

## The Iron Cross

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### Project Description

This curriculum module has been designed through the VaNTH Engineering Research Center (<http://www.vanth.org>) utilizing the Legacy Cycle method of anchored or challenge-based instruction (Schwartz, D. L., Lin, X., Brophy, S., & Bransford, J. D. (1999) Toward the development of flexibly adaptive instructional designs. In Reigeluth (Ed.), *Instructional Design Theories and Models: Volume II*. Hillsdale, NJ: Lawrence Erlbaum Associates. <http://peabody.vanderbilt.edu/ctrs/ltc/brophys/legacy1.html>). The Legacy Cycle is composed of six different phases of learning, beginning with the aforementioned challenge question. The next stage is to “generate ideas” where students talk about what they already know about the challenge question. “Multiple perspectives” are introduced, allowing experts to point out ideas that students may not have considered and to guide their initial learning. The stage “Research and Revise” allows students to pursue the areas in which they identified as useful and relevant. This stage usually consists of teacher lectures, laboratories, demonstrations, homeworks, etc. “Test Your Mettle” is the stage where students begin to state their newly discovered information in a way that receives feedback from the instructor. Students may return to ‘Research and Revise’ after testing their mettle. Finally, students “Go Public” with their final answer to the challenge question.

The Iron Cross legacy cycle is described in detail here.

**Challenge:** What muscle strength is needed for an athlete to hold these positions?



**Generate Ideas:** Journal topics - What are your initial ideas about how these tasks can be accomplished? What background knowledge is needed? Which muscles are most susceptible to injury and why? What is meant by 'muscle strength'? What do you think you need to learn about?

**Multiple Perspectives:** Evaluate journal entries. Read multiple perspectives from four people:

Many muscles are working together to keep the athlete up and steady. You need to know which muscles are active and which are not. (M. W., Sports Medicine PT.)

One reason this maneuver is so difficult is because the athlete's Center of Gravity (COG) is so far from where the forces are applied to the rings. (B. W., Mechanical Engineer)

I wonder how the hand positions influence the muscle forces. I'm sure that has something to do with the analysis. Also, I wonder if it is more difficult when the arms are straight out, or when there is some angle. (J. B., BME graduate student)

The muscles in the athletes' shoulders, arms, wrists, and hands need to counterbalance the force due to gravity of the person's body (i.e., his weight). (D.M., BME graduate student)

**Research and Revise:**

*Is the gymnast in equilibrium while holding the iron cross? What does equilibrium mean?*

Discuss Newton's laws with your class. Show that the sum of the forces in each direction must be zero. Also note that there is no rotation. Discuss torque with your students.

*Does a critical point exist in the iron cross position? If so, what happens physiologically at this point?*

View video clip and measure the critical angle at which the athlete has insufficient strength to hold the position.

[Http://canvas.ltc.vanderbilt.edu/weblegacy/101/media/crit.mov](http://canvas.ltc.vanderbilt.edu/weblegacy/101/media/crit.mov)

*Which muscle group must be active at the shoulder when performing the iron cross?*

Have your students research the possible muscles and muscle groups using Anatomy and Physiology textbooks or software programs such as Adam Anatomy.

*What forces are acting on the arm when performing the iron cross?*

Draw a free-body diagram of the arm.

**Test your Mettle:**

Assign homework problems on simple equilibrium and torque problems. Have your students draw free body diagrams as a part of these assignments.

**Go Public:**

You students have now explored much of the information needed for analyzing the Vertical Iron Cross. Complete your mathematical analysis of the iron cross.

Also, analyze the forces at the shoulder and the wrists for the Inverted Iron Cross shown in the second picture. Assume that the athlete is 175cm tall and 75 kg in mass. What muscle groups at the shoulder and the wrist must be active? What muscle torque must be applied by these muscle groups to maintain equilibrium? What muscle force must be generated at the shoulder and wrist if the average moment arm is 3.8 cm at the shoulder and 1.5 cm at the wrist?

### **Project Goals**

1. Construct a free body diagram.
2. Use Newton's Laws to mathematically analyze the free body diagram.
3. Calculate torques.
4. Understand equilibrium.
5. Identify which muscles come into action when we perform various actions
6. Explain the difference between abductor and adductor muscles
7. Calculate muscle forces
8. Introduce muscle groups and equivalent forces

### **Timeline**

#### **Day 1**

- Introduce the challenge question.
- Have the students independently work in the journals to answer the Generate Ideas questions.
- If possible, have journal responses submitted electronically so that all entries can easily be pulled into one document.
- As a class, review all journal entries.
- On the board, record the needed knowledge areas that students identified. Also record any specific ideas that were generated.
- Read the multiple perspectives provided as a class.

#### **Day 2**

- Discuss forces, lever arms, torques, and equilibrium.
- Assign first homework on simple equilibrium and torque problems.

#### **Day 3**

- Continue discussion of forces, lever arms, torques, and equilibrium.
- Watch video about the critical point in the iron cross. Is there a critical point and what happens physiologically there?
- Assign second homework on simple equilibrium and torque problems.

#### **Day 4**

- Research shoulder anatomy, possibly using Adam Anatomy. Discover which individual muscles and muscle groups exist in the shoulder. What is the role of each group? Which group must be active to perform the iron cross? What major muscles are included in this group?

- Have students try to push themselves up between two desks to feel which muscle groups are active. Also have them hang from between two bars and think about/try to pull themselves up into the iron cross position using caution.
- Make sure understand how muscles act across a joint. For instance, the muscles that control the position of your forearm are not in the forearm itself; rather, they are in the upper arm.
- For homework, have students re-read their original journals and reflect on initial class ideas. How much did they understand initially and where do they think they need to go from here in order to answer the challenge question?
- Assign the torque and COG homework.

#### Day 5

- Discuss findings about the muscle groups and draw a conclusion.
- Collect and/or go over the torque and COG homework assignment.
- Also, discuss the need for both horizontal and vertical forces to be created by the muscles and why they are all diagonally placed in the body.
- Using this knowledge, have students work in groups to construct a FBD of the arm (arm, forearm, hand combination) as it performs the iron cross. Neglect the weight of the total arm. Assume the joint is frictionless.
- Compare student FBD and draw a conclusion.

#### Day 6

- Students work in groups on the answer to the challenge question about the vertical iron cross.

#### Day 7

- Students research additional knowledge needed for the second part of the challenge question regarding the inverted iron cross and work on the problem individually in class.

#### Day 8 (or later)

- Students turn in their answers to the challenge questions.

### **Alignment to Standards**

This module aligns with numerous national science education standards. From the National Science Education Standards published by the National Academy Press in 2000, this module addresses high school content standards A, B, E, and G and teaching standards A through E. This module also satisfies assessment standards A and C.

This module also aligns with parts of the AAAS Project 2061. Specifically from the Benchmarks for Habits of Mind, this module satisfies, “Find answers to problems by substituting numerical values in simple algebraic formulas and judge whether the answer is reasonable by reviewing the process and checking against typical values” by solving problems in torque and Newton’s laws equations. Also, “Make up and write out simple algorithms for solving problems that take several steps” is satisfied by analyzing the challenge question. “Express and compare very small and very large numbers using

powers-of-ten notation” is addressed by solving problems in torque and Newton’s laws and solving the grand challenge. “Make and interpret scale drawings” is addressed by creating free body diagrams of the shoulder. “Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions” is met by working in groups to analyze part of the challenge question.

Also from AAAS Project 2061, some of the Benchmarks of the Physics Setting are met. “The change in motion of an object is proportional to the applied force and inversely proportional to the mass” is met by study of Newton’s laws. “Whenever one thing exerts a force on another, an equal amount of force is exerted back on it” is satisfied through a study of Newton’s laws.

### **Equipment Required**

Internet Access for viewing critical angle video  
Anatomy and Physiology textbooks or references

### **Duration of Project**

This module may be completed in eight fifty minute periods.

### **Lesson Plans**

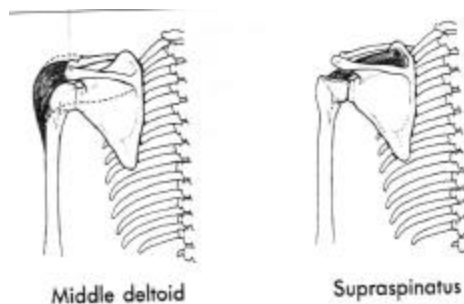
The lesson plans are described in the Timeline section.

### **Sample Handouts**

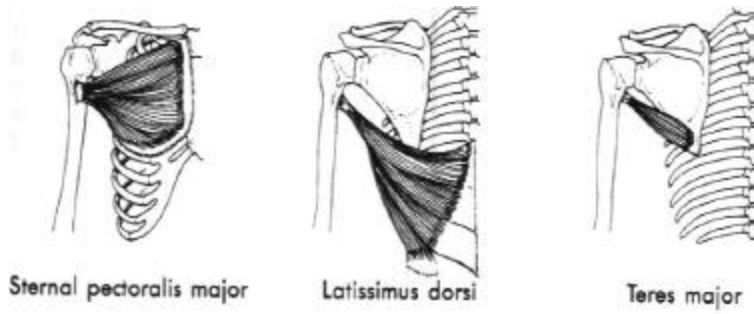
#### **Active Muscle Group at Shoulder Iron Cross**

Which muscle group must be active at the shoulder when performing the iron cross?

#### **1. Shoulder Abductors**

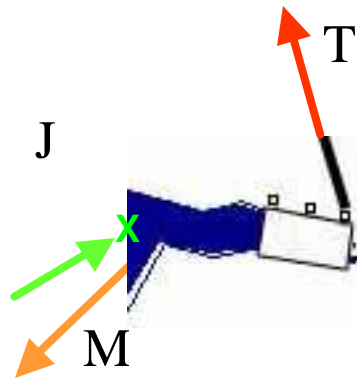


## 2. Shoulder Adductors



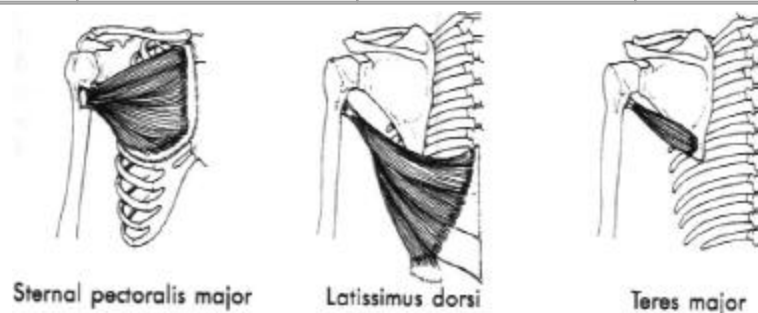
### Free Body Diagram Iron Cross

Students should arrive at a FBD that resembles the diagram below. J represents the Joint Force, T represents the tension force, and M represents the muscle force.



### Origin & Insertion coordinates for arm at 90 degree position

Muscle	Insertion (x,y;cm)	Origin(x,y;cm)	Maximum Force (N)
Teres Major	(+2.78, 0)	(-11, -14)	5072
Latissimus Dorsi	(+1.5, 0)	(-8, -28)	6828
Pectoralis Major	(+2.06, 0)	(-9, -19)	7608



Notes about the table above: The point (0,0) is at the center of the shoulder joint. The origin is where the muscle originates in the body chest, and the insertion point is where the muscle is inserted into the shoulder joint. A two-dimensional assessment is used.

One way to determine if an individual has the strength to hold the iron cross position on the rings is to assume the athlete contracts all adductor muscles that cross the shoulder to their maximum extent. Then one can compute the maximum muscle moment and compare it with the moment caused by the upward pull of the rings. Assume the three muscles above (sternal pectoralis major, latissimus dorsi, and teres major) are stimulated to produce maximum strength.

Use the information provided in the table to find:

- The horizontal and vertical components of force created by each muscle individually
- The resultant force (magnitude and direction) of these three muscles
- Can the gymnast develop enough muscle force to hold the iron cross position? He is 178 cm tall and his mass is 75 kg. Remember that the gymnast is fighting the urge to let his arms rotate so that his weight pulls him downward and his arms are completely vertical.
- Find the horizontal (x) distance from the shoulder to the line of action of the resultant force.
- If he cannot hold the position, at what modified angle could the gymnast hold the iron cross position?

Name: \_\_\_\_\_

### Inverted Iron Cross



Wrist extensors



Wrist flexors

Assume that the athlete is 175cm tall and 75 kg in mass.

- a) What muscle groups at the shoulder must be active? Why?
- b) At the wrist, two muscle groups are found: the flexors and the extensors. The flexors cause a decrease in angle between the palm of the hand and the front of the forearm, and the extensors straighten the arm and increase the angle. Which wrist muscle group must be active here? Why?
- c) What muscle torque must be applied by these muscle groups to maintain equilibrium? Calculate the torque for the muscle group and the wrist group separately. Assume that both the wrist and the shoulder must be capable of supporting the body's weight.
- d) What muscle force must be generated at the shoulder and wrist if the average muscle lever arm is 3.8 cm at the shoulder and 1.5 cm at the wrist?

### **Project Results (benefits to the students, awards, and recognitions)**

From survey results, the students enjoy learning about torque and Newton's Laws in such an applied manner, particularly one that relates to the human body. Prior to module implementation, a pre-test and post-test were constructed. The pre-test consisted of six relatively simple questions that assessed the amount of knowledge students had gained from prior courses. The post-test consisted of a repeat of the pre-test questions, three application questions similar to those found on a chapter test on torque and Newton's Laws, and one 'near-transfer' question that was specific to the module. These tests were given to 69 students in experimental classes using the Iron Cross module and to 34 students in control classes covering Newton's Laws and torque in traditional fashion. Statistical analysis of the test scores was made using ANCOVA. The experimental group outscored the control group at a statistically significant level on the post-test in all three sections (0.01 for pre-test repeats, 0.001 on the application items, and <0.001 on the near transfer question). We believe that these results indicate that the iron cross module is more effectively teaching the basic physics than traditional instruction.

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### **Photo Gallery**