Fig. 6.1: Force at hip joint

- Bearing force
- Muscle force
- Gravity
- Line of force action
- Brittle fracture

[Acetabulum]
[Femoral head]
Fig. 6.2: Principle of leverage

Moment of force
Fig. 6.3: Circular motion and Centrifugation

(a) Centripetal force

\[ F = m \frac{v^2}{r} = m r \omega^2 \]  

(b) Centrifuge

\[ \text{plasma} \]

\[ \text{Blood cells} \]

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Fig. 6.4: Deformation ratio

\[
y = \frac{(a-b)}{(a+b)} \tag{6.2}
\]
Fig. 6.5: Erythrocyte deformation in shear field

(a) $y=0$

(b) $y=0.2$

(c) $y=0.3$

(d) $y=0.4$

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Fig. 6.6: Deformability of erythrocyte

Deformation ratio \( y \)

\[
y = y_0 \left(1 - \exp\left(-\frac{\tau}{\tau_0}\right)\right)
\]  

(6.3)

\( y_0 \)

\( 0.63y_0 \)

\( \tau_0 \)

\( \tau \)

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Fig. 6.7: Myoblasts differentiate to myotubes

0.05 mm

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Fig. 6.8: Degree of freedom (Translation, Rotation)
Fig. 6.9: Motion direction

- Abduction
- Adduction
- Spination
- Inner rotation
- Valgus
- Varus
- Pronation
- External rotation
- [Forearm]
- [Leg]
- [Foot, Thumb]

[Horizontal plane]
[Frontal plane]
[Frontal plane]
[Horizontal plane]
Fig. 6.10: Cylindrical cam

[Rotational motion]  [Reciprocating motion]

Cylindrical cam

Eccentric distance

Piston

Spring

Reciprocating

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Fig. 6.11: Motion of piston

Position of piston

Reciprocating

Systole

Diastole

Time

Reciprocating

Systole

Diastole

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Fig. 6.12: Damping of vibration

\[ y = y_0 (1 - e^{-(t/\tau)}) \]  \hspace{1cm} (6.4)

Critical damping

\( \tau \): Time constant
Fig. 6.13: Control

Summing point

Input + Signal → Element → Output

± Signal

Feedback coupling

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Fig. 6.14: Biological cell

- Proliferation
- Differentiation
- Uptake
- Deformation
  - movement
  - Membrane
- Excretion
- [Environment]
Fig. 6.16: Friction angle

**Normal force:** $F_n$

**Frictional force:** $F_s$

**Friction angle:** $\theta$

**Gravity:** $Mg$

Coefficient of friction

$$\mu = \frac{F_s}{F_n} \quad (6.5)$$

Coefficient of friction

$$\mu = \frac{(Mg \sin \theta)}{(Mg \cos \theta)} = \tan \theta = \mu \quad (6.6)$$
Fig. 6.17: True area of contact

True area of contact

[Apparent area of contact]
Fig. 6.18: Surface of solid

[Adsorbed molecules]

Oxide film  Nitrogen  Water  Oxygen

Solid

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Fig. 6.19: Roller pump
Fig. 6.20: Screw pump
Fig. 6.21: Contact angle: $\theta$

Hydrophobic
$\theta > (\pi/2)$

Hydrophilic
$\theta < (\pi/2)$
Fig. 6.22: Clot
Fig.6.23: Clotting system

- Coagulation
  - Platelet aggregation
  - Activation factor XII
  - Thrombin
  - Fibrinolysis

- Platelet factor III
- Surface contact
- Thromboxane A2
Fig. 6.24: Blood circulation circuit

Centrifugal type artificial heart

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Fig. 6.25: Clot formation in tube (low flow)

Fig. 6.26: Clot formation in tube (high flow)
Fig. 6.27: Clot at bearing

Casing

Impeller

Clot

50 mm
Fig. 6.28: Clot behind impeller

Casing
Thrombus

50 mm
Fig. 6.29: Modified pivot of Artificial Heart

50 mm
Fig. 6.30: Concave and convex cones

50 mm

Segmented polyurethane

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Fig. 6.31: Wear

(a) Abrasive wear

(b) Adhesive wear

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Fig. 6.32: Transition of wear

(a) Wear volume

Initial wear
Mild wear

Friction distance

(b) Wear volume

Severe wear
Seizing

Friction distance
Fig. 6.33: Joint prosthesis

Femoral head

Stem

[Ceramics]

Acetabulum

Femoral head

Stem

(Metal)

(Loosening)

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Fig. 6.34: Cardiac valve prosthesis

- Rotation
- Wear scar of disc
- Wear of pivot
- Opening and closing
- Leaflet
- Strut wear
- Valve seat
- Flow

(a) Mono-leaflet
(b) Bi-leaflet

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Fig. 6.35: Articular surface lubrication

(a) Wedge film lubrication

(b) Squeeze film lubrication