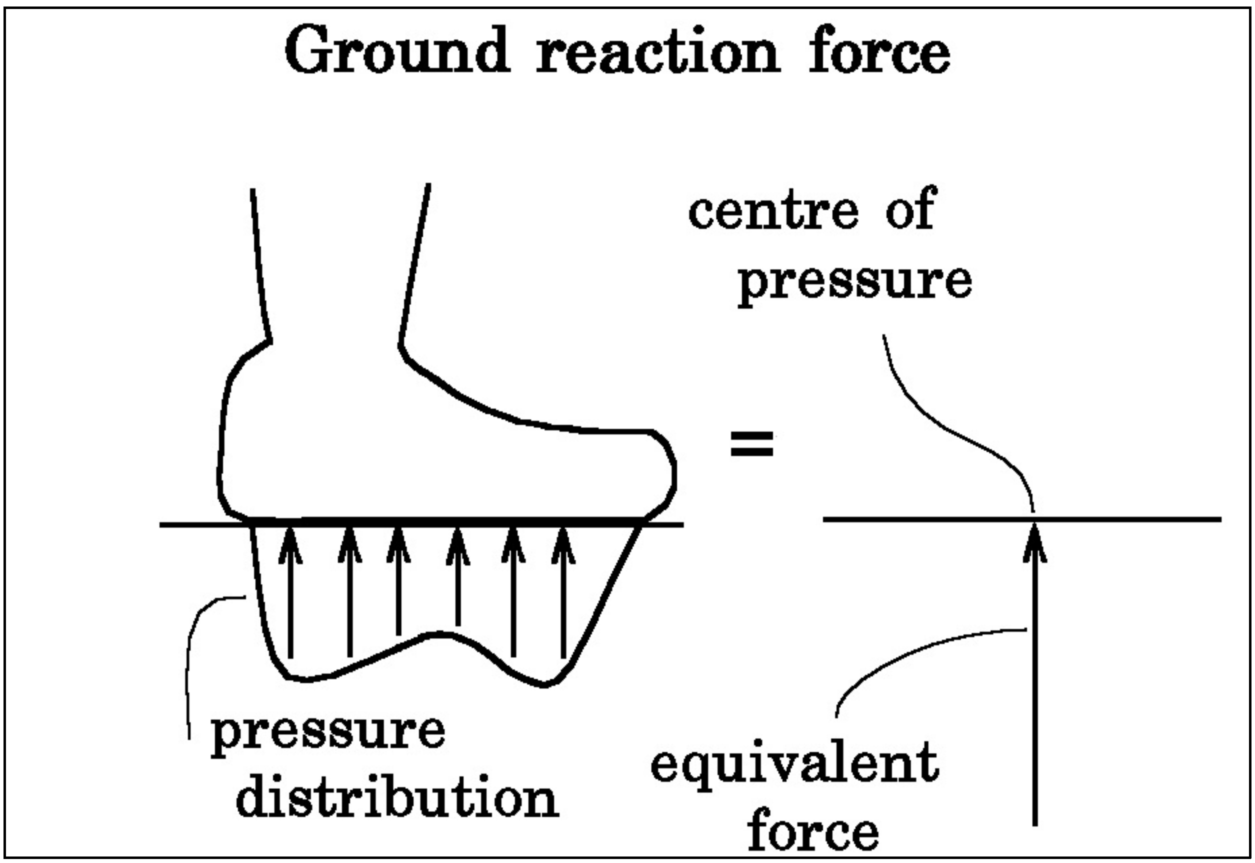
$$1 \; kilogram \approx 2.205 \; lbs.$$
$$1 \; pounds \approx .454 \; kg$$

For conversion between kilograms and newtons use:

$$1 \; kilogram \approx 9.81 \; newtons$$

Distributed Forces:

Many contact forces are actually pressure distributions which can be more easily represented by a **single equivalent force** and its associated **centre of pressure**. Force platforms convert the distributed forces acting upon them to the single equivalent ground reaction force needed to perform kinetic analyses of gait.



Moments of Force

Moment of a Force:

- turning effect of a force
- units are newton metres or N.m
- also called torque (especially when effect is about the longitudinal axis)
- product of moment times force

Moment: - is the perpendicular distance between a line (e.g., line of force) and a point or an axis. (other uses: moment of inertia, moment of moment)

Directions:

- counter-clockwise (right-hand rule) is positive
- clockwise is negative

$$\underline{M} = \underline{r} \times \underline{F}$$

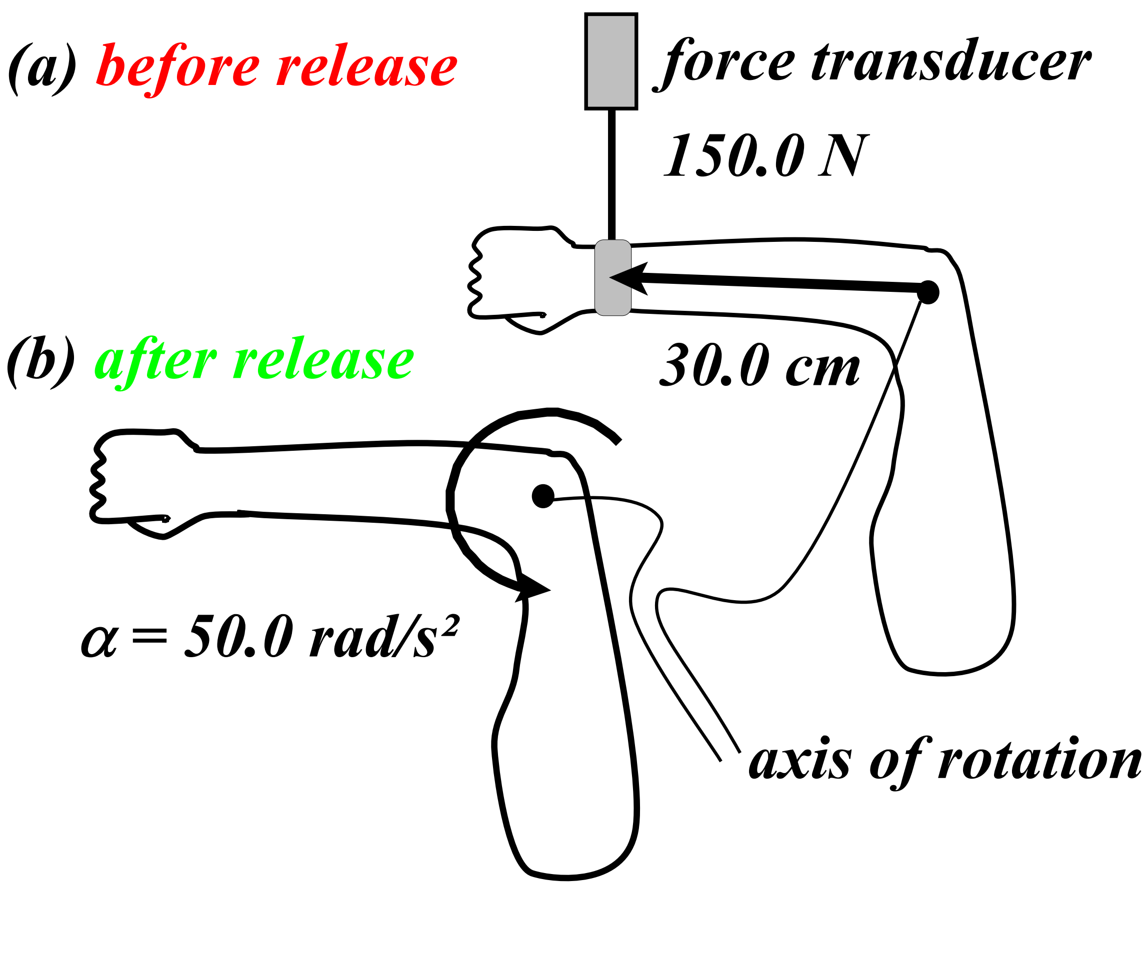
$$[\underline{M}]_z = r \cdot F \cdot \sin\theta$$

where

θ = *angle between* $\underline{r}$ *and* $\underline{F}$

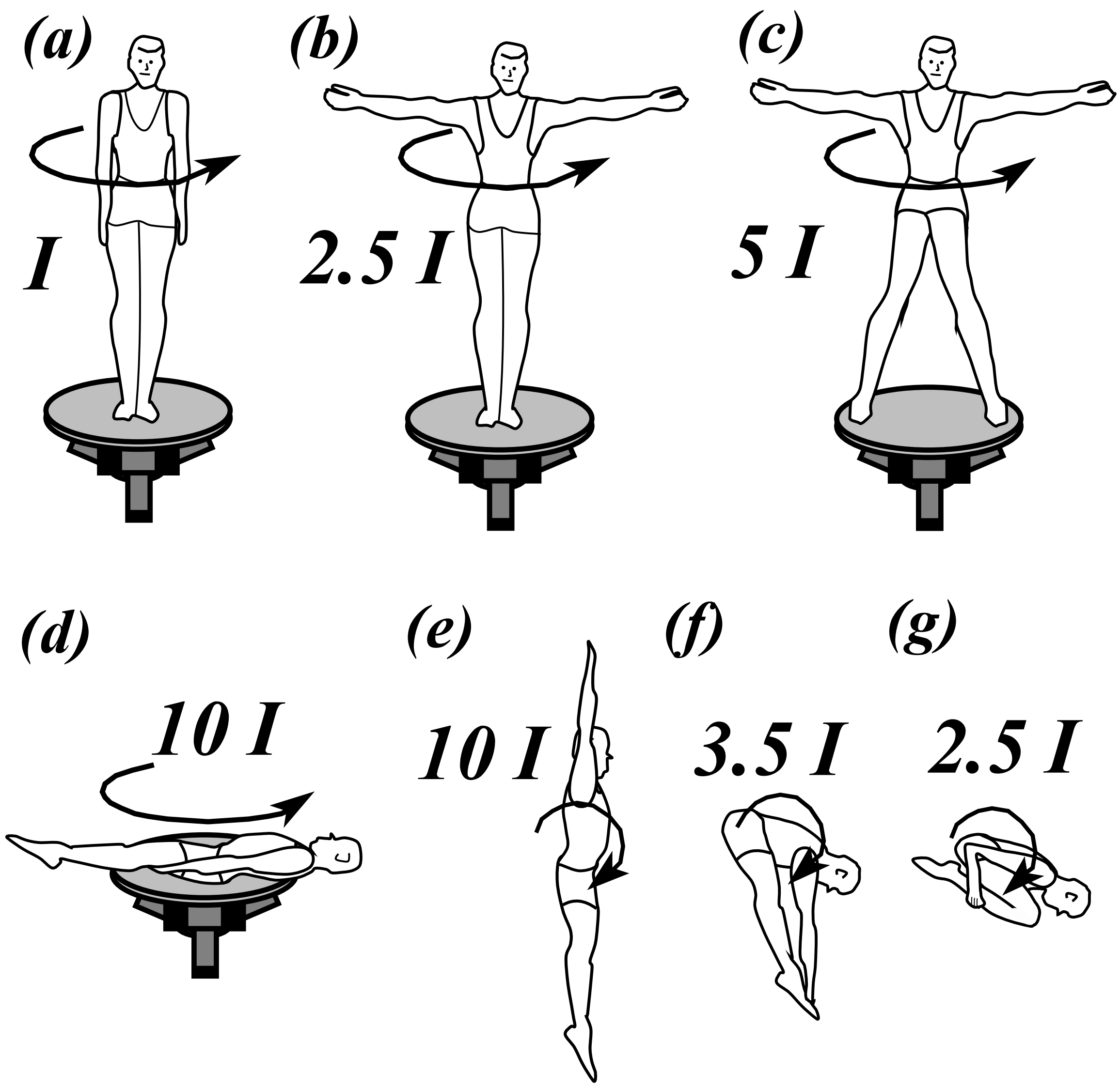
Quick Release Experiment

- used to measure moments of inertia non-invasively
- assumes no friction in the joints
- performed in the horizontal plane to eliminate gravity effects
- angular acceleration is measured by video analysis or electrogoniometry



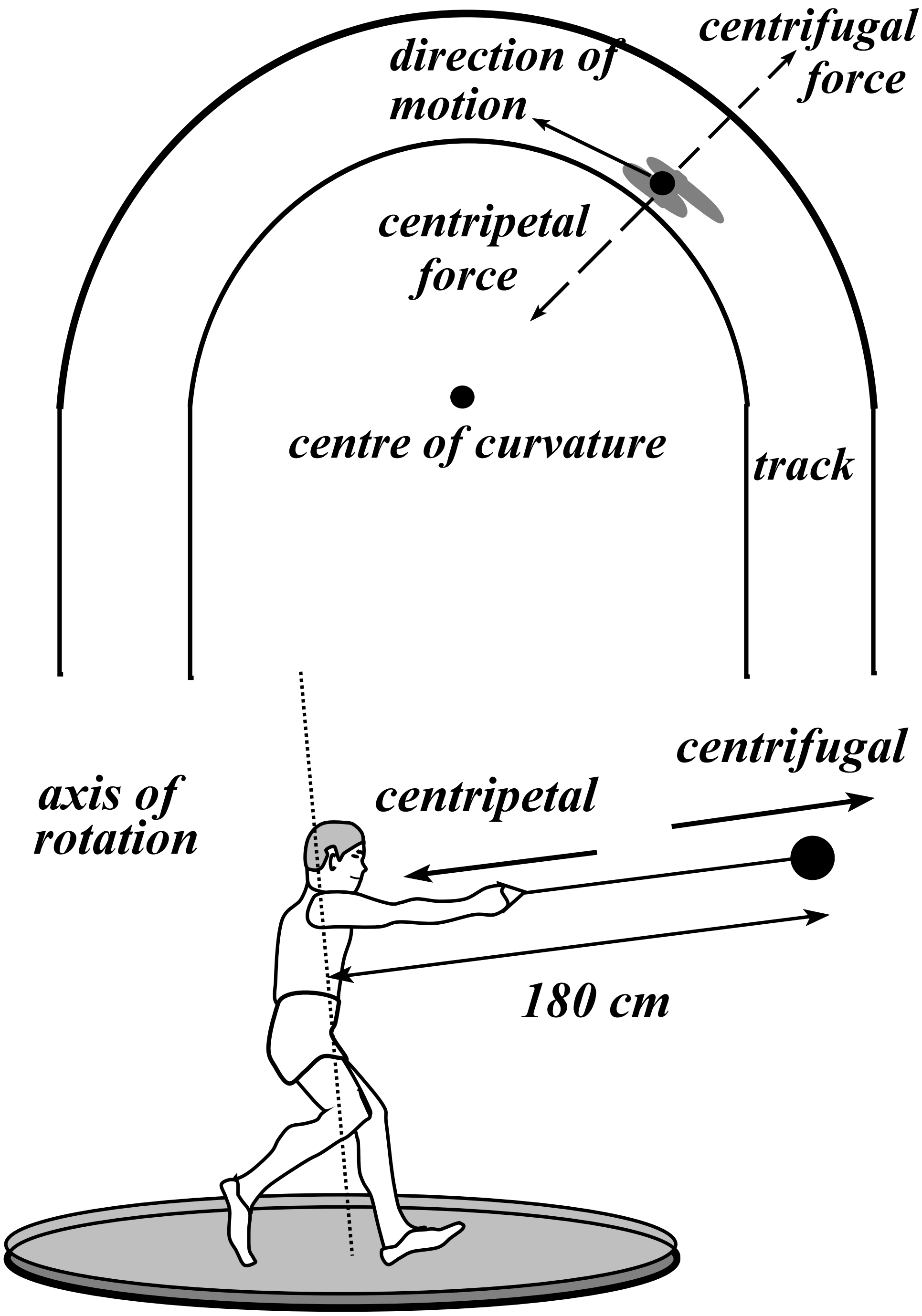
Moments of Inertia

- smallest about longitudinal axis
- increases proportional to mass and squared distance from axis
- varies depending on axis of rotation (x, y, and z)

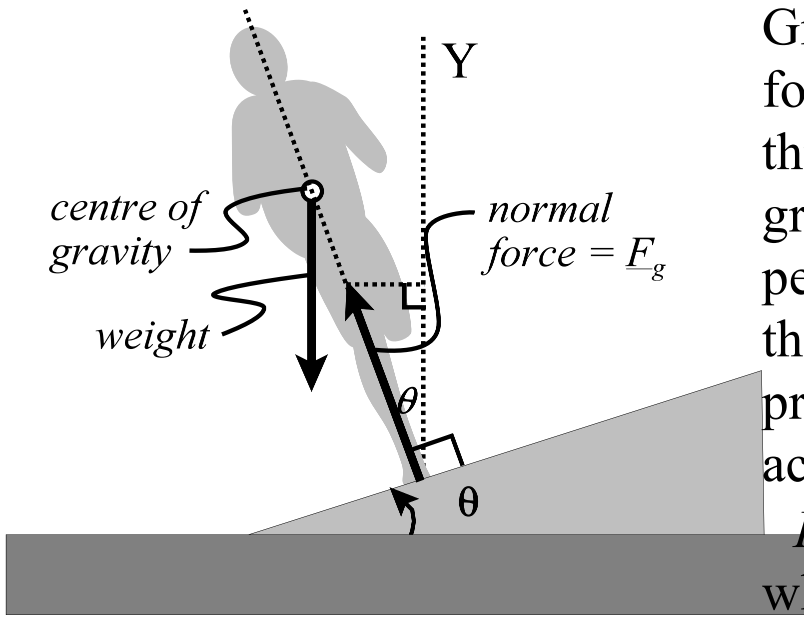


Centripetal Forces

- centripetal force is caused by runner and track or thrower that permits travel along the curved path
- centrifugal (centre-fleeing) is pseudo-force felt by runner and thrower



Banking of Curves



Ground reaction force ($\underline{F}_g$) should pass through centre of gravity otherwise person rotates. To run the bend $\underline{F}_g$ must provide a radial acceleration. I.e.,

$F_x = ma_r = -mv_t^2/r$

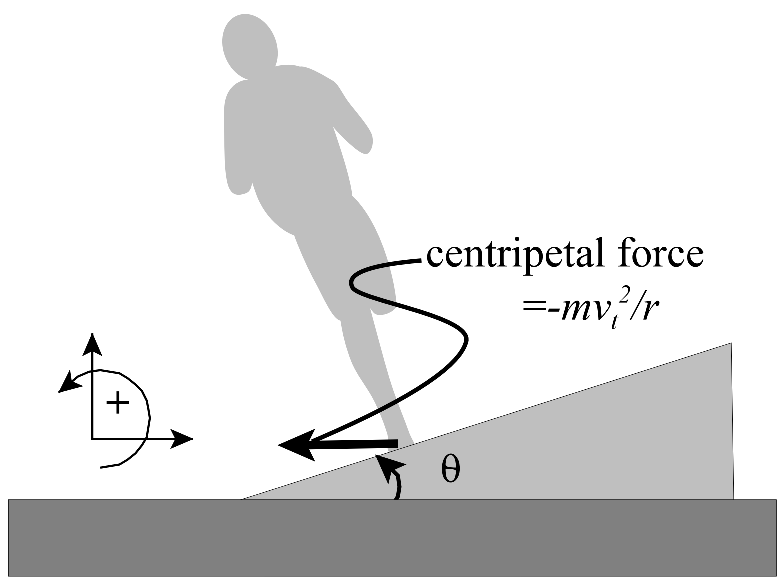
where r is radius of curvature of the bend.

Since, $F_y = 0$:

$F_g \cos \quad - mg = 0$

then

$F_g = mg/\cos$



and $F_x = ma_x$:

$F_x = -mv_t^2/r$

$-F_g \sin \quad = -mv_t^2/r$

substitute $mg/\cos$ for F_g to get

$-mg \sin \quad /\cos \quad = -mv_t^2/r$

simplify and rearrange to

$\sin \quad /\cos \quad = \tan \quad = v_t^2/rg$ or

Ideal angle of banking = $\quad = \tan^{-1}(v_t^2/rg)$