MAS.S66
Computational Wireless Sensing

Lecture 8:
Inertial Sensing & Acoustic Attacks

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Lecture Outline

- Logistics update
- Overview of Inertial Sensing
- WALNUT
- BackDoor
- MUTE
- Project meetings

Post-Mid-semester Grade Update

Reminder Re: Grading:

- 1 Course Project (60%)
- 1 Paper Presentation (10%)
- Participation (30%)
  - Includes submitting reviews before every lecture (15%)
  - Attendance is mandatory (15%)
  - May skip one review without affecting grade

Other logistics:

- 17 paper reviews => score = (# full reviews submitted) / 16
  - Get bonus points if you submit all 17

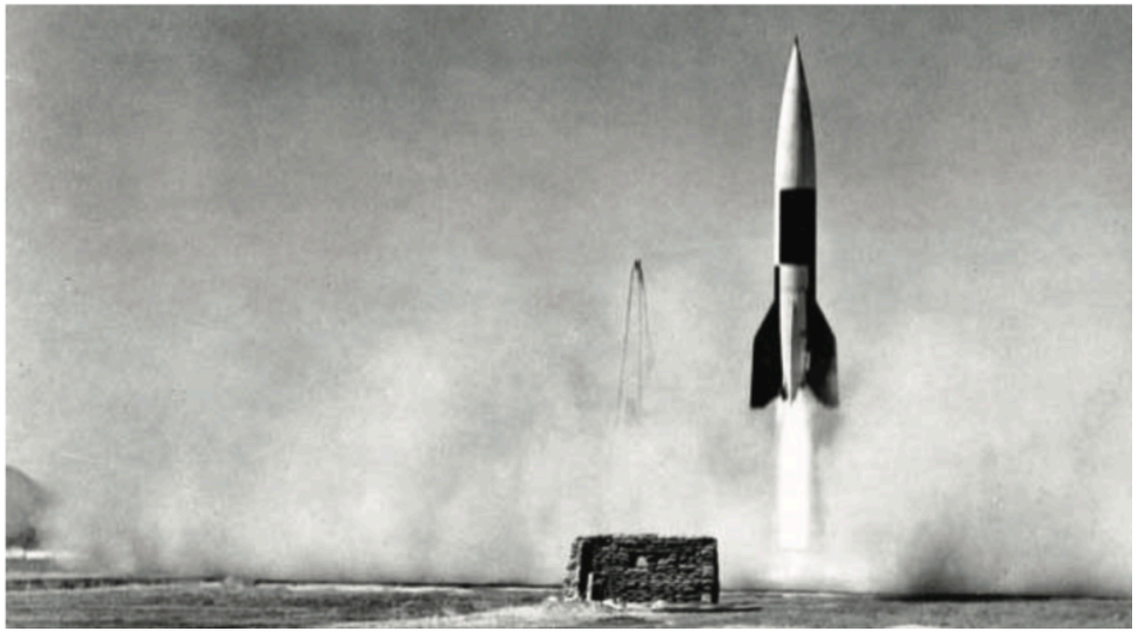
Types of IMUs?

- **Gyroscope** measures angular velocity **ω** in degrees/s
- **Accelerometer** measures linear acceleration **a** in m/s^2
- **Magnetometer** measures magnetic field strength **m** in μT (micro-Teslas).

Why is it called IMU?

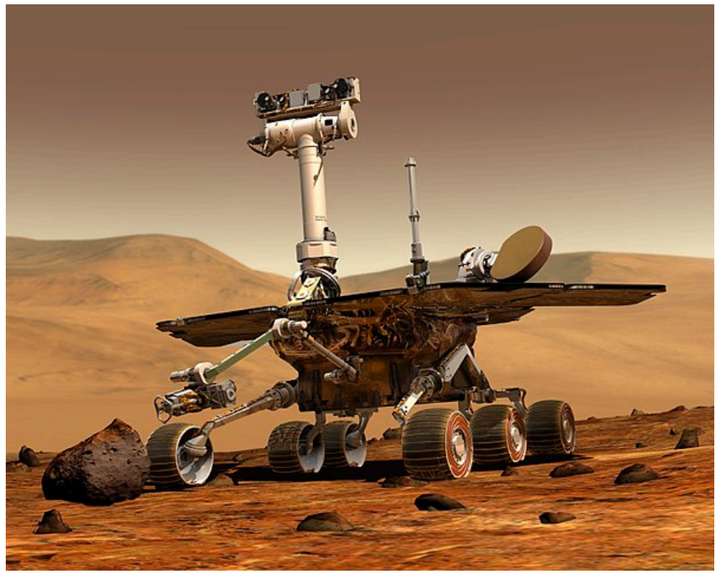
History of IMUs

- Earliest use of gyroscopes goes back to German ballistic missiles (V-2 rocket) in WW2 for stability



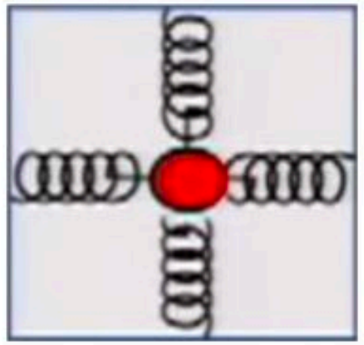
- In the 1950s, MIT played a central role in the development of IMUs (Instrumentation Lab)

Uses/Applications of IMUs?



How Accelerometers Work

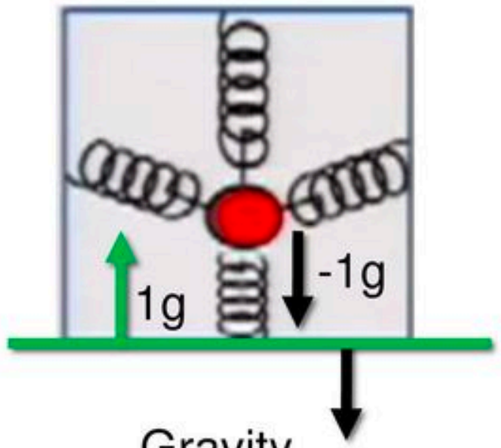
Mass on spring



How does it deform at rest?

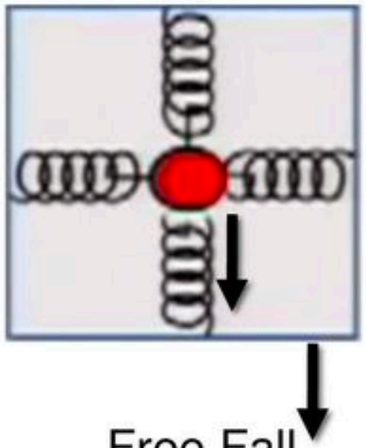
Free fall?

Linear acc in x direction?

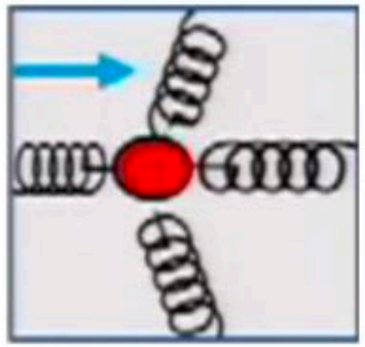


Gravity

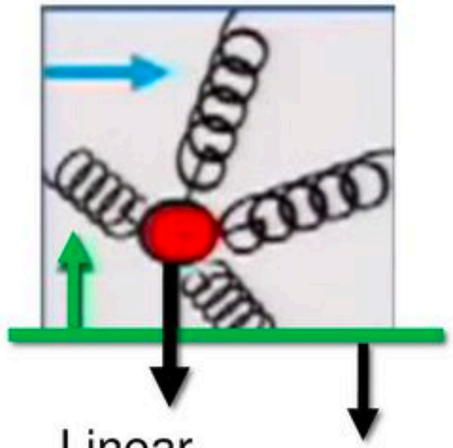
$1g = 9.8m/s^2$



Free Fall

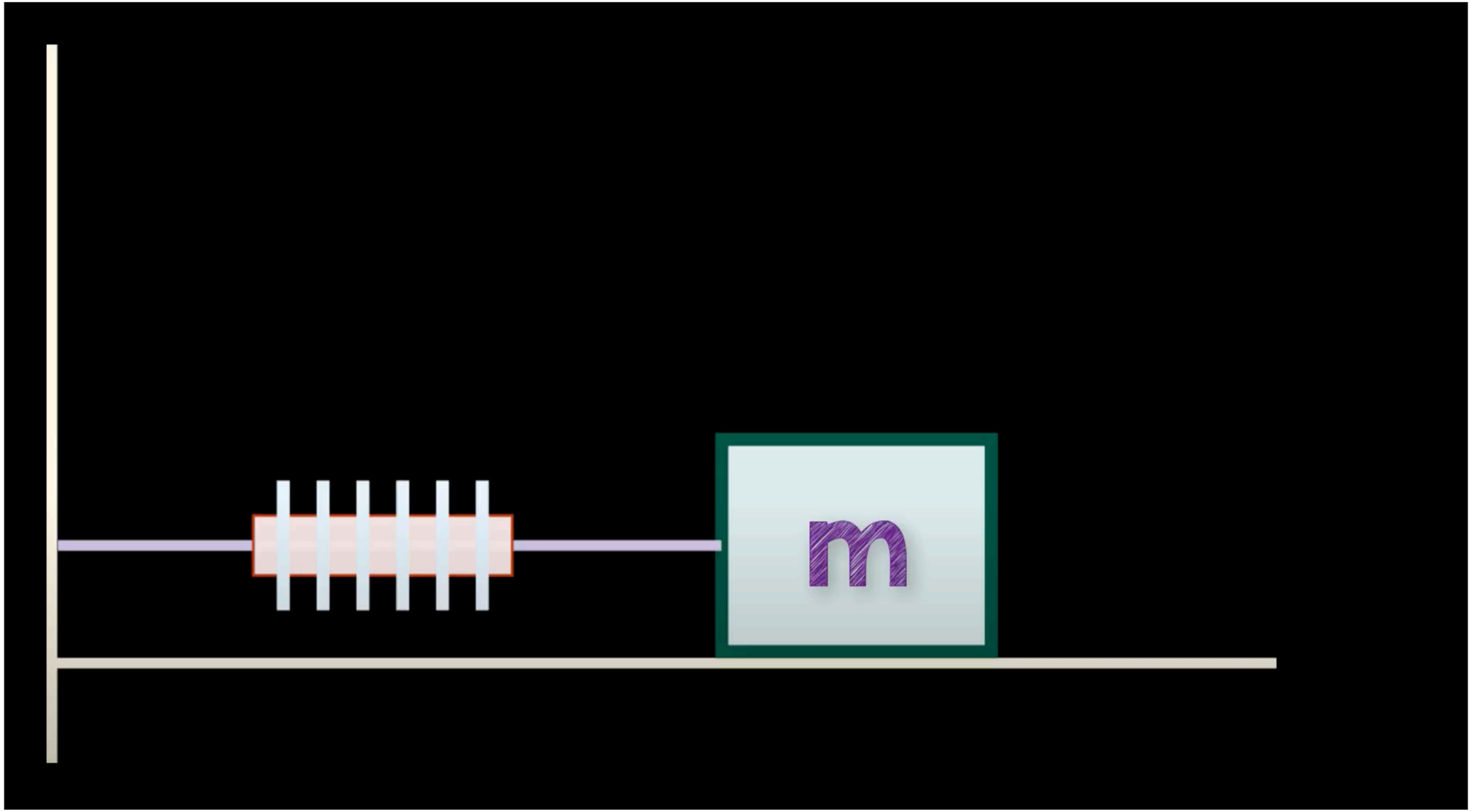


Linear Acceleration

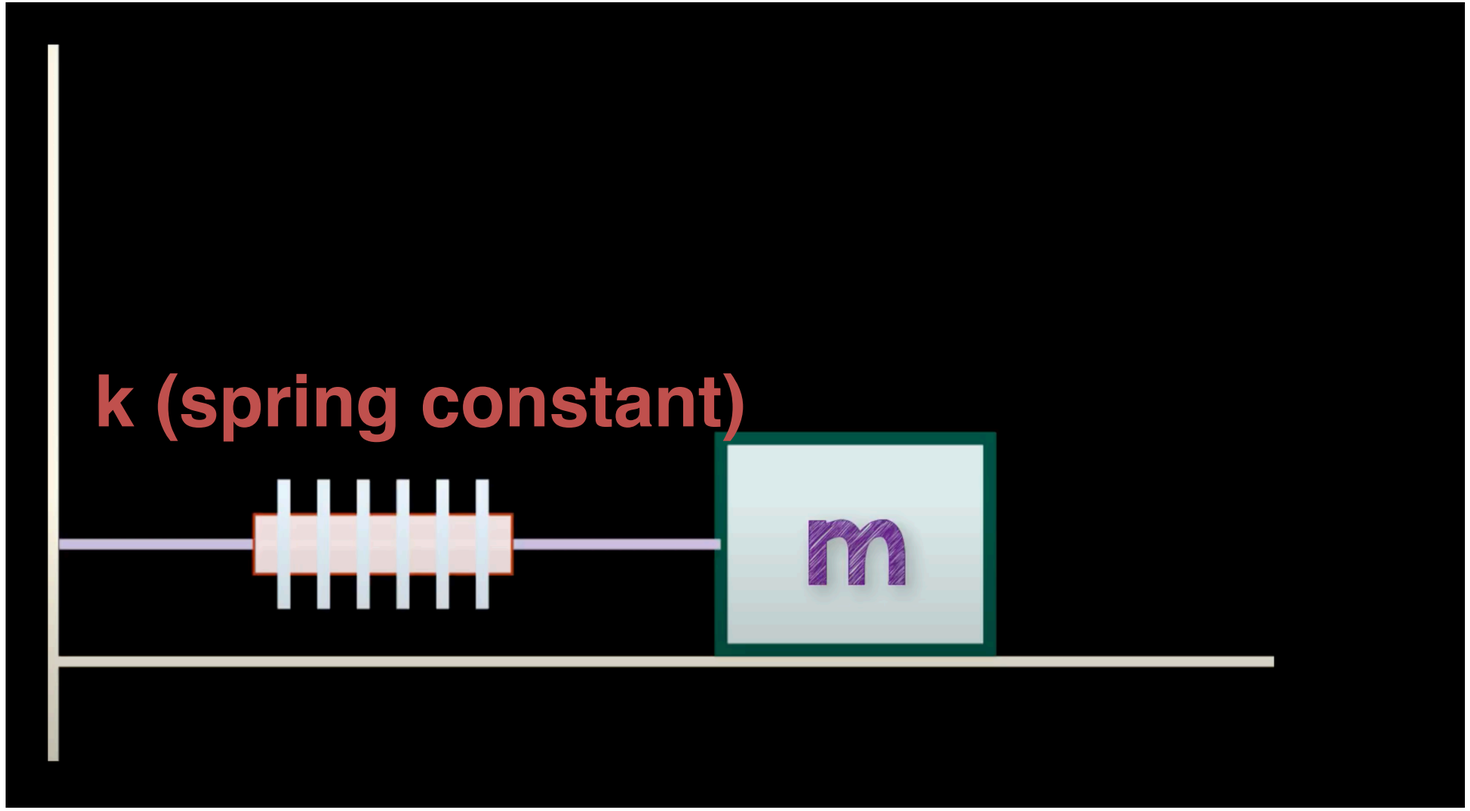


Linear Acceleration plus gravity

How Accelerometers Work



What matters is the displacement



Hook's Law

$$F = kx$$

Newton's Law

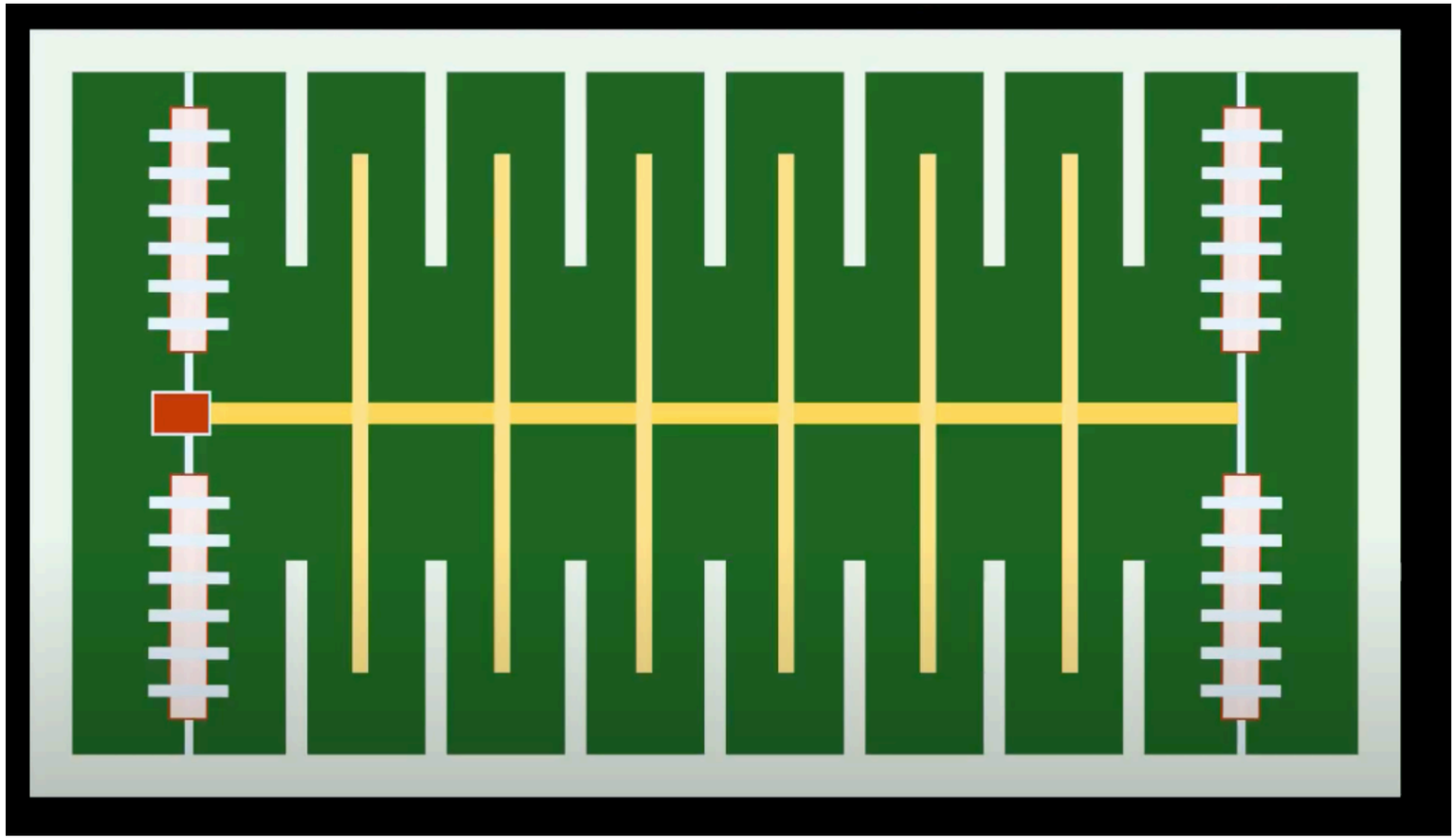
$$F = ma$$

$$=> a = \frac{k}{m}x$$

Why not simply use displacement to measure displacement?

Measuring Displacement

- How do we measure displacement?
- Most common approach is to use capacitance and MEMS (Micro electro-mechanical systems)



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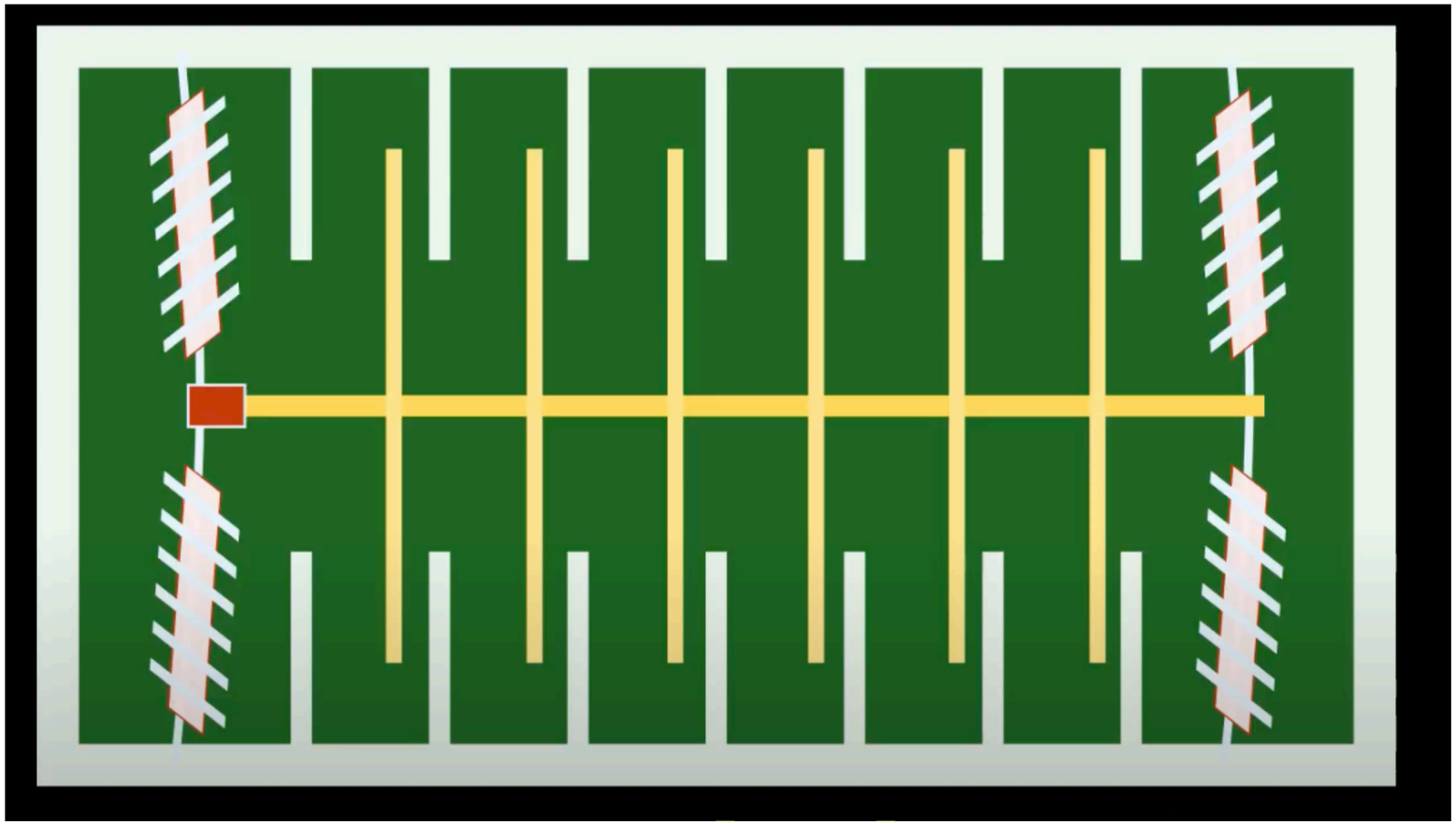
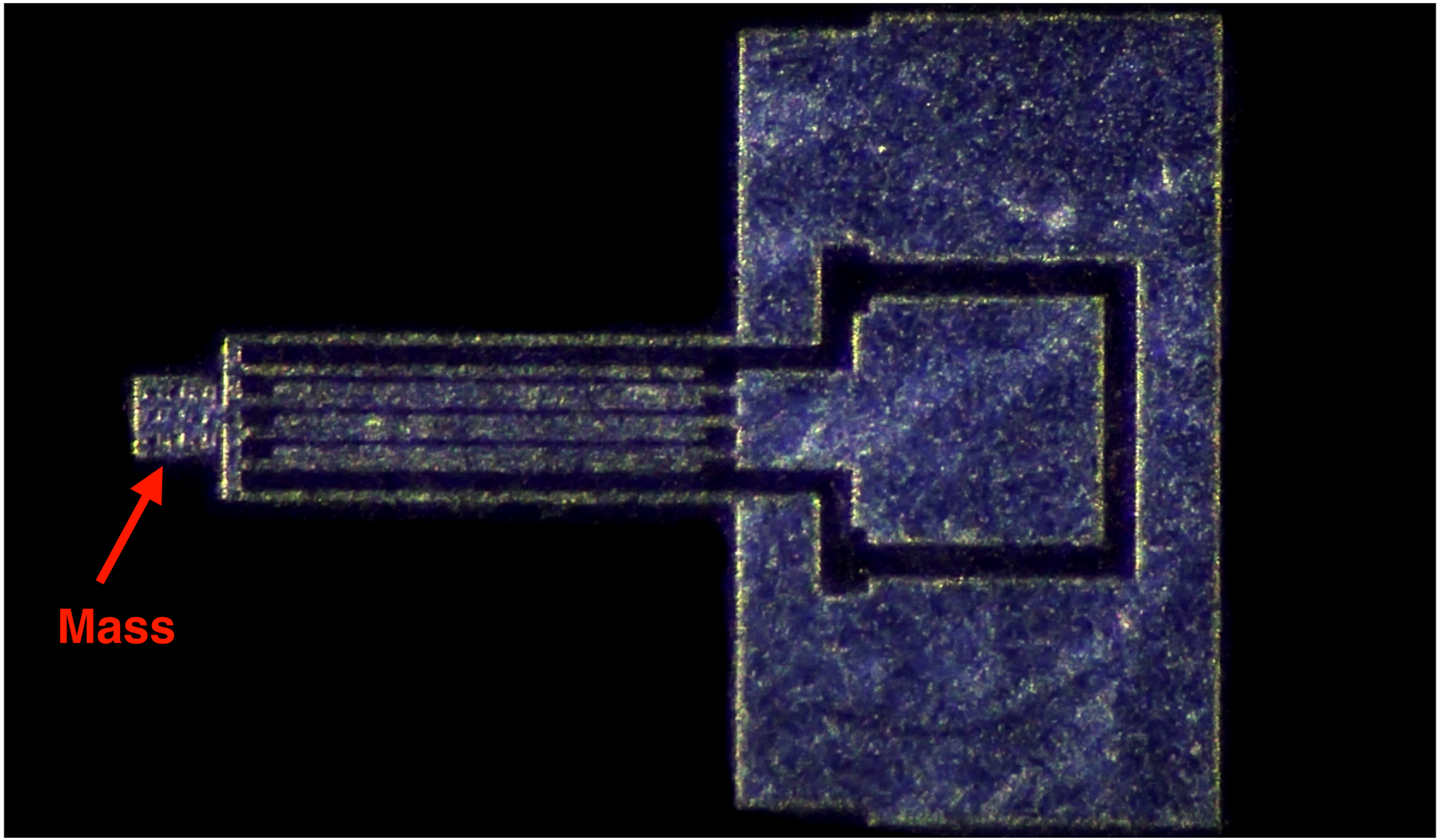
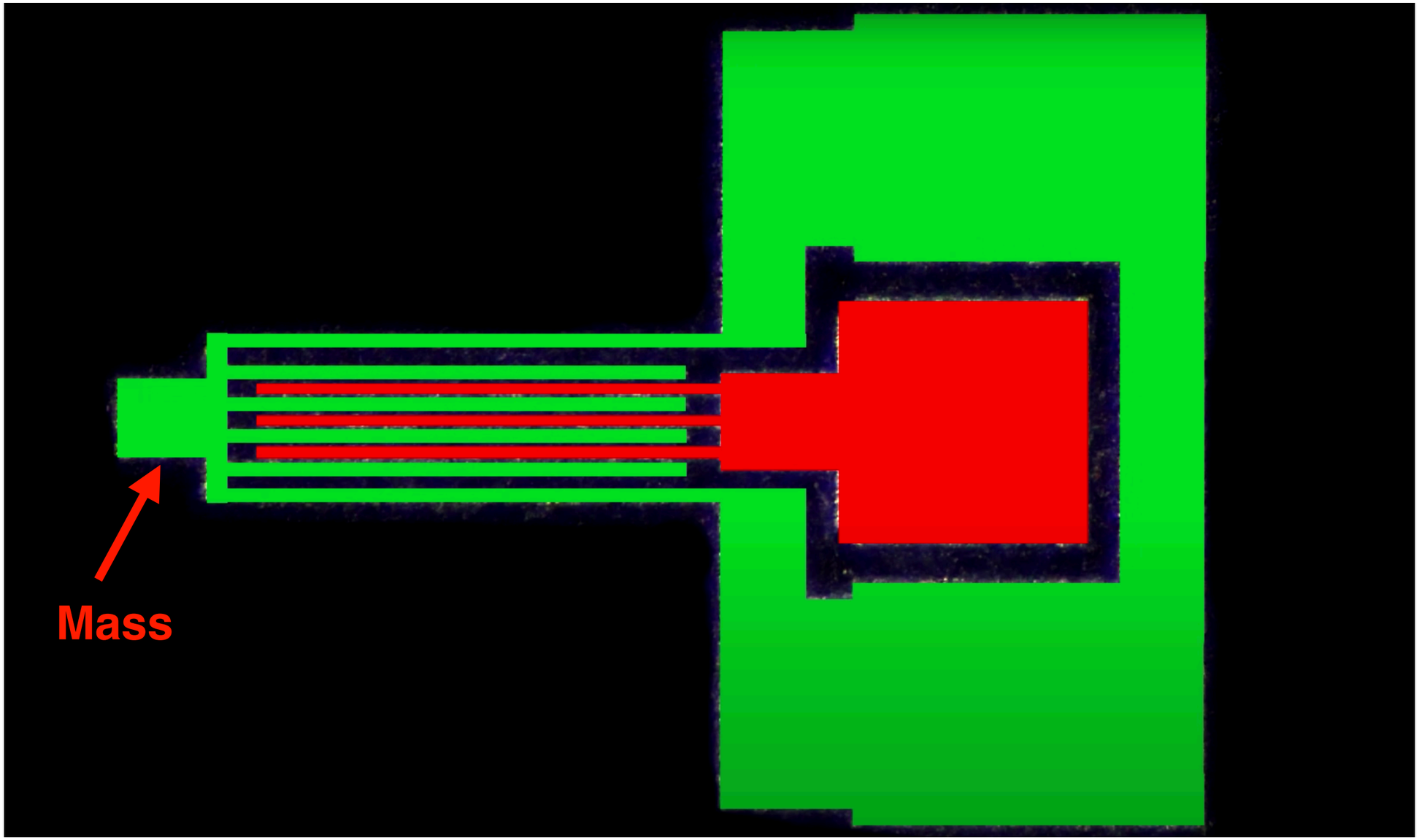
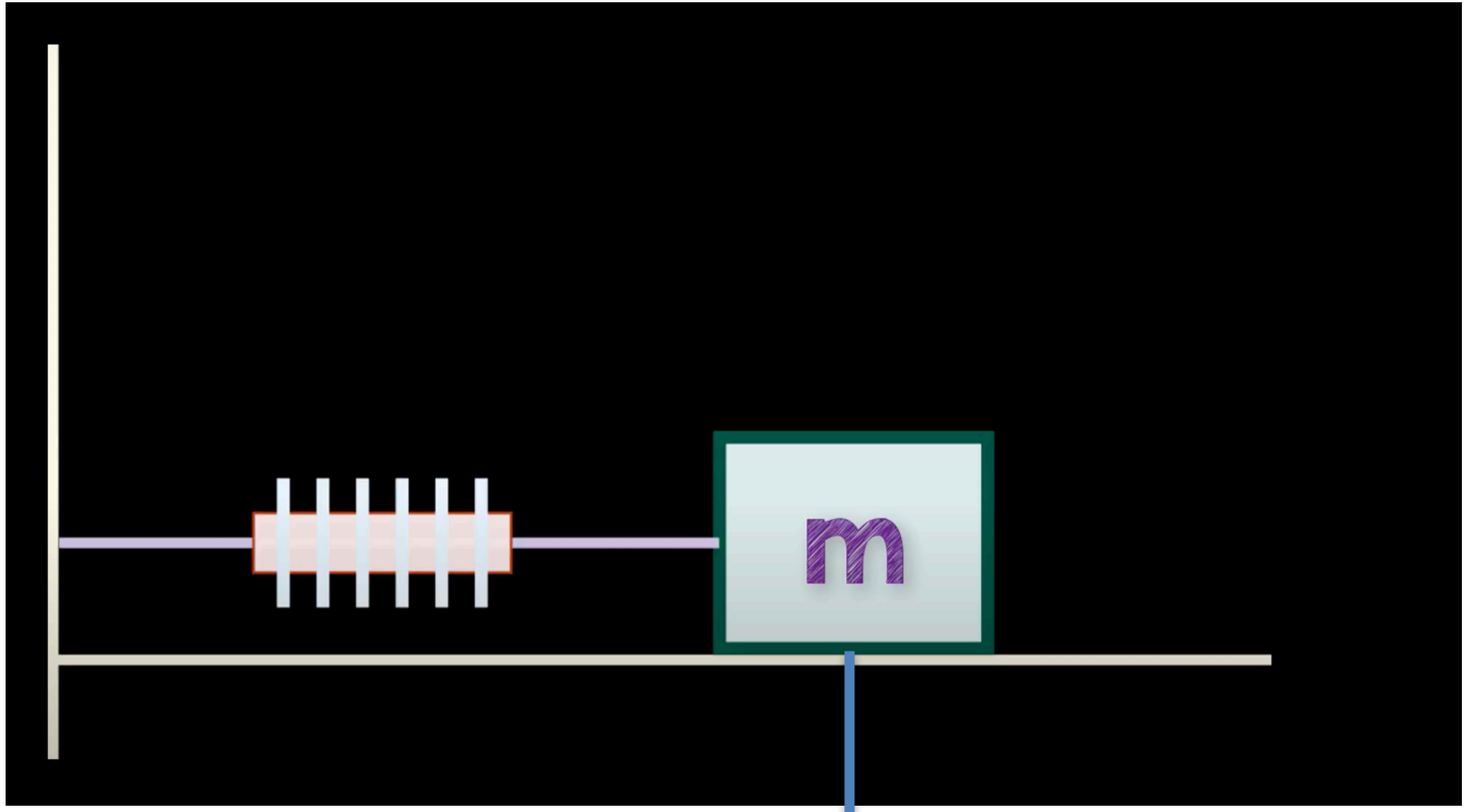


MEMS Accelerometer

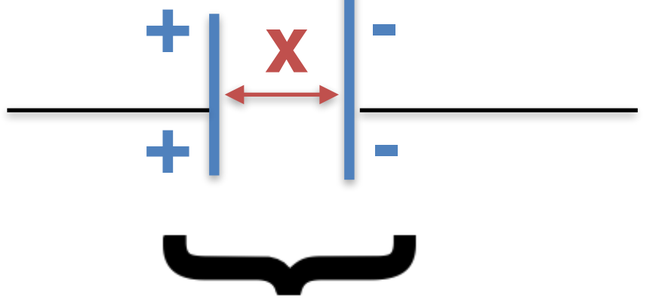


MEMS Accelerometer



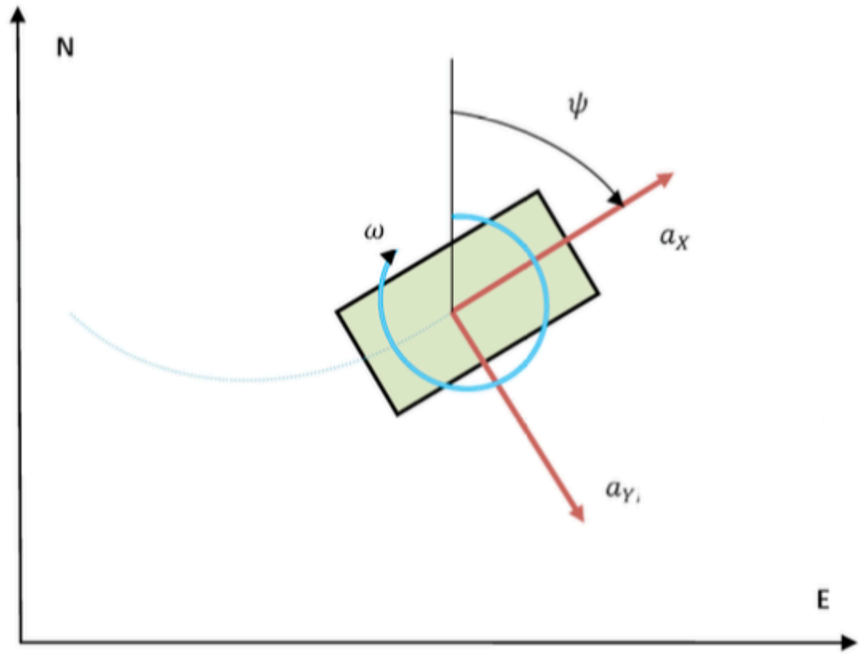


Capacitor



$$C = \epsilon \frac{Area}{x}$$

2D Inertial Navigation in Strapdown System



$$\begin{bmatrix} a_N \\ a_E \end{bmatrix} = \begin{bmatrix} cos\psi & -sin\psi \\ sin\psi & cos\psi \end{bmatrix} \begin{bmatrix} a_X \\ a_Y \end{bmatrix}$$

Source: Basic Principles of Inertial Navigation
Seminar on inertial navigation systems
Tampere University of Technology

2D Inertial Navigation in Strapdown System

$$\begin{bmatrix} a_N \\ a_E \end{bmatrix} = \begin{bmatrix} cos\psi & -sin\psi \\ sin\psi & cos\psi \end{bmatrix} \begin{bmatrix} a_X \\ a_Y \end{bmatrix}$$

$$V_N(t) = V_N(t_0) + \int_{t_0}^{t} a_N(t)dt \qquad X_N(t) = X_N(t_0) + \int_{t_0}^{t} V_N(t)dt$$

$$V_E(t) = V_E(t_0) + \int_{t_0}^{t} a_E(t)dt \qquad X_E(t) = X_E(t_0) + \int_{t_0}^{t} V_E(t)dt$$