# CE 311K: Control flow

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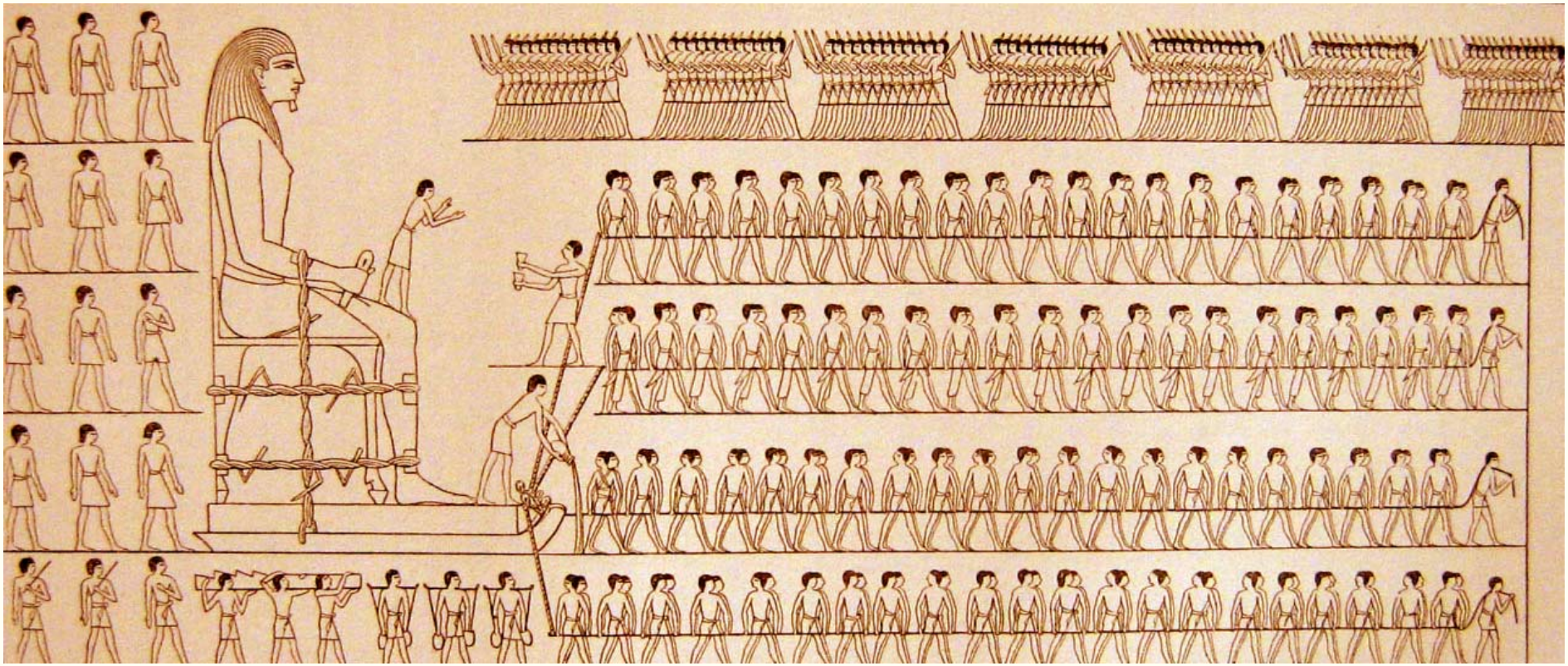
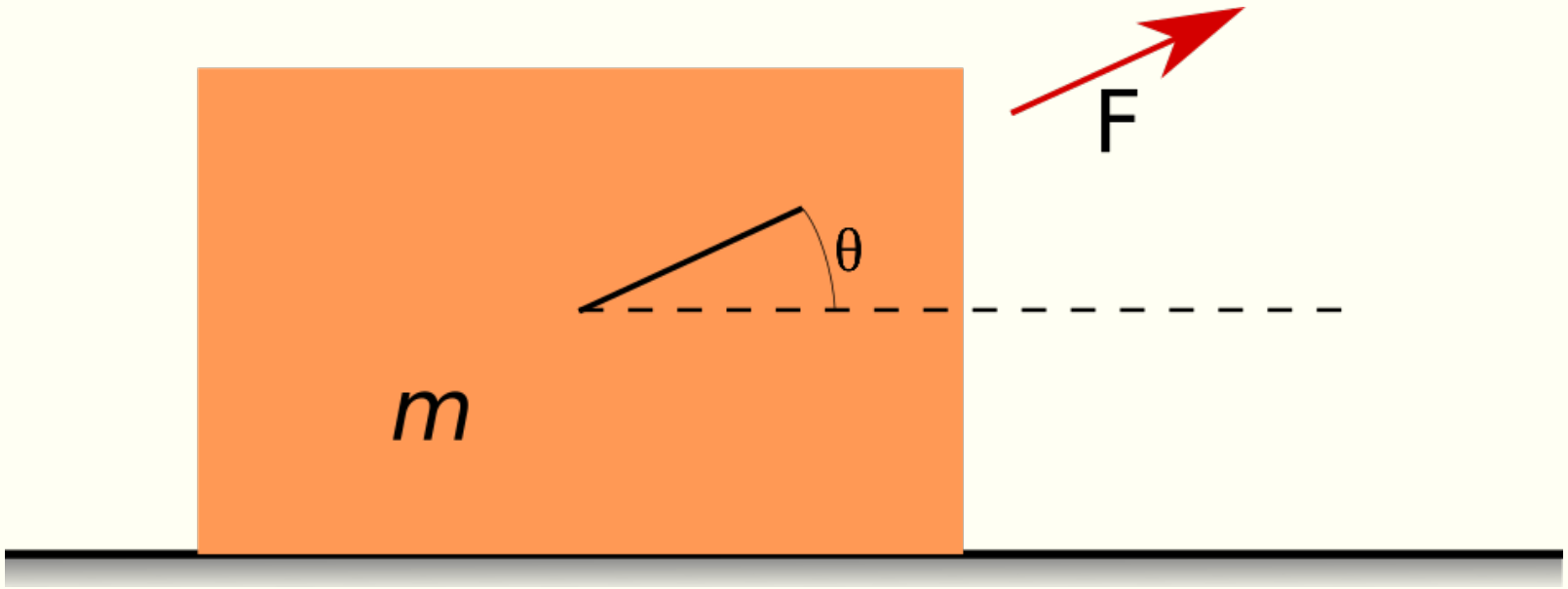
1. Numerical solution
   - Numerical solution of a sliding block

# What is the optimal angle to pull the statue?



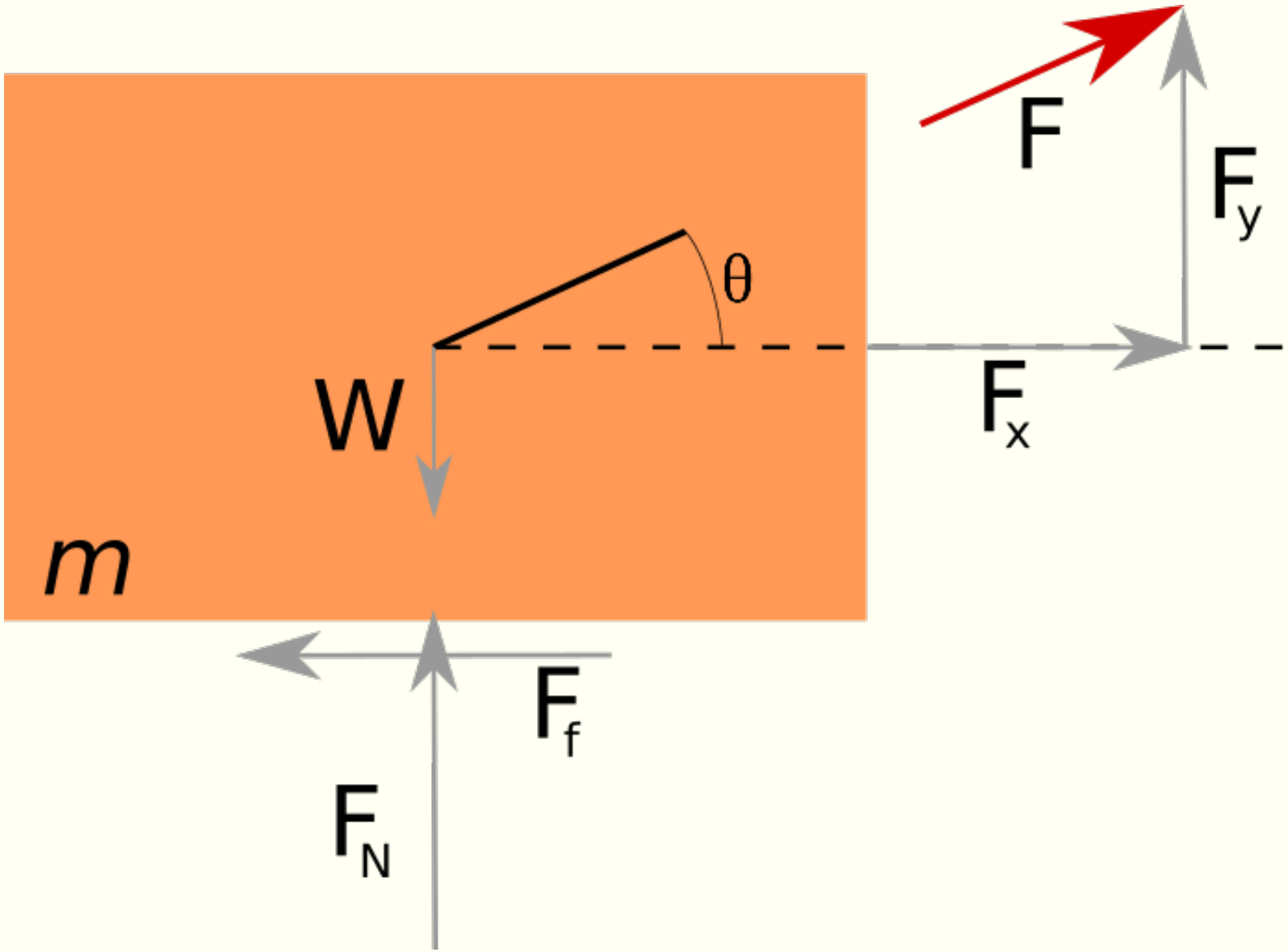
A wall painting from the tomb of Djehutihotep (credit: martinhumanities.com)

# Numerical solution of a sliding block: Approximation




What is the optimal angle to pull the block applying the least amount of force?

# Numerical solution of a sliding block: Forces



# Numerical solution of a sliding block: Forces

$$F_x = F\cos\theta \quad \& \quad F_y = F\sin\theta$$

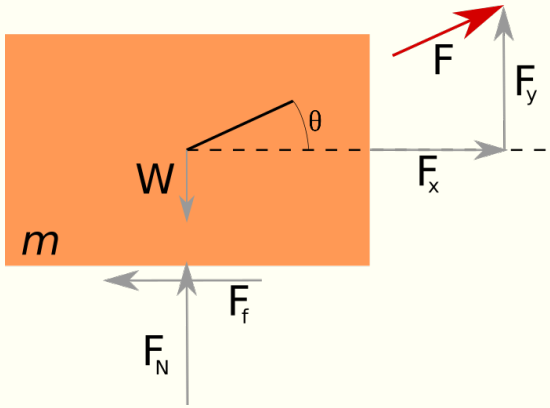
$$F_f = \mu \cdot F_N = \mu \cdot W - \mu F_y = \mu mg - \mu F\sin\theta$$

Vertical forces $\sum F_{vert} \uparrow$: $F_y + F_N - W = 0$

$$F_N = \mu mg - F\sin\theta$$

Horizontal forces $\sum F_{hor} \rightarrow$: $F_x + F_f = 0$

$$F\cos\theta - \mu mg + \mu F\sin\theta = 0$$



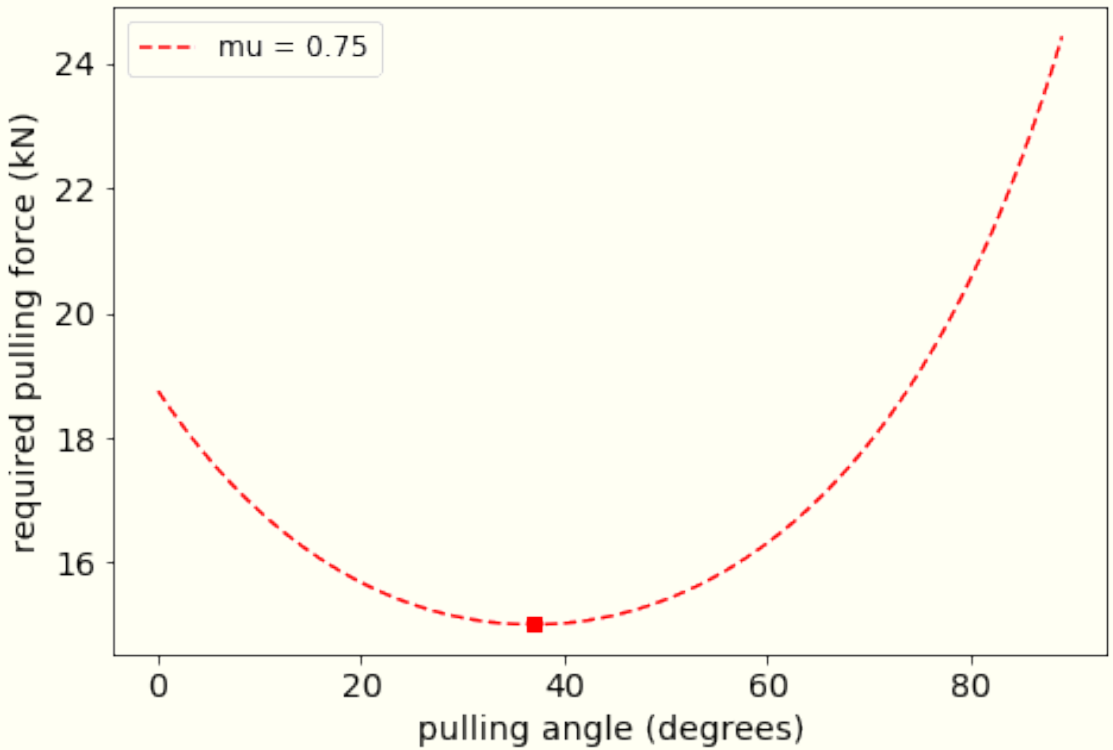

$$F = \frac{\mu \cdot mg}{(\cos\theta + \mu\sin\theta)}$$

# Numerical solution of a sliding block: Compute force

- Given $W = 25kN(2500\,\text{kg})$, $\theta = 45^o$ and $\mu = 0.75$ $(35^o)$:

$$F = \frac{0.75 \times 25}{\cos(45) + 0.75\sin(45)} = 15.15\,\text{kN}.$$

- Given $F = 17.5kN(1750\,\text{kg})$ and $\mu = 0.75$, what's $\theta$?



# Numerical solution of a sliding block: Compute force

- Given $F = 17.5kN(1750\,\text{kg})$ and $\mu = 0.75$, what's $\theta$?

$$Try\ \theta = 60^o: \quad F = \frac{0.75 \times 25}{\cos(60) + 0.75\sin(60)} = 16.31\,\text{kN}.$$

$$Try\ \theta = 70^o: \quad F = \frac{0.75 \times 25}{\cos(70) + 0.75\sin(70)} = 17.91\,\text{kN}.$$

$$Try\ \theta = 65^o: \quad F = \frac{0.75 \times 25}{\cos(65) + 0.75\sin(65)} = 17.00\,\text{kN}.$$

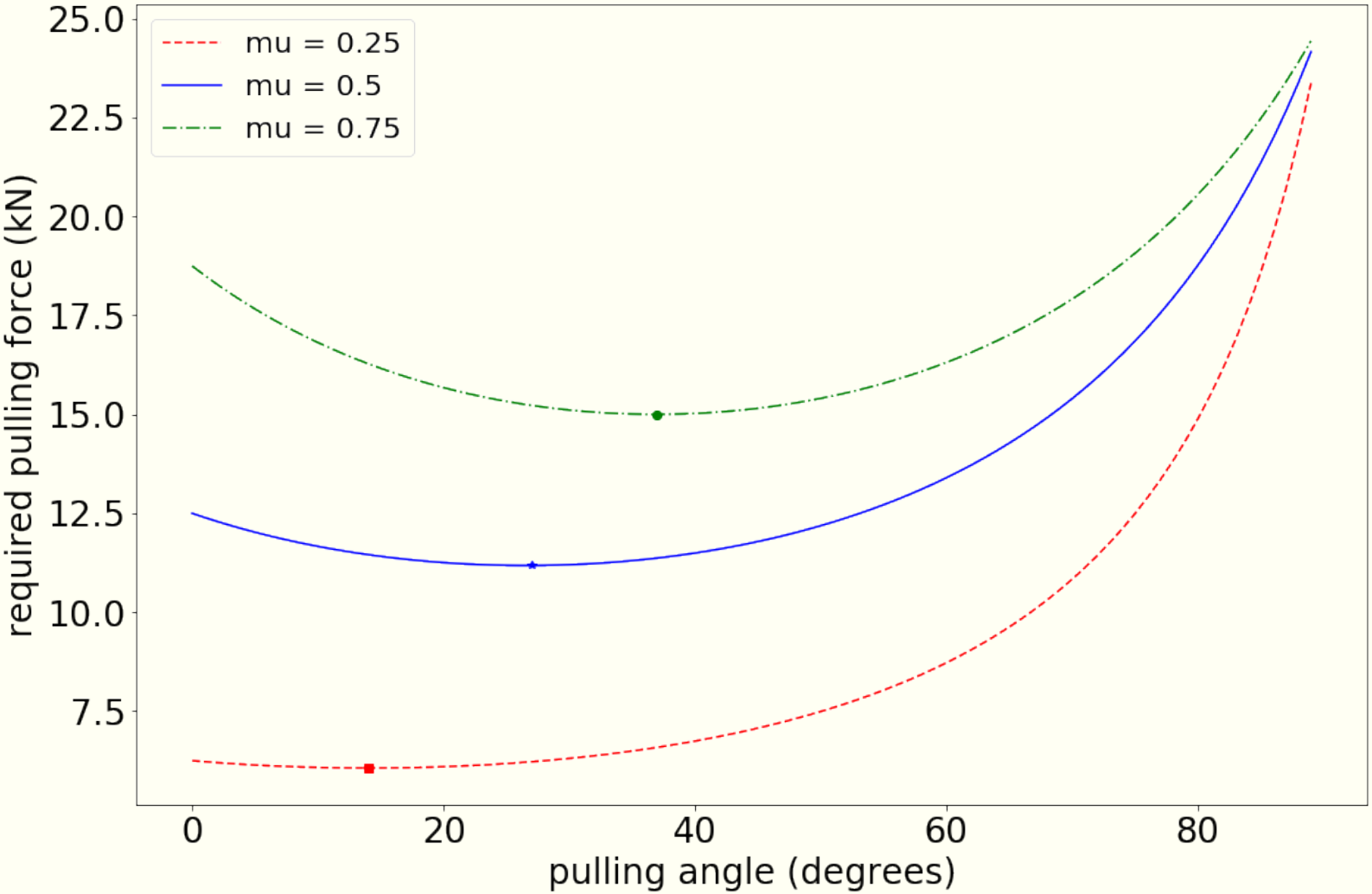
$$Try\ \theta = 67,5^o: \quad F = \frac{0.75 \times 25}{\cos(67.5) + 0.75\sin(67.5)} = 17.43\,\text{kN}.$$

This is **bisection method!**

# What are the characteristics of a numerical solution?

- A numerical recipe is *a sequence of simple steps*
- *Flow of control* as each step is executed.
- Yields an *approximate* numerical answer (a finite number) for the problem
- These solutions can be very accurate
- Most answers are determined in an iterative approach (numerical method: mathematical / computer-aided technique) until a desired minimum/acceptable accuracy is obtained
- Typically, a finite set of iterations (steps) are used in the numerical method to obtain a solution. A means of determining *when to stop*.

# Numerical solution of a sliding block: Friction angles



# Printing to console

To show the output from code to a user `print` command:

```
In [1]: 3+2
Out[1]: 5    "out": interactive shell

In [2]: print(3+2)
        5    "No out": Shown to user
```