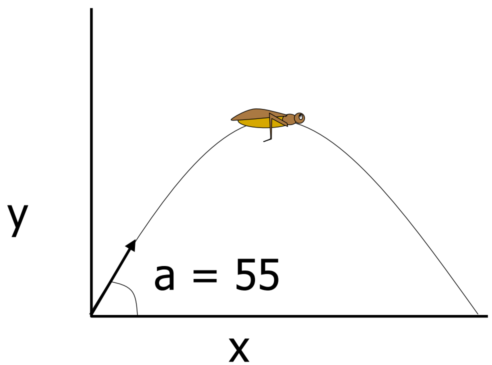
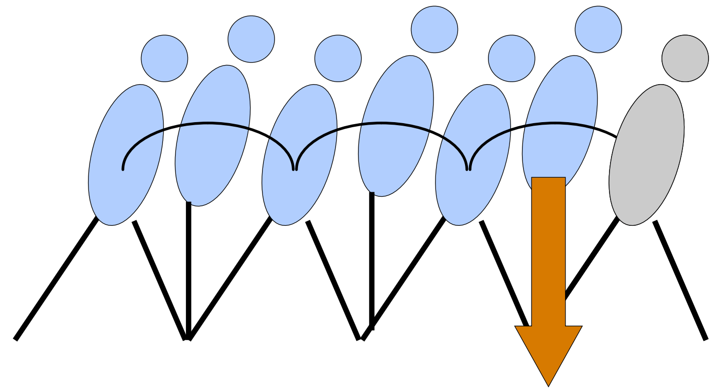
Lecture 3. Terrestrial locomotion II: mechanical analysis of gaits and jumpiness.

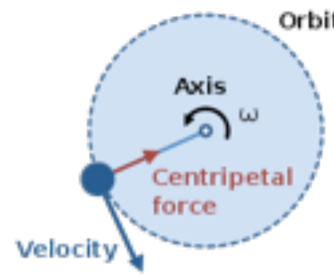
- Recap: gaits and ballistic walking
- When the Froude Number ($V^2/g\ L$) is greater than 1, simple ballistic walking is no longer possible.
- More aspects of jumping (energy and force)
- The jumper model accounts for an airborne phase of movement.
- Calculating optimal gaits for energy expenditure

Running: a combination of walking and jumping

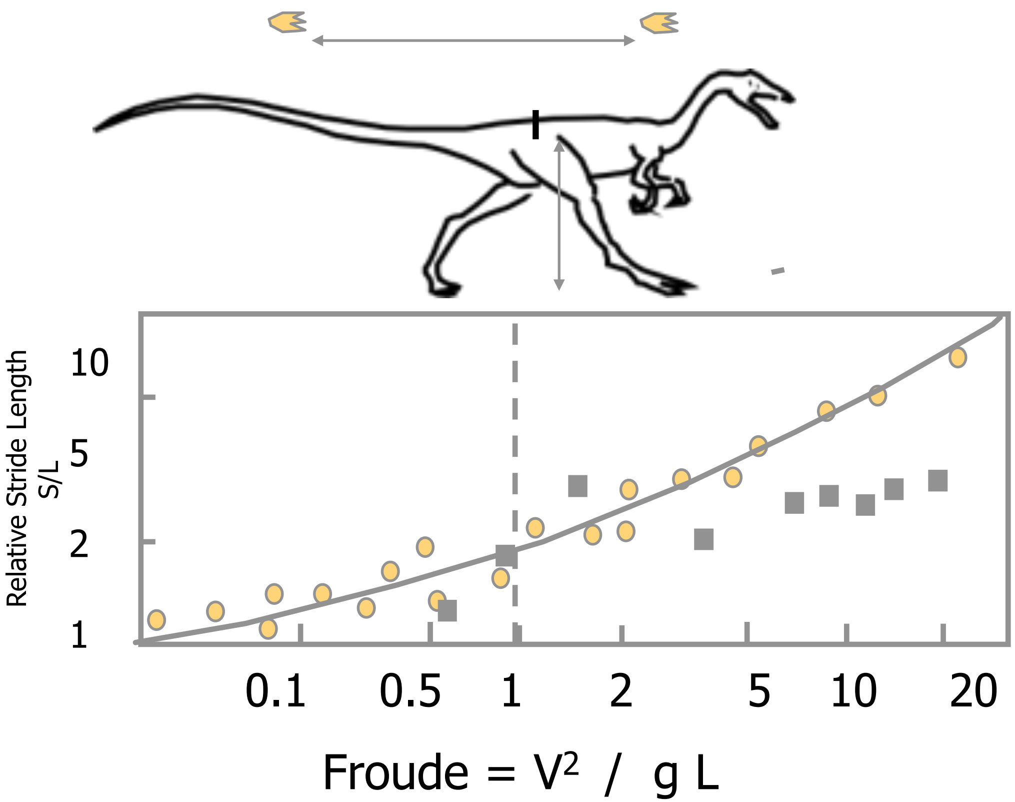


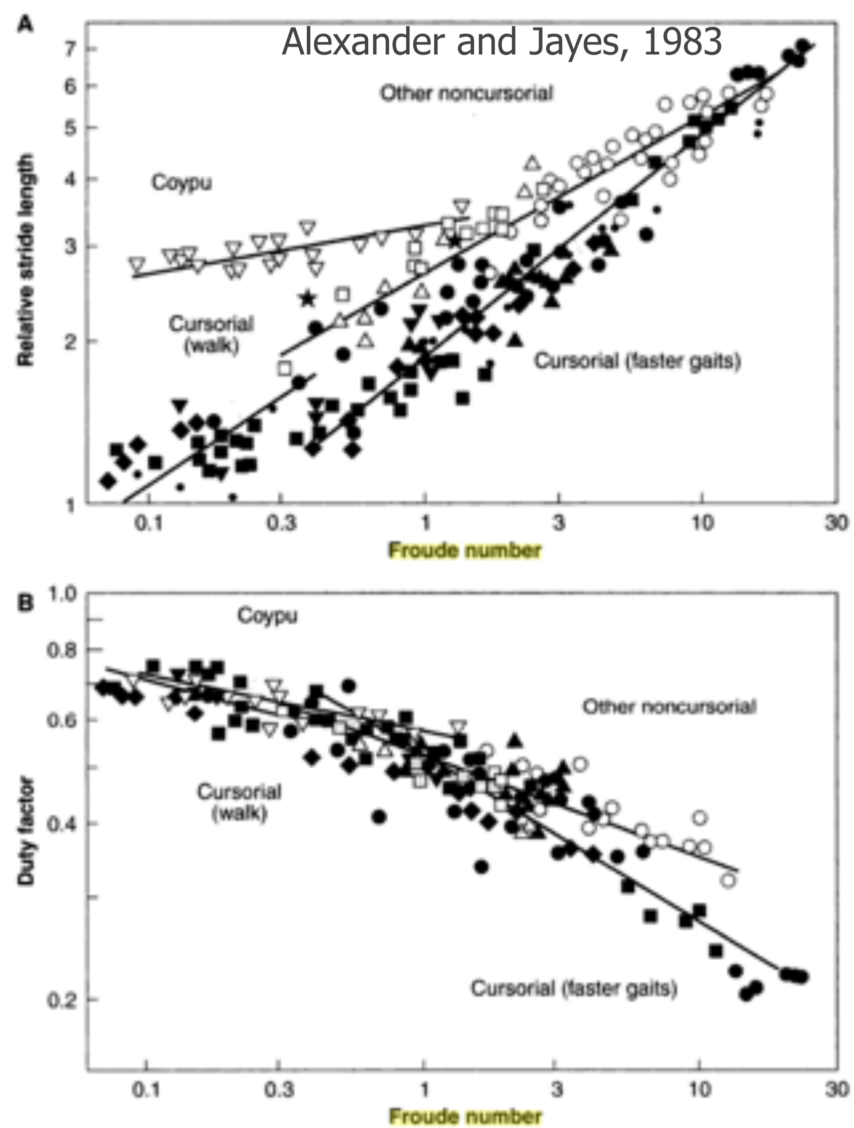


$v^2 < g\,L$

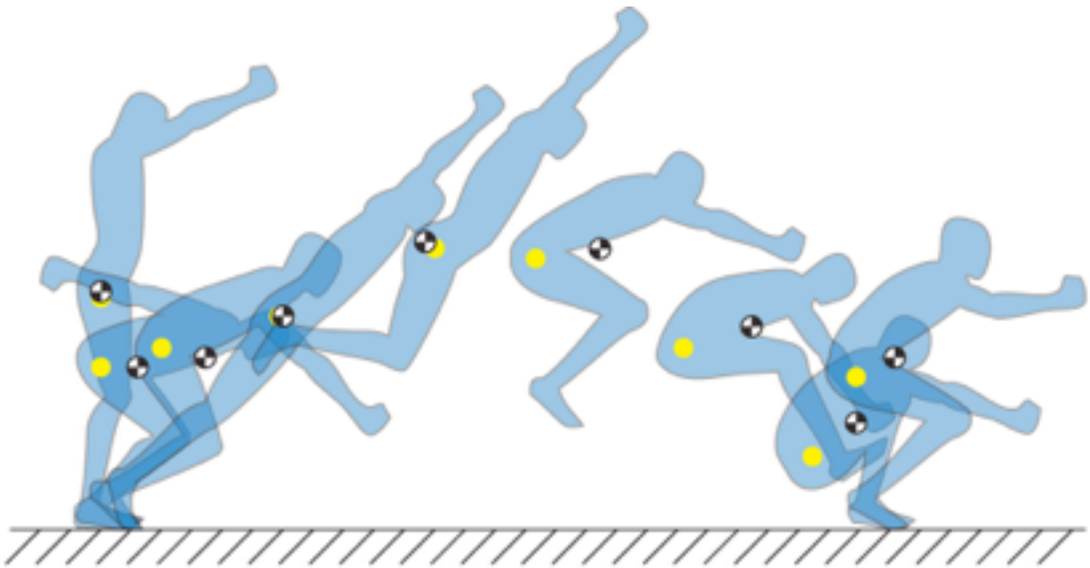


$F_c = m\,a_c = m\,v^2/r$


Relative Stride Length
S/L
10
5
2
1
0.1
0.5
1
2
5
10
20
Froude = V^2 / g L


A
Alexander and Jayes, 1983
Other noncursorial
Coypu
Cursorial (walk)
Cursorial (faster gaits)
Relative stride length
Froude number
B
Coypu
Other noncursorial
Cursorial (walk)
Cursorial (faster gaits)
Duty factor
Froude number

Kinematics and dynamics of jumping



Center of mass is a function of *shape*.

Animals move by exerting forces on their environment.

$$\Sigma \mathbf{F} = M \cdot \mathbf{a}$$

At which point on the moving body do we measure acceleration?

center of mass

$$x_{COM} = \frac{1}{M} \int_0^M x \ dm$$

$$y_{COM} = \frac{1}{M} \int_0^M y \ dm$$

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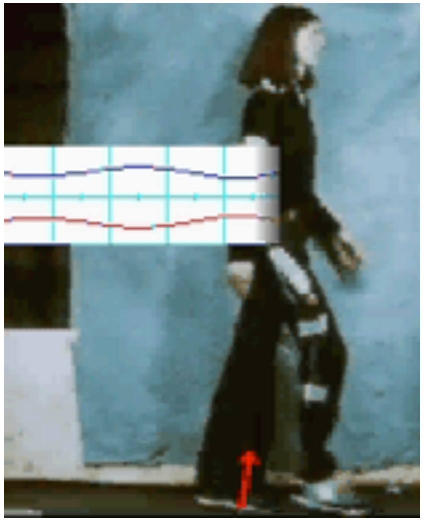
The tradeoff between potential and kinetic energy



Kinetic Energy
energy due to motion

kinetic energy of a moving body $\frac{1}{2}mv^2$

Potential Energy
energy of an object in a force field

gravitational potential energy mgh

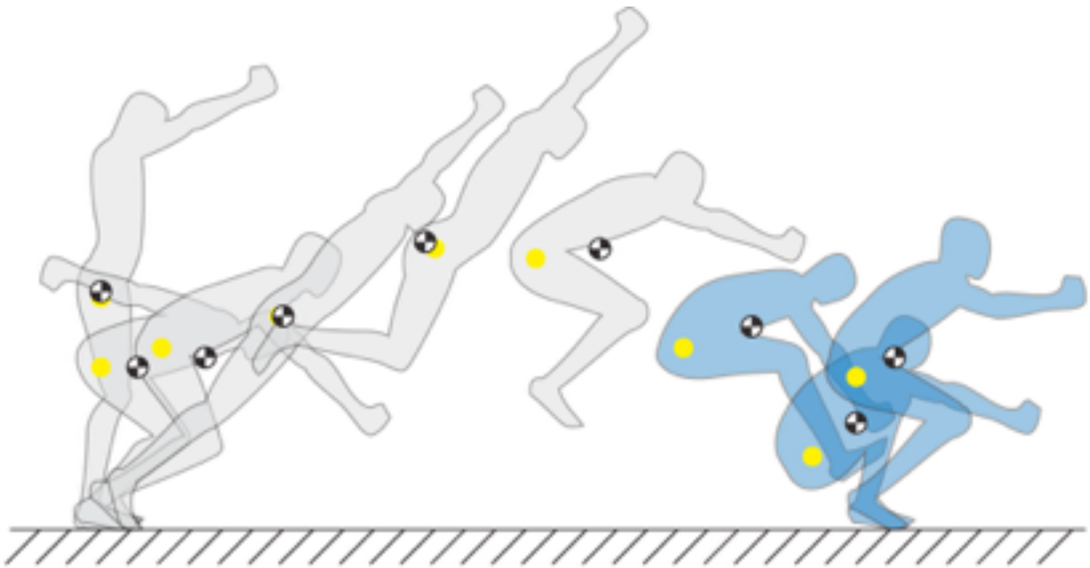
elastic potential energy $\frac{1}{2}kx^2$

Work
changes the energy of a system

Force in the same direction of motion yields positive work.

Force opposing the motion yields negative work.

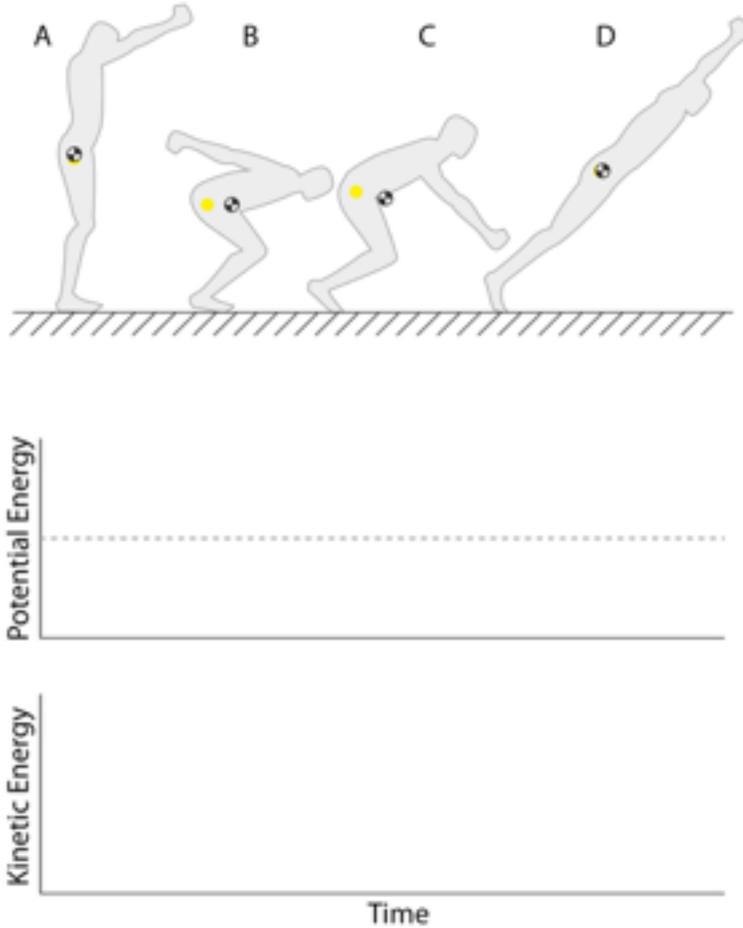
The tradeoff between potential and kinetic energy



What are the forces at play?

What are the kinetic and potential energy of the system?

What is the work being done?

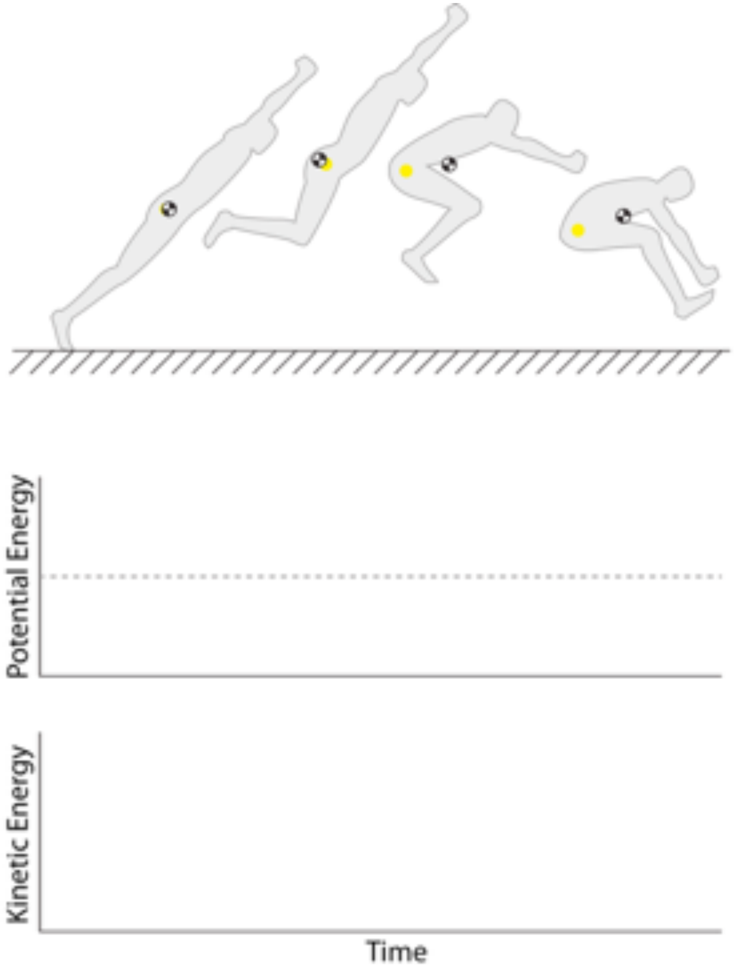


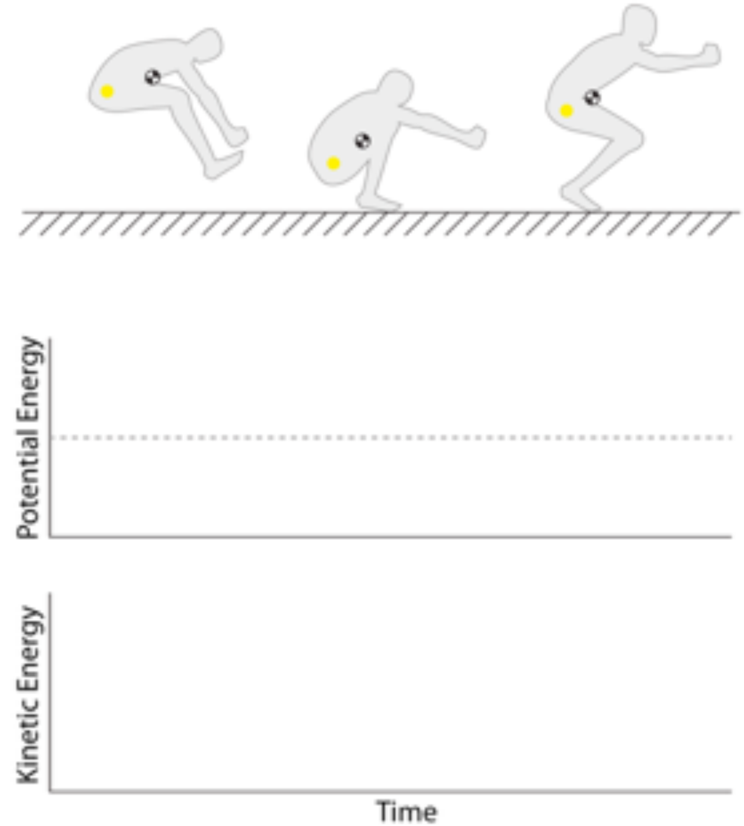
What are the forces at play?

What are the kinetic and potential energy of the system?

What is the work being done?

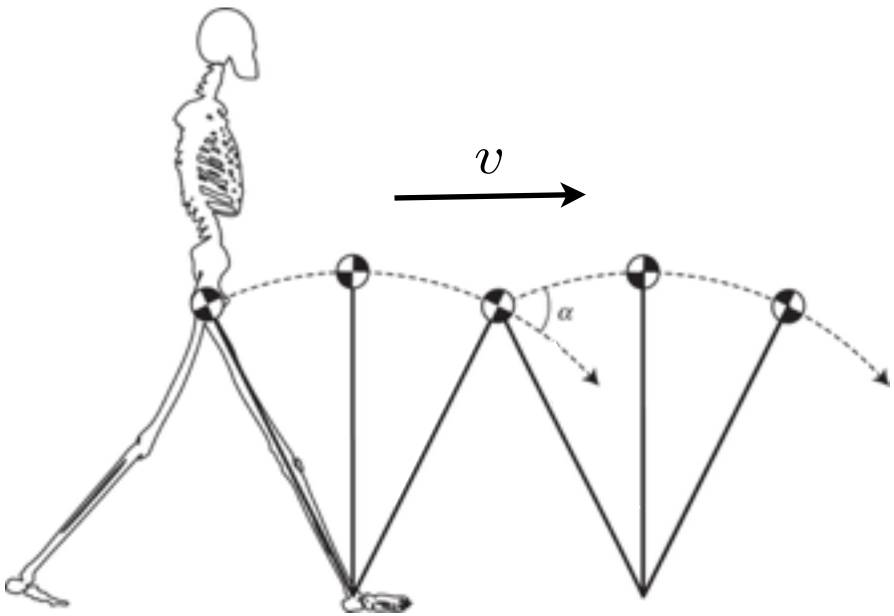
What work was done? Where are losses?





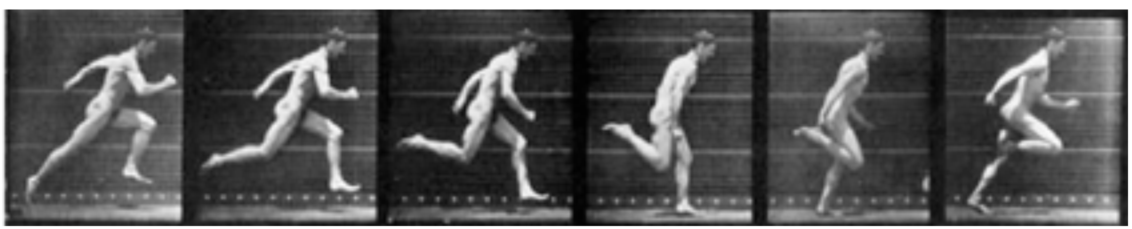
Review of walking

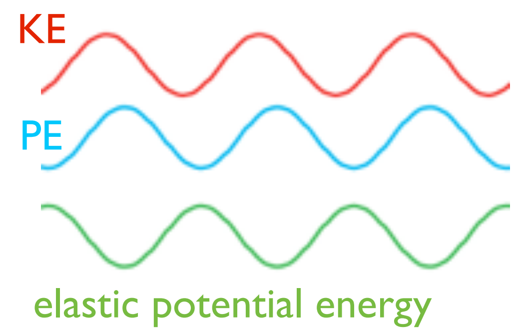
How much energy input is needed for walking?



Matthis & Fajen, 2013

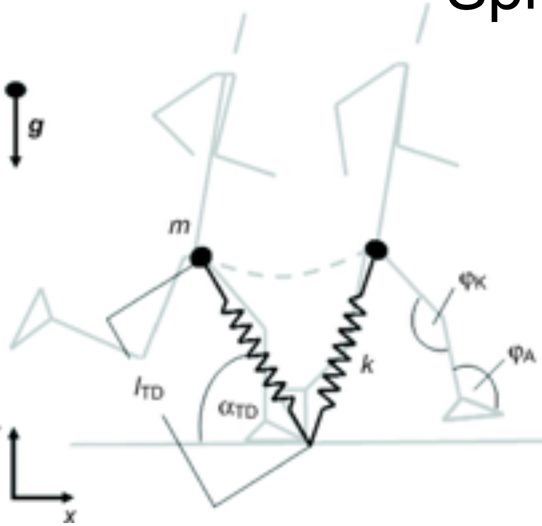
Energy tradeoffs in walking and running

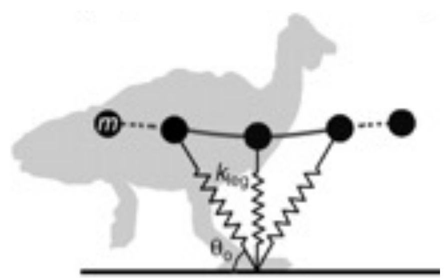


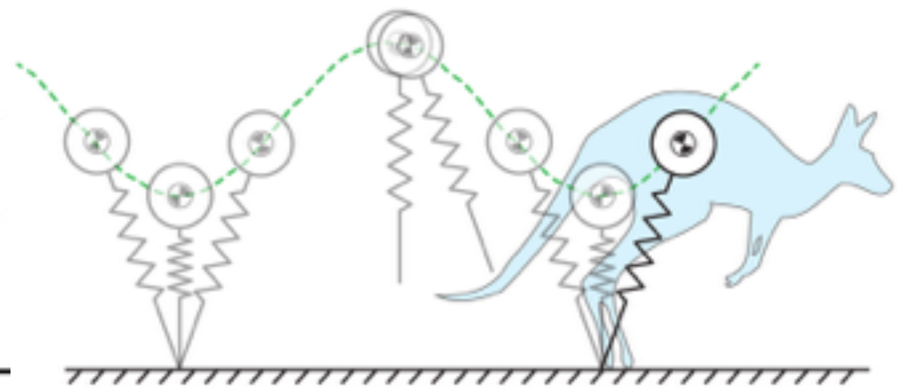


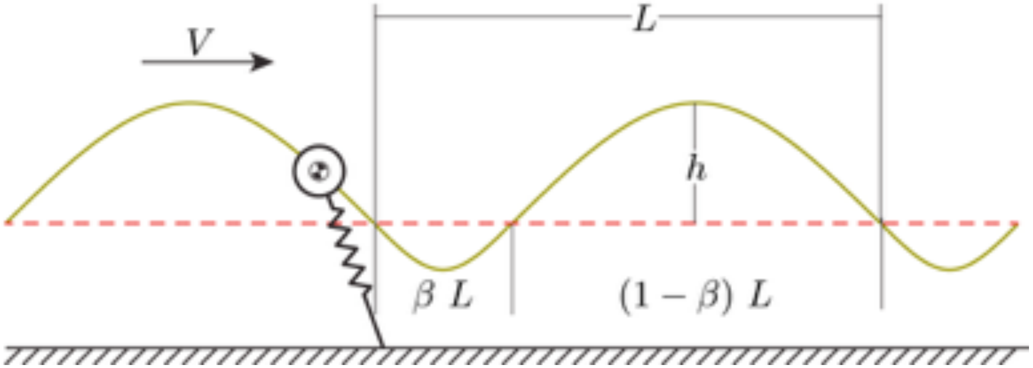
The jumper: for speeds greater than Fr = 1, gait must change with an airborne phase

Spring Loaded Inverted Pendulum









$$h = \frac{1}{2} g (\frac{T_{\text{air}}}{2})^2 = (1-\beta)^2 \frac{m\ g\ L^2}{8\ V^2}$$

Energy

$$W = PE + KE$$

$$PE = m\ g\ h = (1-\beta)^2 \frac{m\ g^2\ L^2}{8\ V^2}$$

$$KE = \frac{1}{2} m\ V^2$$

What is the average power per stride?
What is the power during stance?