Magneto: Joint Angle Analysis Using an Electromagnet-Based Sensing Method

Amanda Watson*, Andrew Lyubovsky+, Kenneth Koltermann+, Gang Zhou+

*University of Pennsylvania

+William and Mary

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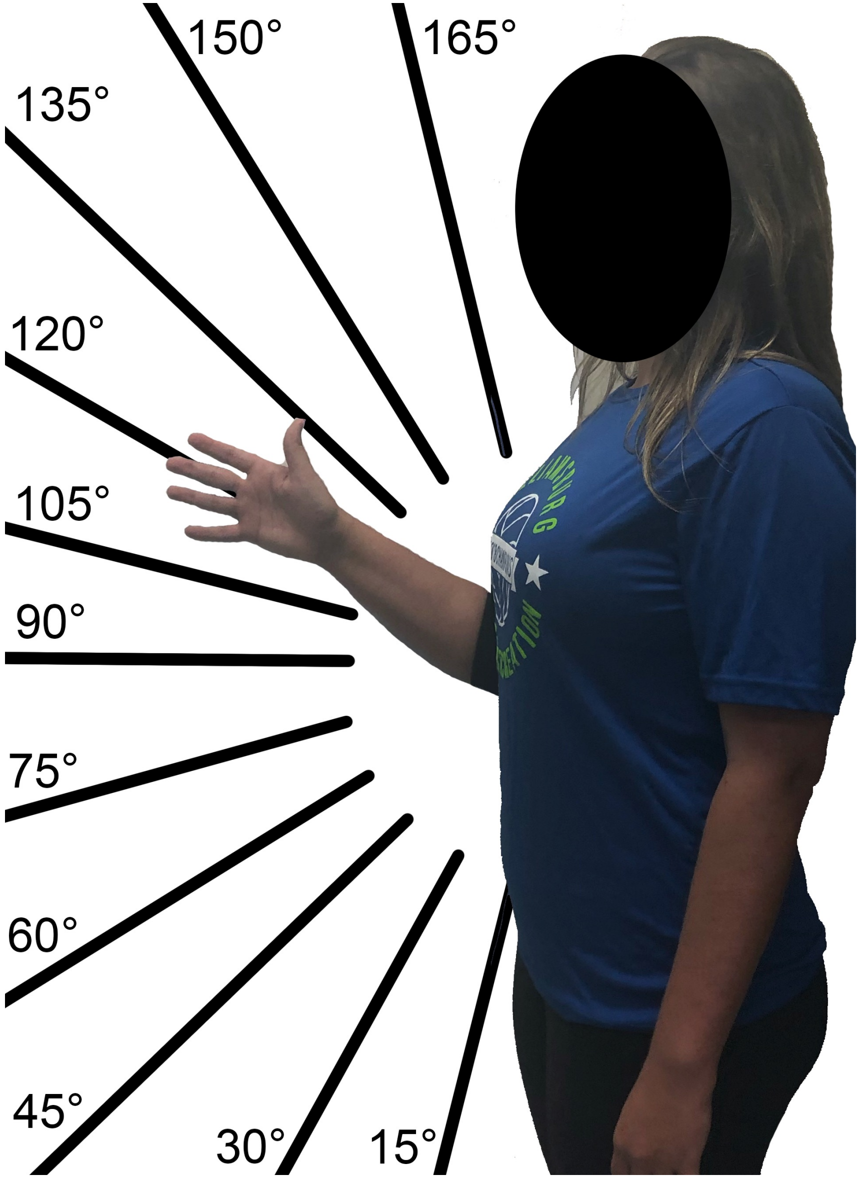
PRECISE

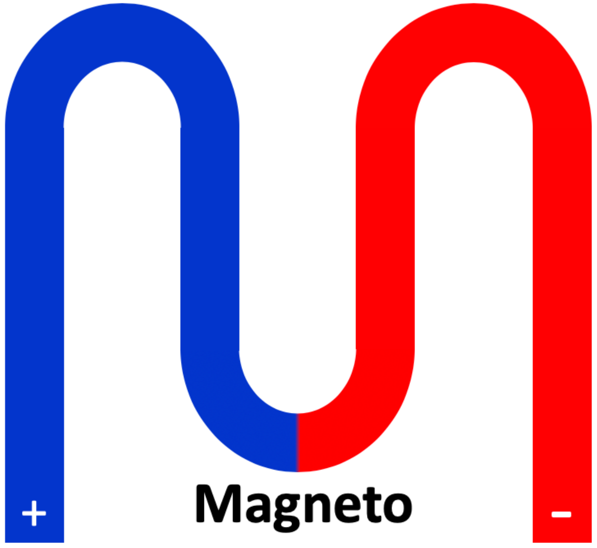
Introduction

- Knowledge of joint angles is used for:
  - Preventing injuries
  - Decreasing rehabilitation time
  - Accurate activity monitoring
- Wearable sensors are commonly used for monitoring joint angles since they are directly worn on the body



Challenges

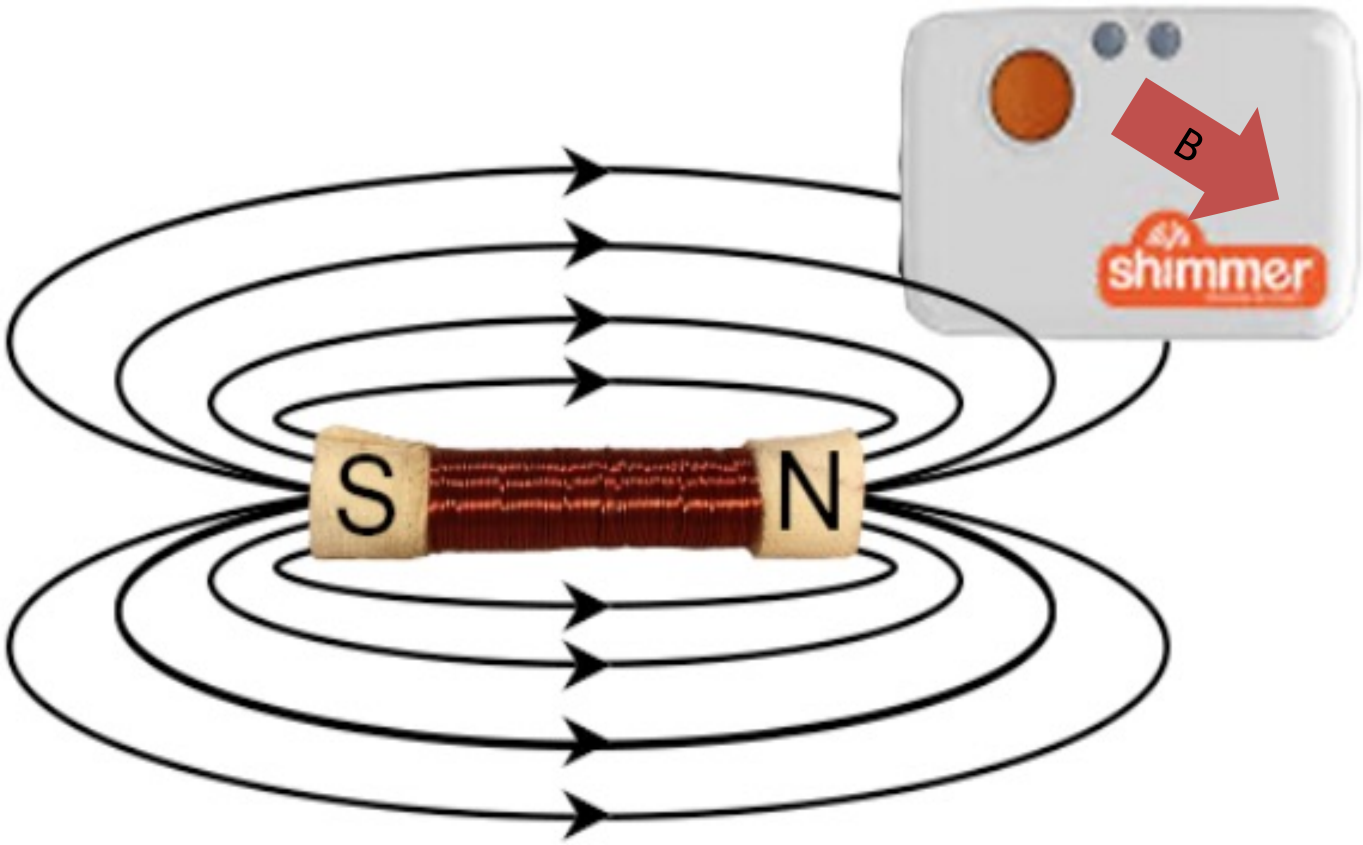
- We want to design a wearable sensor that is:
  - Affordable
  - Low Power
  - Widely Available
  - Allows for Sensing of Joint Angles
- Magnetic field sensors - When combined with magnets, they allow smaller scale sensing, and can be used for joint angle tracking



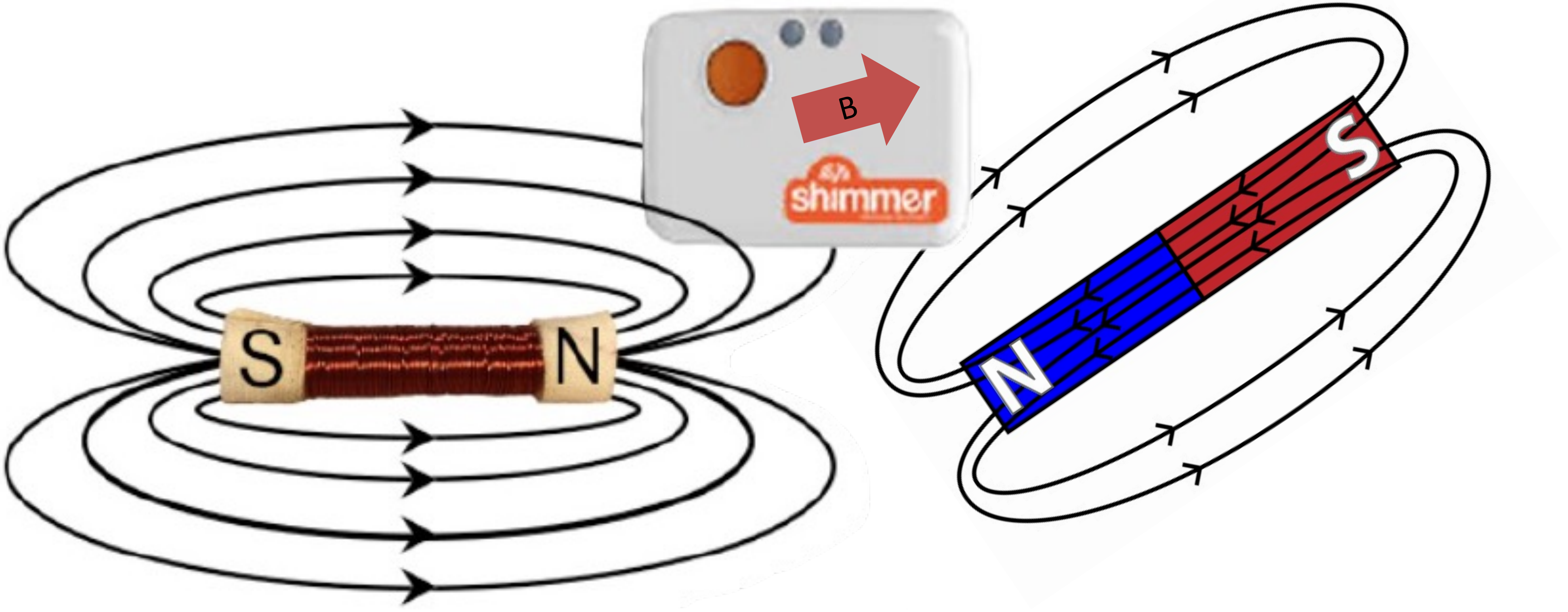
Outline

- Introduction
- Magneto Hardware
- Elimination of Environmental Interference
- Localization of the Electromagnet
- Elbow Flexion Angle Pilot Study
- Future Work
- Conclusion

Magnetic Sensing



Magnetic Sensing



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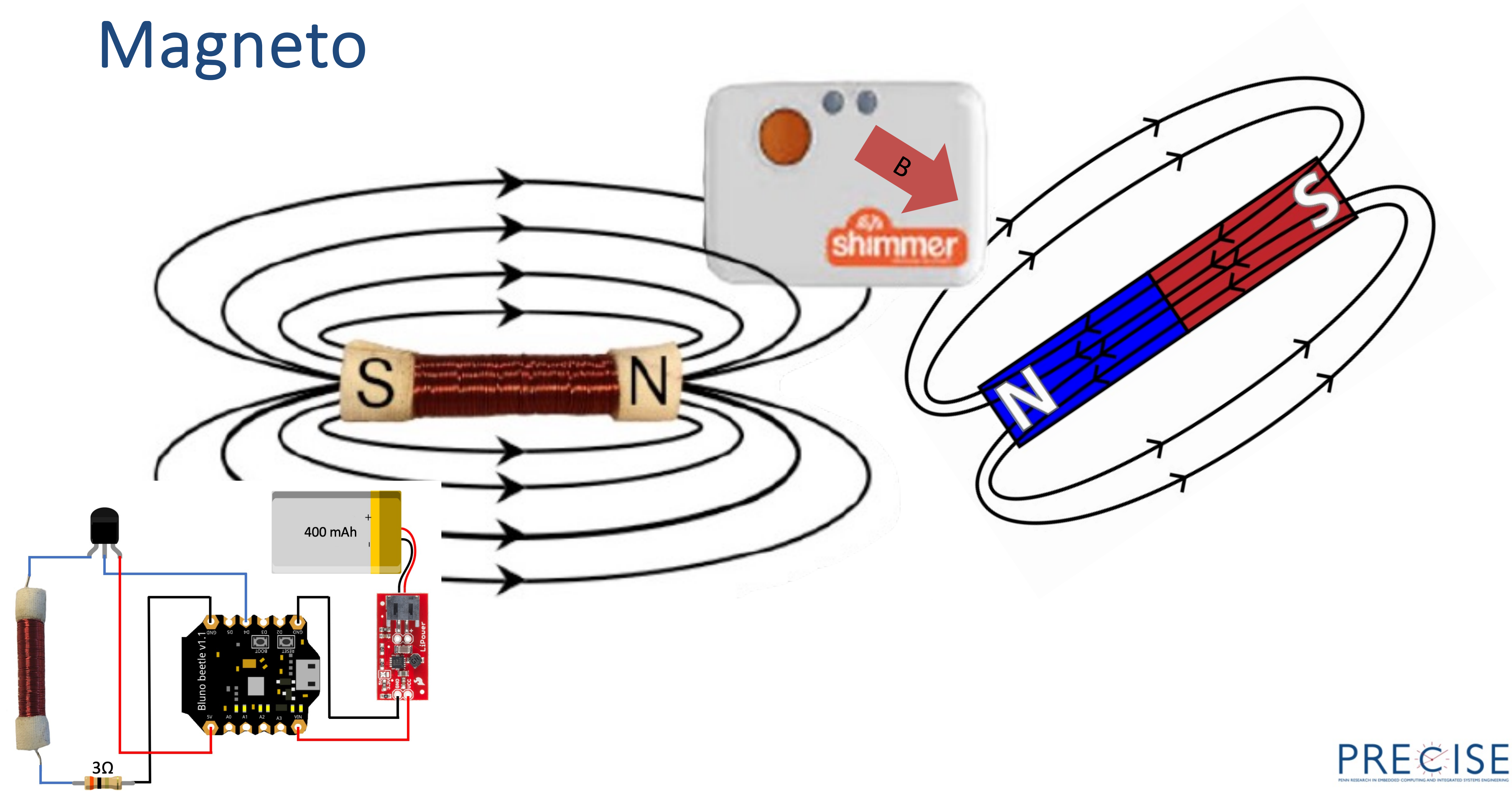
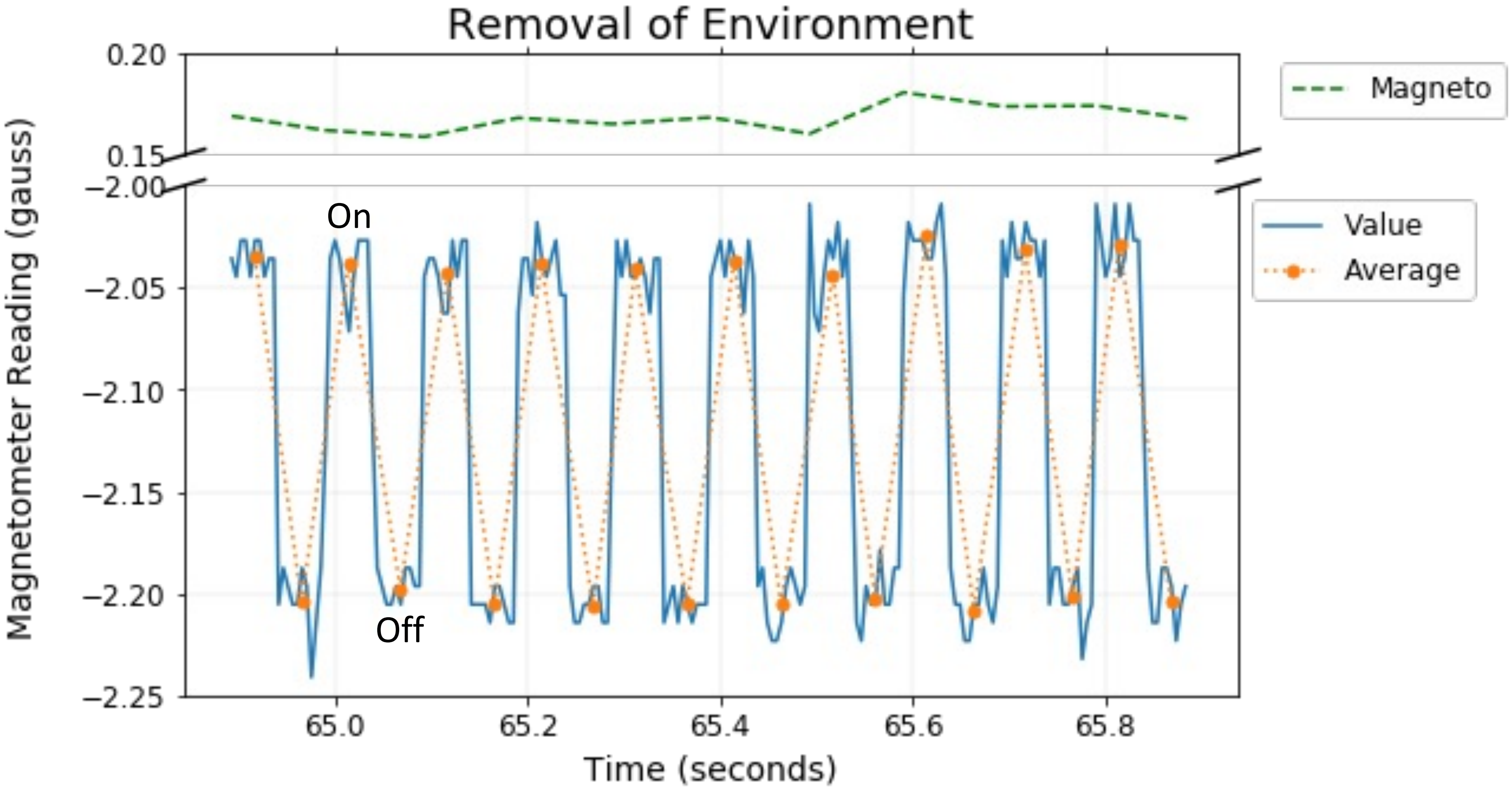
Magneto



Environment-less Sensing



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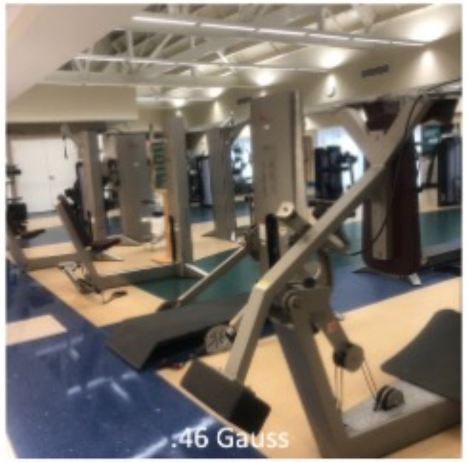
Evaluation

(a) Outside

(b) Lab

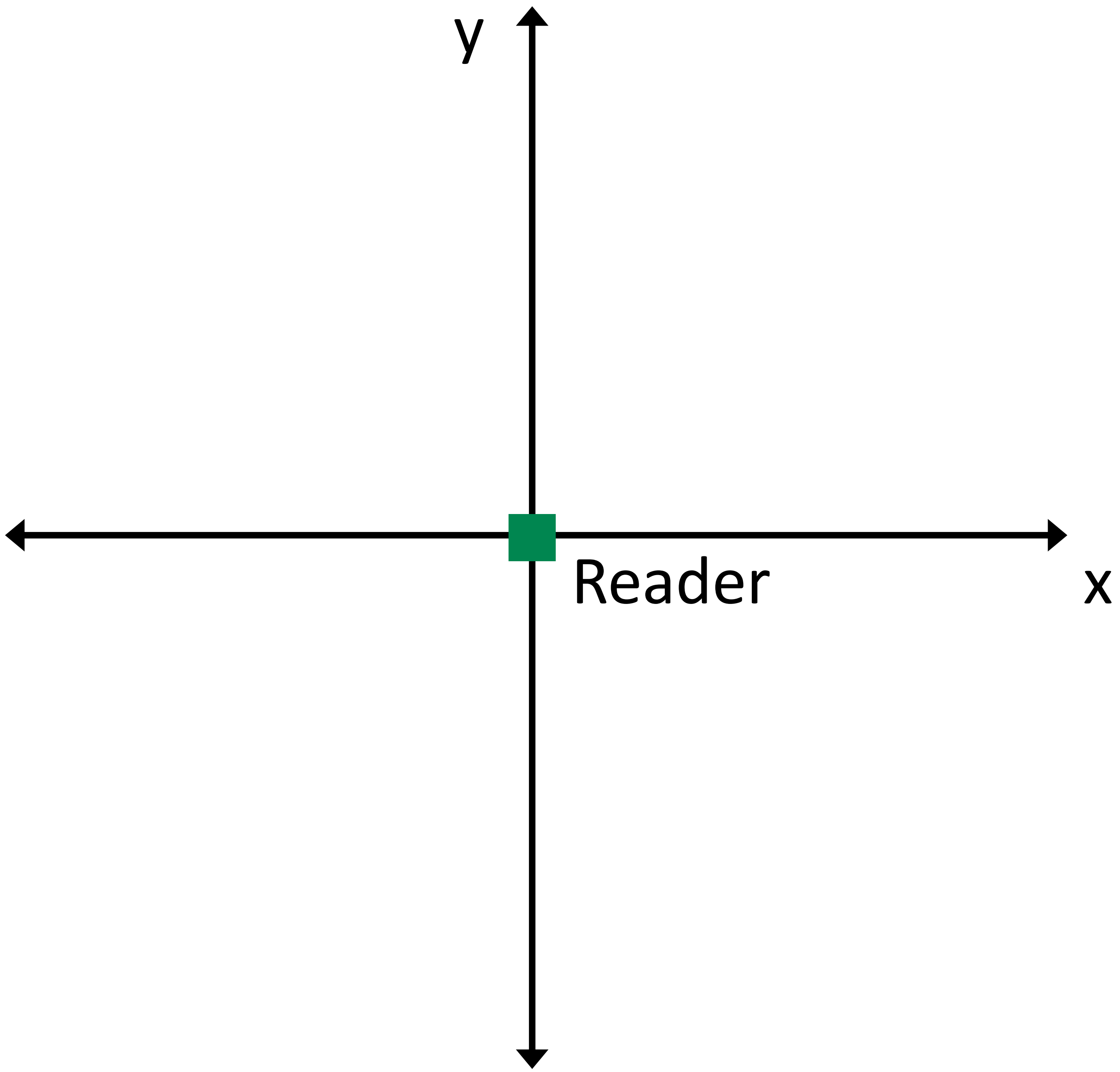


(c) Gymnasium

(d) Hallway

(e) Stairwell

(f) Elevator



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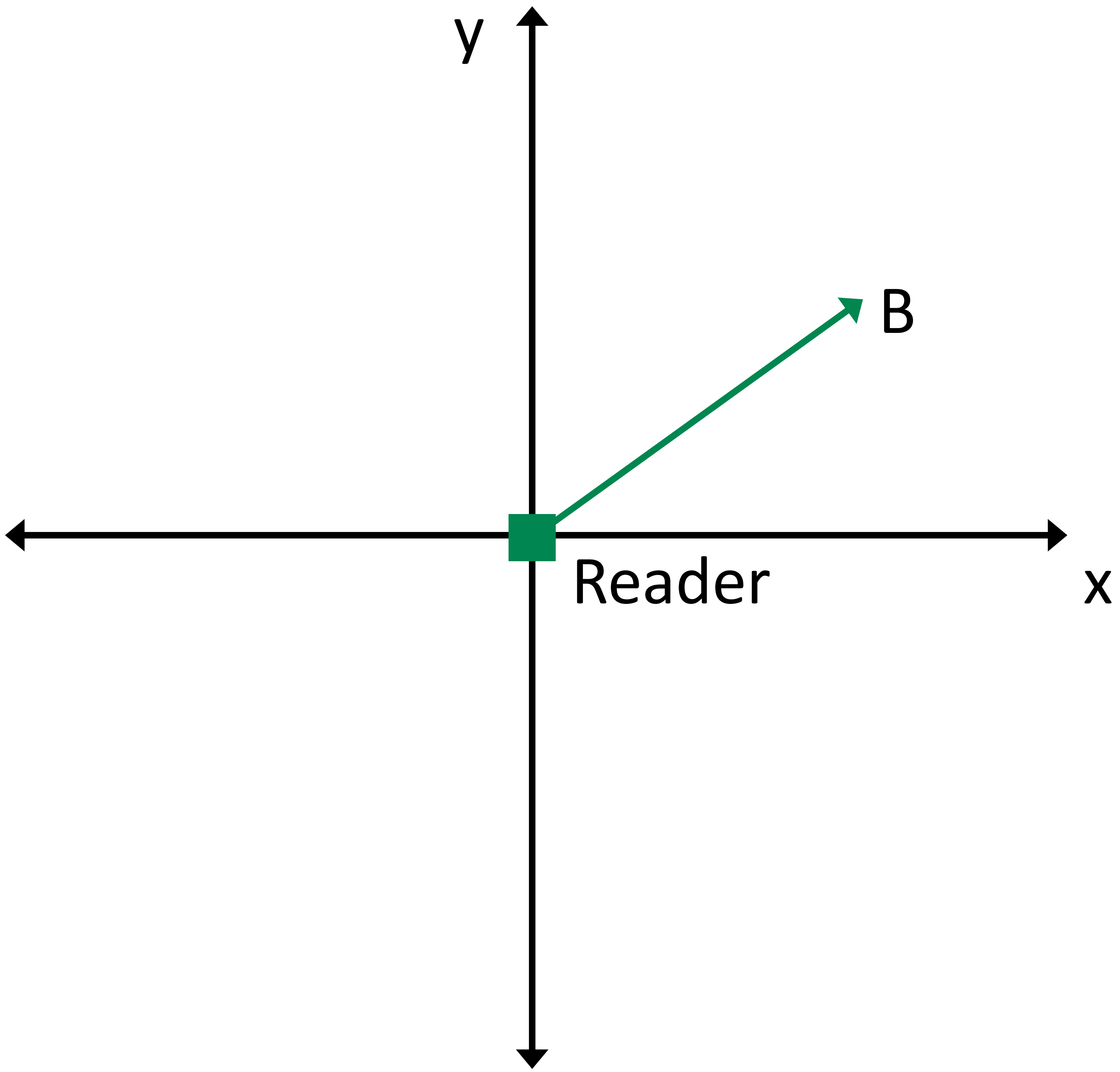
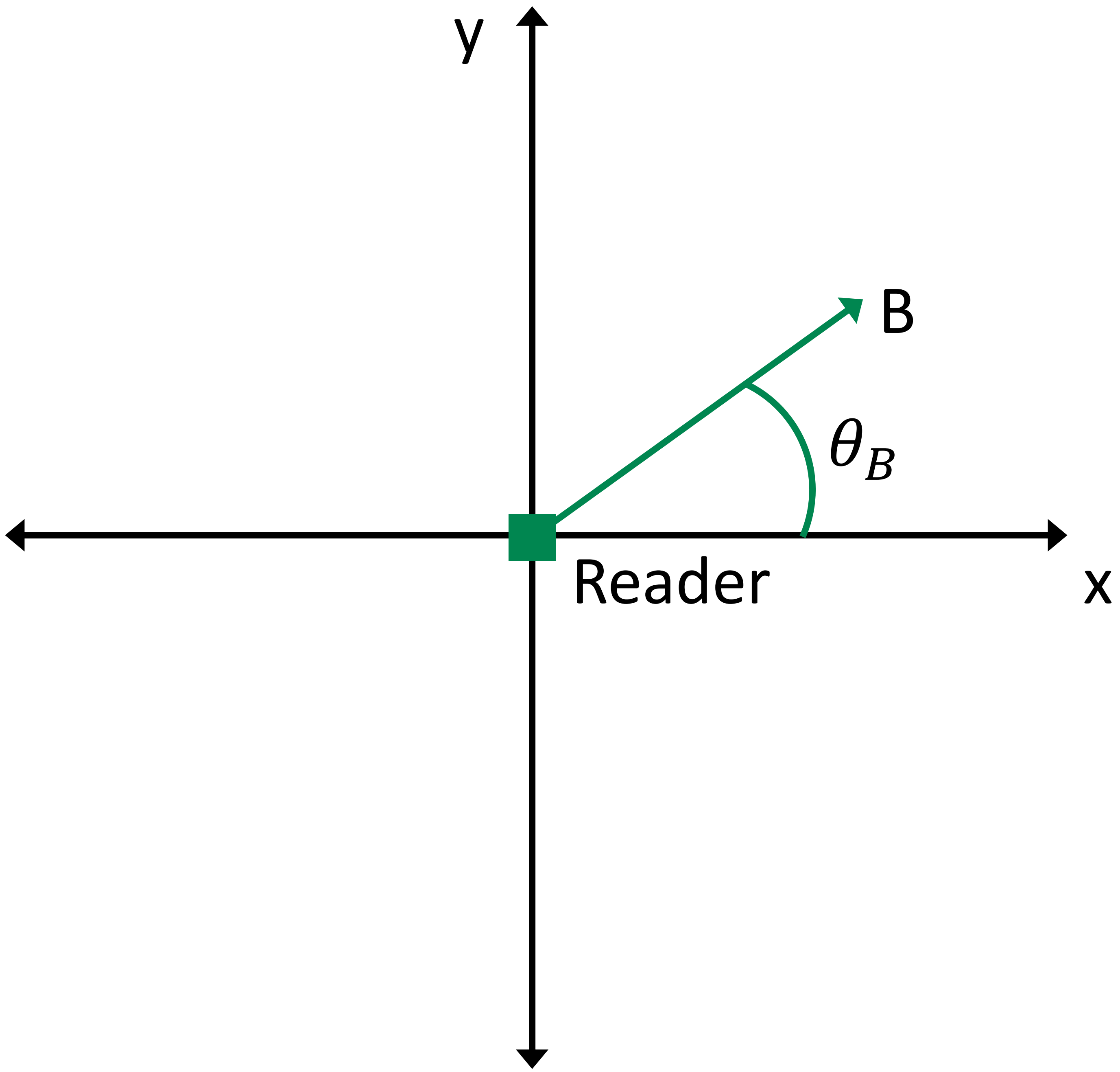
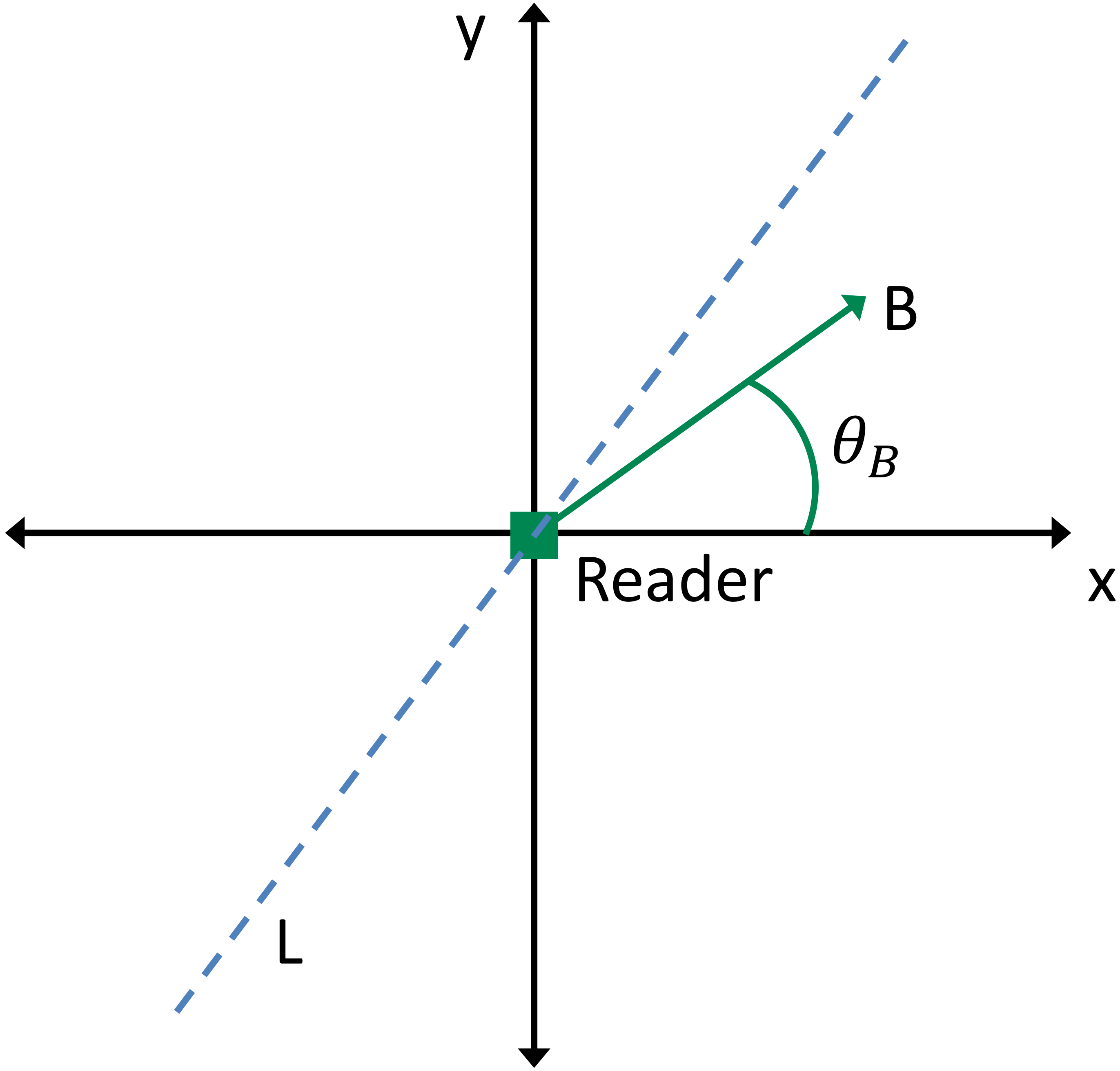
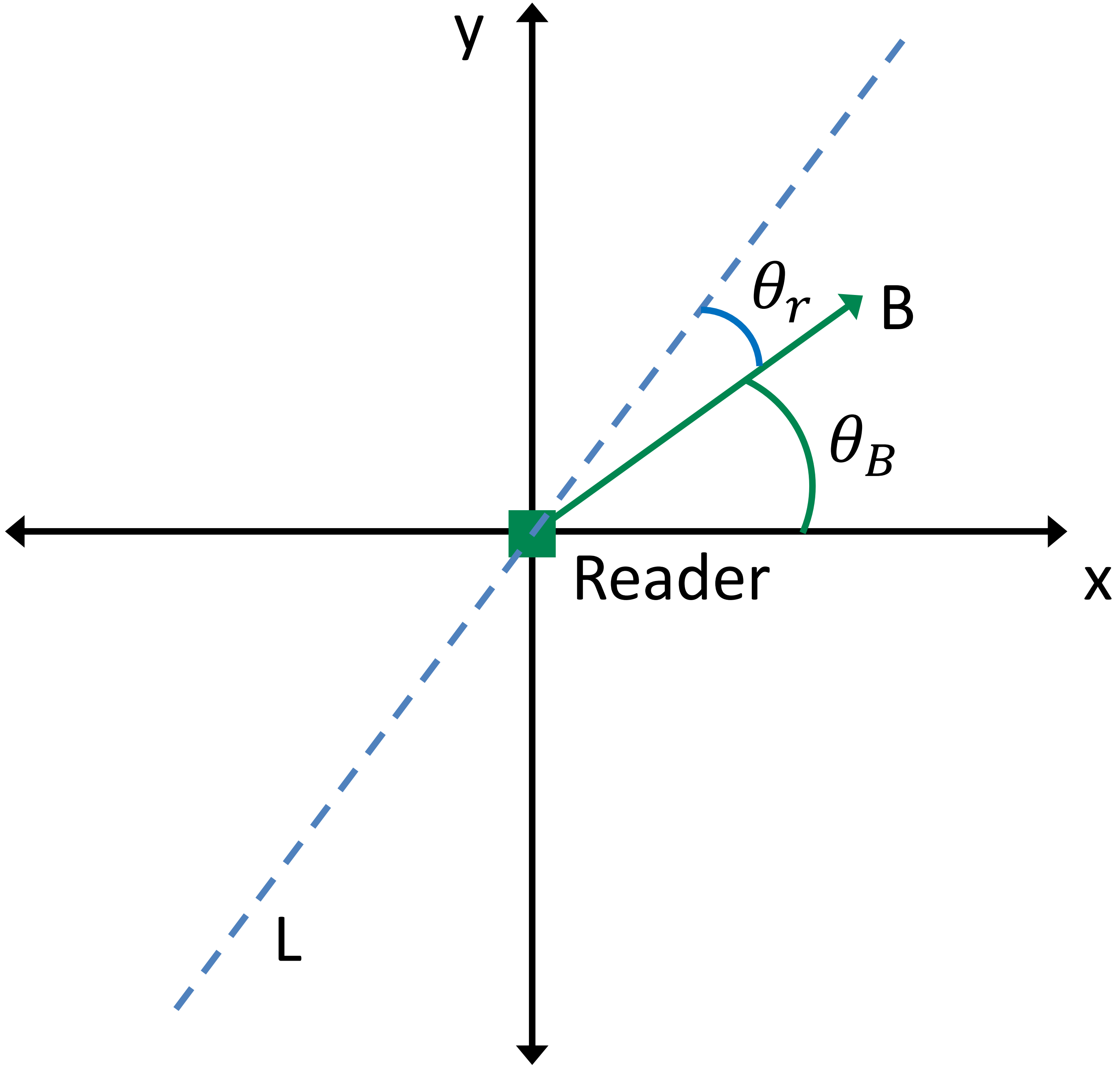
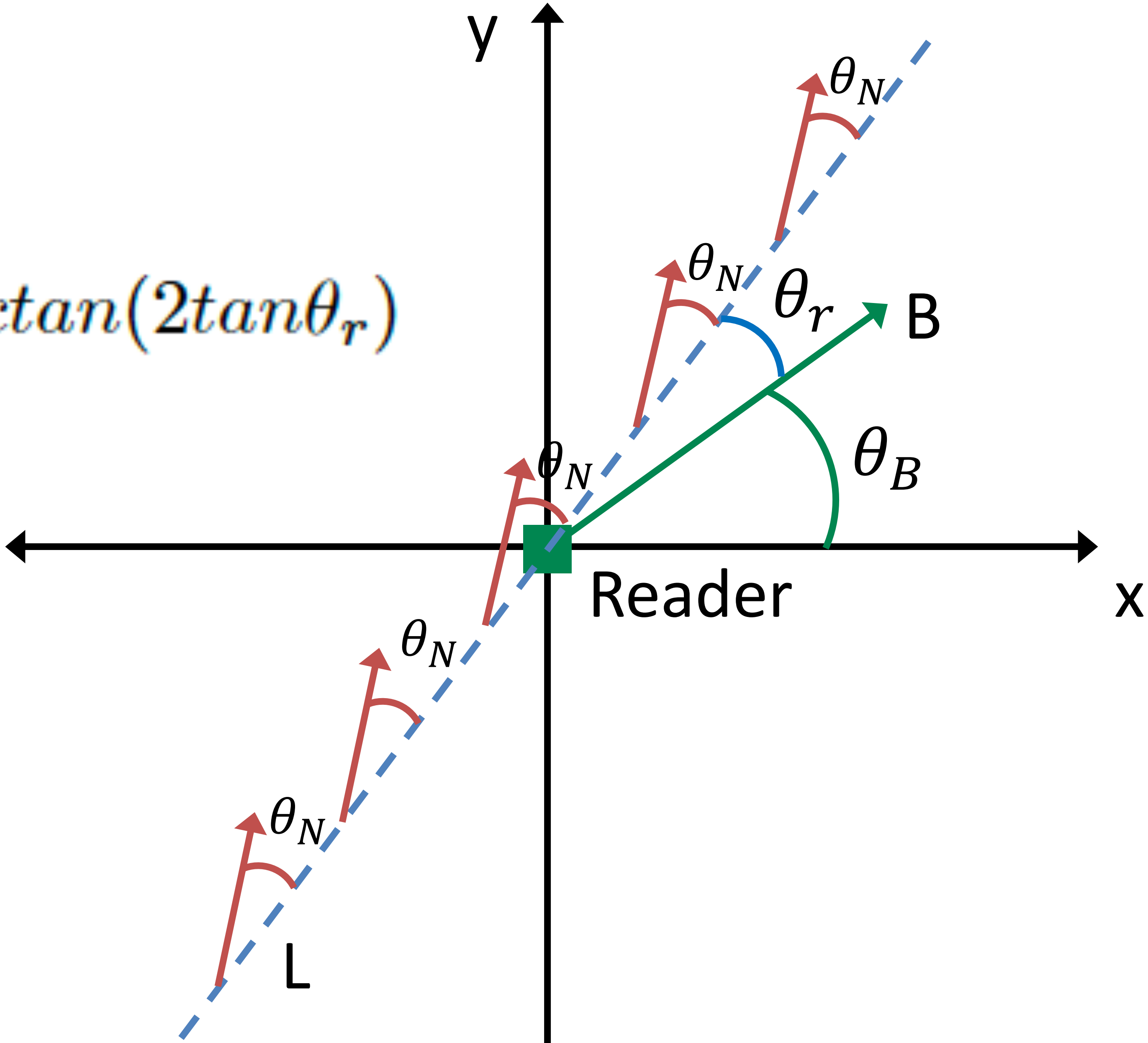

y
B
Reader
x


y
B
θ_B
Reader
x

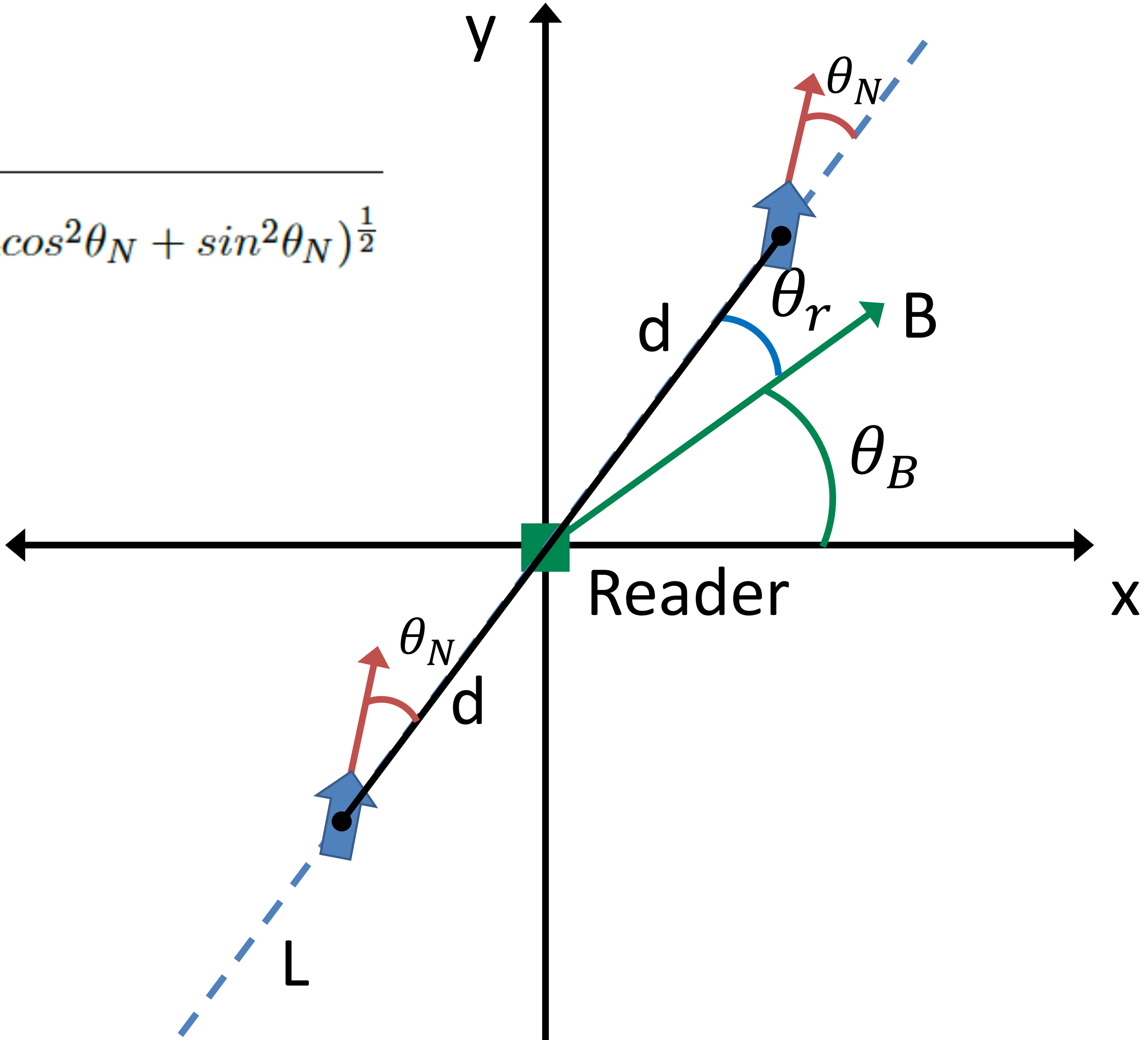

y
B
θ_B
Reader
x
L

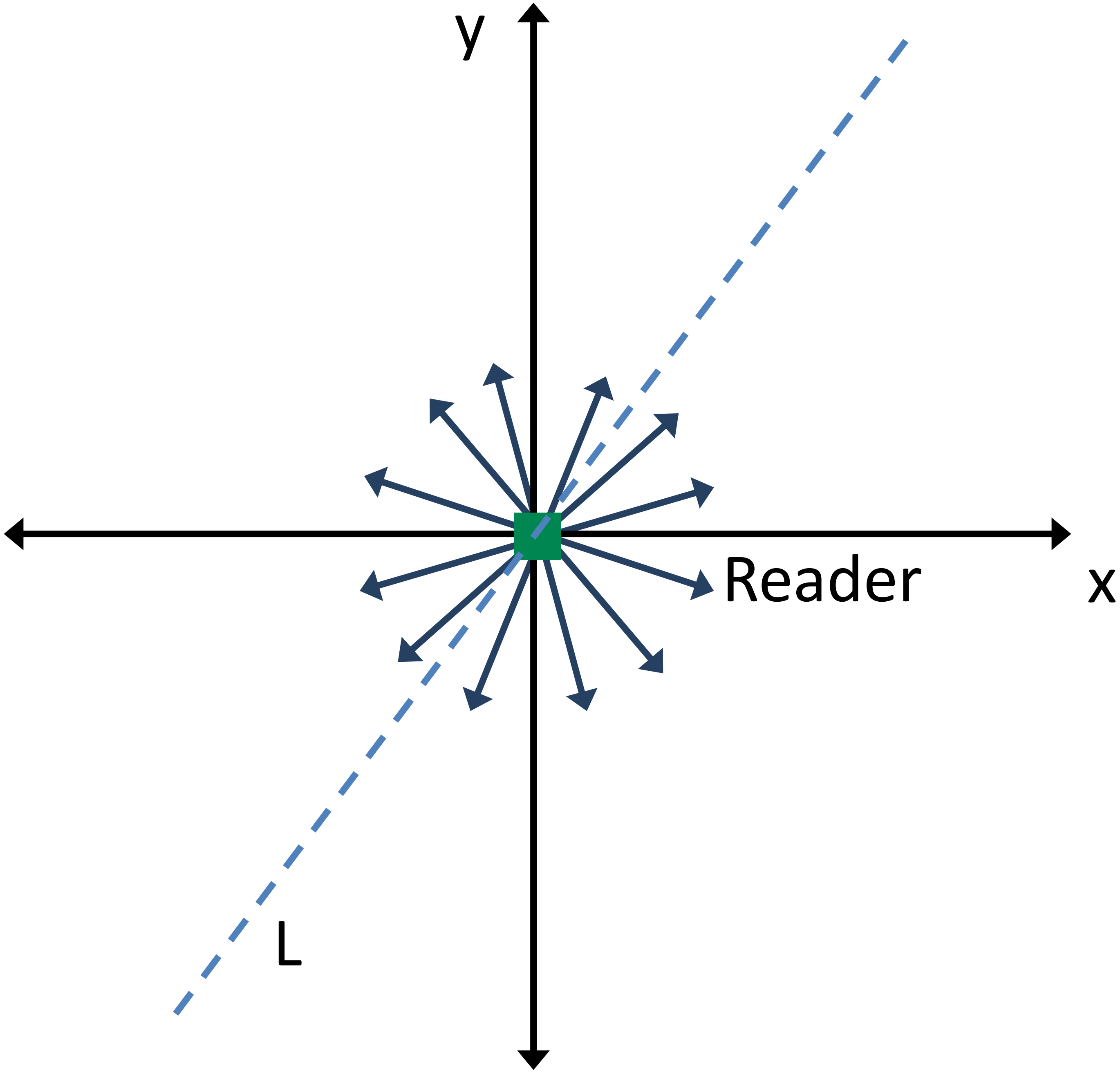

y
θ_r
B
θ_B
Reader
x
L

$$\theta_N = arctan(2tan\theta_r)$$



$$d = \sqrt[3]{\frac{\mu_0|m|}{4\pi|B|}(4cos^2\theta_N + sin^2\theta_N)^{\frac{1}{2}}}$$





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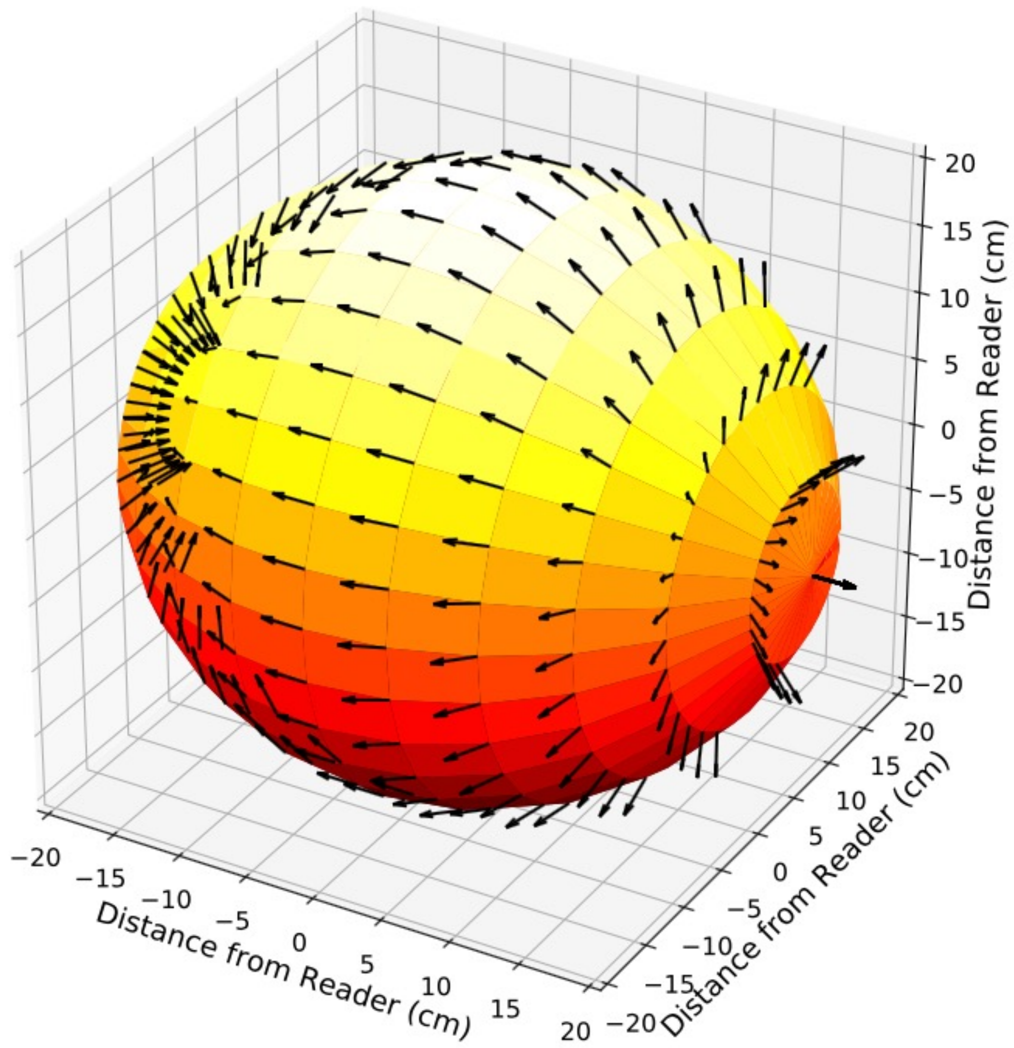
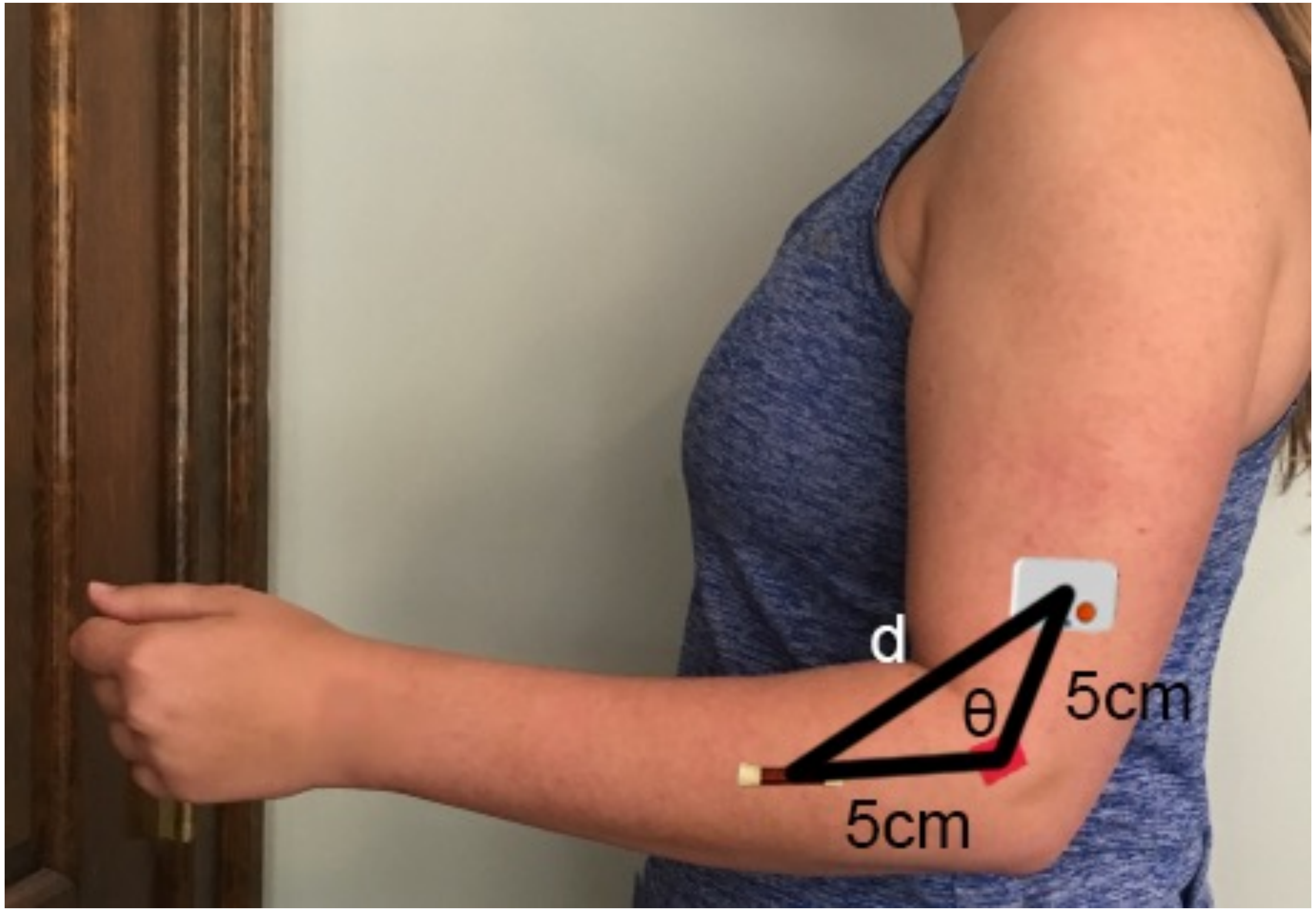
Localization of the Electromagnet



Elbow Angles Application



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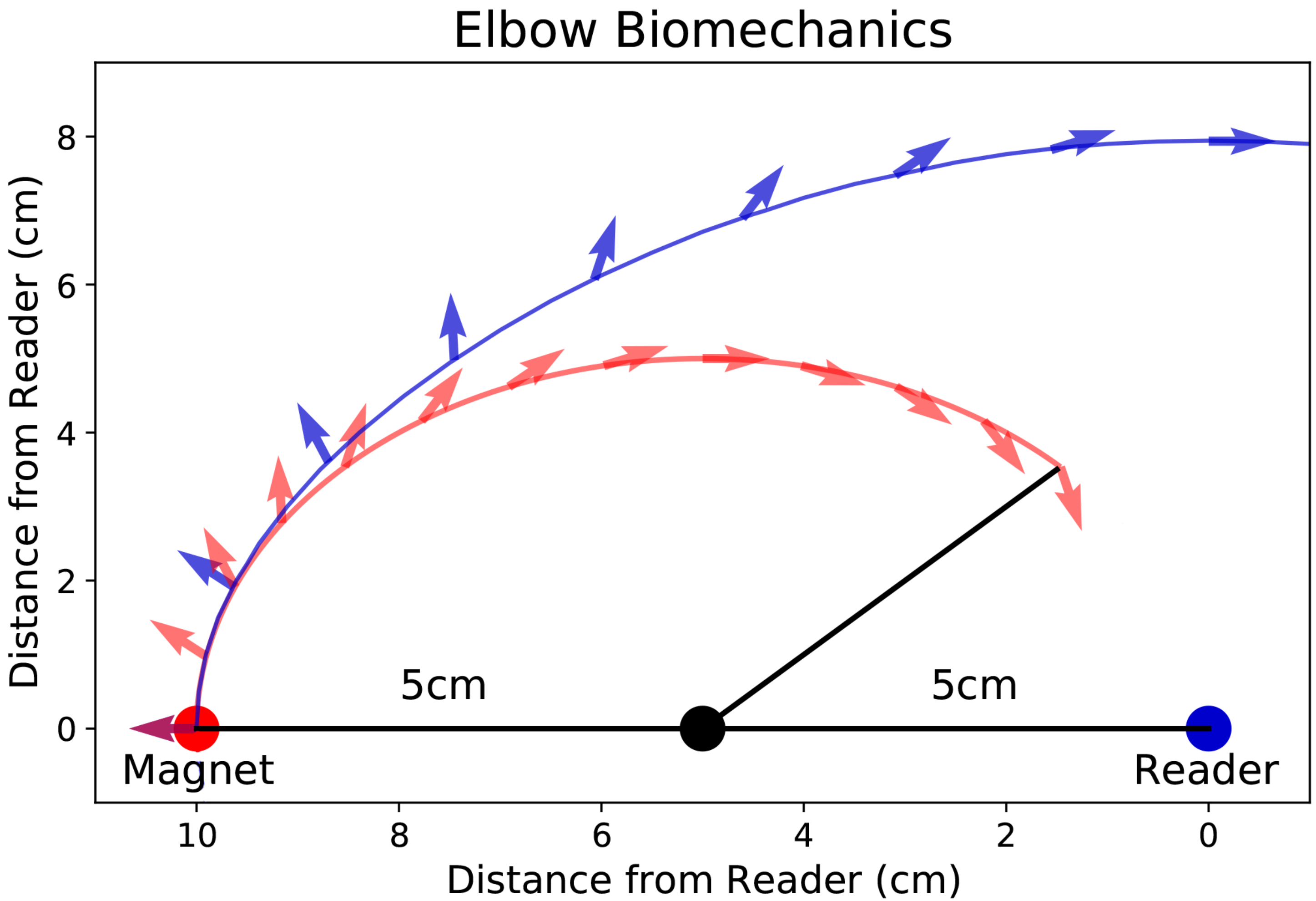
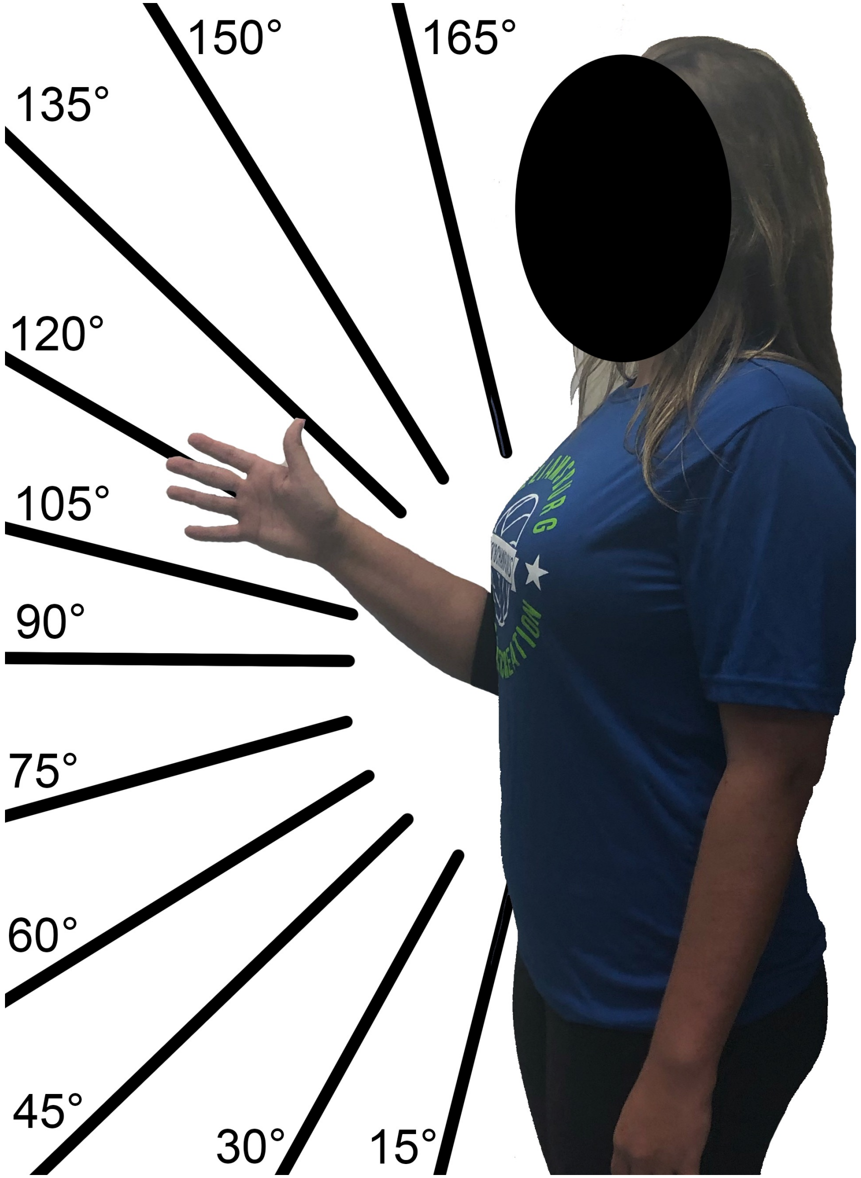
Elbow Motion

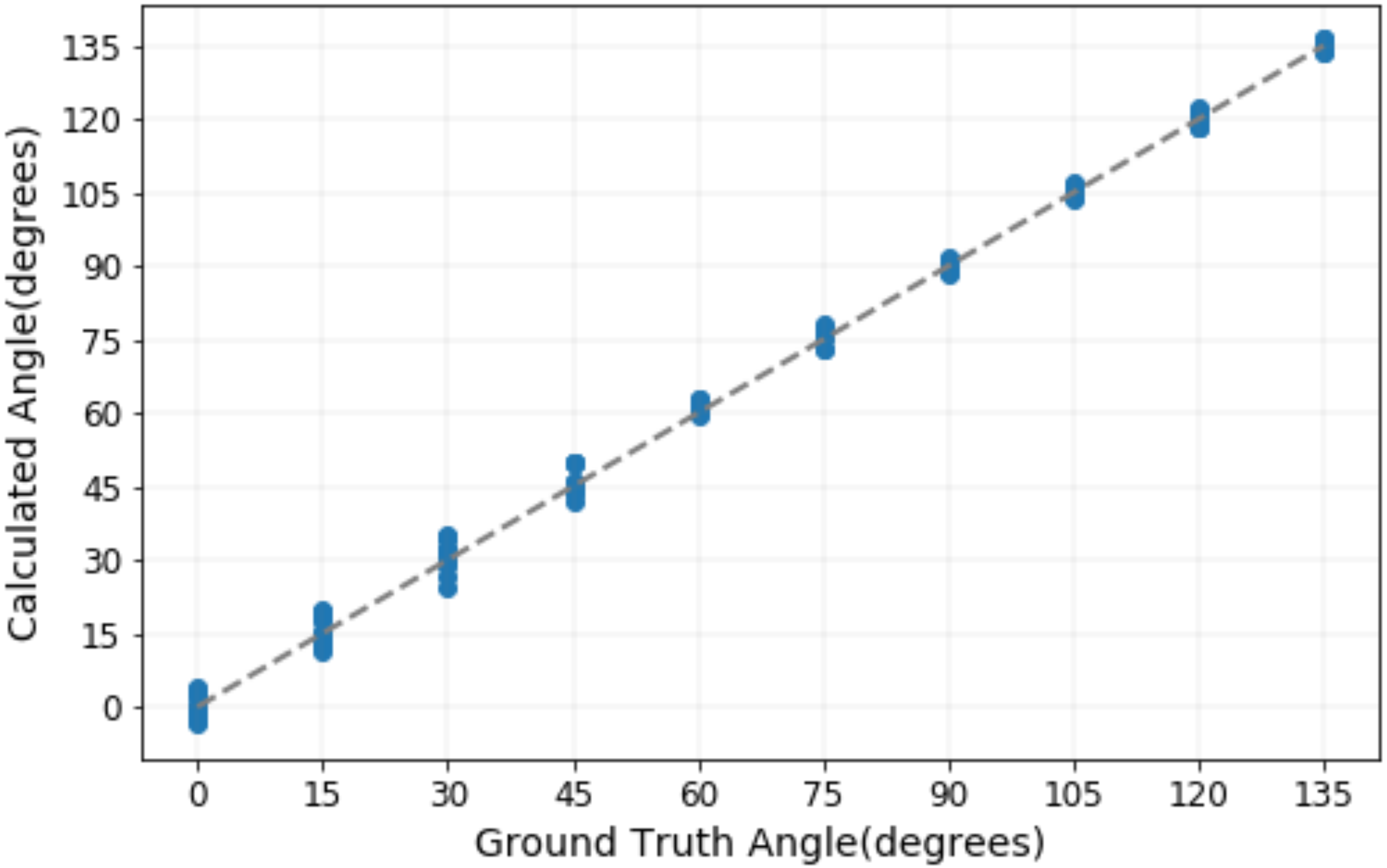


Elbow Angles

- User Study
  - 13 Participants (7F/6M)
  - 130 Angles per participant



Elbow Angles Results



Overall: 93.8% accuracy

Future Work

- Motion Analysis
- Shoulder Support in 3 Dimensions
- Increasing the Strength of the Electromagnet
- Increasing the Cycling Rate
- Multiple Electromagnets

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Conclusion

- Magneto uses the combination of an **electromagnet** and **magnetometer** to remove **environmental interference** from magnetic field readings in a dynamically changing environment.
- Given this **purified reading**, we **localized** the electromagnet with respect to the magnetic field reader.
- We completed a **pilot study** where we calculated elbow angles to the nearest 15°with **93.8% accuracy**.

THANK YOU!

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http://precise.seas.upenn.edu