Exercise 3.2 Calculating Mechanical Advantage

Objective

At the conclusion of this exercise, you will be able to do the following:

1. Identify the six simple machines.
2. Calculate the slope, ideal mechanical advantage (IMA), actual mechanical advantage (AMA), efficiency, ideal effort force, and actual effort force of an inclined plane.
3. Calculate the slope, ideal mechanical advantage (IMA), actual mechanical advantage (AMA), load capacity, and ideal effort force of a wedge.
4. Identify the three classes of levers.
5. Calculate the ideal mechanical advantage (IMA), actual mechanical advantage (AMA), ideal effort force, and actual effort force of a lever.
6. Calculate the ideal mechanical advantage (IMA), actual mechanical advantage (AMA), ideal effort force, and actual effort force of a wheel and axle system.
7. Calculate the ideal mechanical advantage (IMA), actual mechanical advantage (AMA), effort rope length, ideal effort force, and actual effort force of a pulley system.
8. Determine the pitch of a screw thread.
9. Calculate the ideal mechanical advantage (IMA), efficiency, ideal effort force, and actual effort force of a screw.

Procedure

Read the section on mechanical advantage in Chapter 3, "The Mechanical Advantage" in the *Principles of Engineering* textbook.

Problem 3.1 The inclined plane shown in Figure 3-3 is used to move load L a vertical distance h. The actual amount of effort force that is required to move the load up the inclined surface is 50 lb. Complete the following exercises using the values L = 100 lb; θ = 25°, and h = 42 in. Show your math work in the spaces provided.

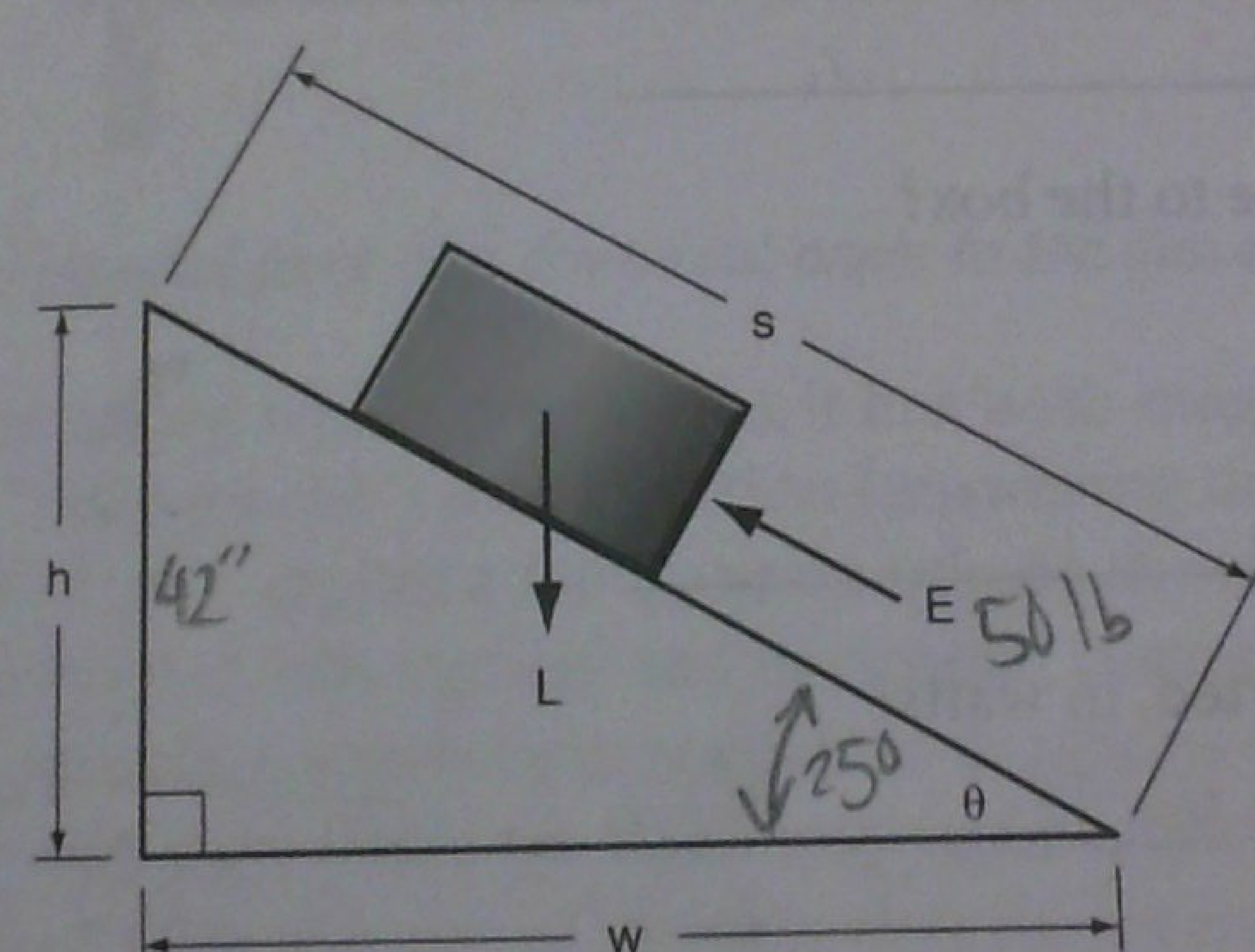

FIGURE 3-3 *An inclined plane.*

1. Calculate the length, s, of the inclined plane's slope.

$\sin(25) = \frac{42}{x}$ $\frac{42}{\sin(25)} = x$

s = 99.38 in

2. Calculate the ideal mechanical advantage (IMA) of the inclined plane.

$IMA = \frac{s}{h} = \frac{99.38}{42}$

IMA = 2.4:1

3. Calculate the actual mechanical advantage (AMA) of the inclined plane.

$AMA = \frac{L}{E_a} = \frac{100}{50} = 2$

AMA = 2:1

4. What is the efficiency (η) of this inclined plane system?

$\frac{AMA}{IMA} = \frac{2}{2.4}$

η = 0.83 83%

5. What is the ideal effort force (E_I) that would be needed to push the load up the inclined plane in the absence of friction?

$E_I = \frac{L}{IMA} = \frac{100}{2.4}$

E_I = 41.67

Problem 3.2 The table shown in Figure 3-4 contains data that describe four inclined planes, A, B, C, and D. Use the information provided to calculate the missing data for each of the four inclined planes. Show your math work in the spaces provided.

	Load Weight (lb)	Slope Length (in)	Inclined Plane Height (in)	Inclined Plane Width (in)	Slope Angle (degrees)	E_I Ideal Effort Force (lb)	E_A Actual Effort Force (lb)	IMA Ideal Mechanical Advantage	AMA Actual Mechanical Advantage	η Efficiency (%)
A	20.00	23.97	8.20	22.65	20.00	6.82	9.89	2.92	2.02	0.69
B	100.00	24.00	8.21	22.55	20.00	34.4	45.45	2.90	2.20	0.76
C	97.80	163.65	96.00	132.54	35.92	58.56	88.91	1.67	1.10	.66
D	50.00	192	96.00	166.28	30.00	25.00	50	2.00	1.00	0.5

FIGURE 3-4 *A table of inclined planes.*

Inclined Plane A: $\sin(20) = \frac{8.2}{x}$

$\frac{8.2}{\sin(20)} = x$

23.97

$\frac{s}{h} = \frac{23.97}{8.2} = IMA$ $\frac{20}{9.89} = AMA$

$\eta = \frac{IMA}{AMA} = \frac{2.02}{2.92}$

Slope length: 23.97

IMA: 2.92

AMA: 2.02

η: 0.69

Inclined Plane B:

$\sin(20) = \frac{h}{24}$ $\sin(20)(24) = h$

$8.21^2 + x^2 = 24^2$ $24^2 - 8.21^2 = x^2$

Height: 8.21

Width: 22.55

E_I: 34.4

E_A: 45.45

η: 0.76

$\frac{L}{E_a} = AMA$

$\frac{100}{2.20} = E_a$

$\eta = \frac{2.2}{2.9}$

$E_I = \frac{L}{IMA} = \frac{100}{2.9}$

$\frac{100}{E_a} = 2.2$

Inclined Plane C: $\eta = \frac{AMA}{IMA}$ $\frac{AMA}{\eta} = IMA$ $1.10 / 0.66 = IMA$

$AMA = \frac{L}{E_a}$

$132.54^2 + 96^2 = x^2$

$\tan^{-1}(96/132.54) = \text{angle}$

$1.10 = \frac{L}{88.91}$ $1.10(88.91)$

$E_I = \frac{L}{IMA} = \frac{97.8}{1.73}$

Load: 97.80
Slope angle: 35.92
IMA: 1.67
Slope length: 163.65
E_I: 58.56

Inclined Plane D:

$\sin(30) = \frac{96}{x}$

$x = \frac{96}{\sin(30)}$

$\cos(30) = \frac{x}{192}$ $\cos(30)(192) = x$

$AMA = \frac{L}{E_a}$ $E_a = \frac{L}{AMA}$

$= \frac{50}{1} = 50$

Slope length: 192
E_A: 50
Width: 166.28
η: 0.5

Problem 3.3 A hydraulic-powered log splitter, like the one shown in Figure 3-5A, is used to cut large logs in half. A wedge, located on one end of the device, provides the cutting action. The shape of the wedge is an isosceles triangle that is 6 in. thick by 12 in. wide. An *actual* effort force of 300 lb is required to split a log. The cutting action of the wedge is 80% efficient. Use this information to answer the following questions. Show your math work in the spaces provided.

$IMA_{wedge} = \frac{\text{slope length}}{\text{thickness of wedge}}$


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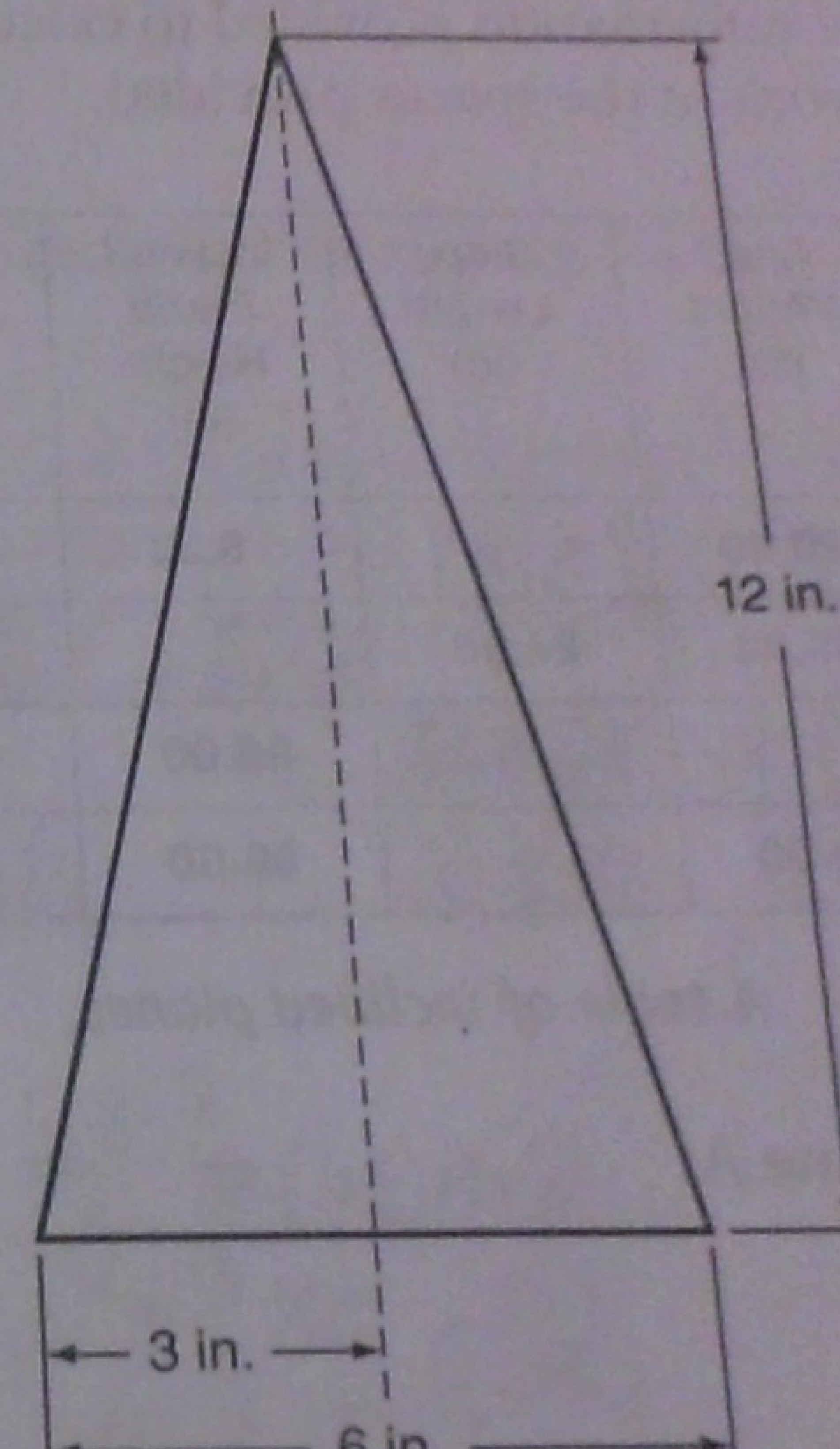
(A)



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(B)

FIGURE 3-5 *(A) Log splitter and (B) wedge profile.*

$3^2 + 12^2 = x^2$

$9 + 144 = x^2$

1. What is the slope length (s) on either side of the wedge?

$s =$ 12.37

2. What is the ideal mechanical advantage (IMA) of the wedge?

$\frac{12.37}{6}$

IMA = 2.06

3. What is the actual mechanical advantage (AMA) of the wedge?

$\eta(IMA) = AMA$

$0.8(2.06) = AMA$

AMA = 1.65

4. How much resistance does the log provide against the cutting action of the wedge?

$AMA = \frac{L}{E_A}$ $E_A(AMA) = L$

$1.65(300)$

Load = 495 lb

5. If friction is not a consideration, what would the ideal effort force (E_I) need to be to split the log?

$E_I = \frac{L}{IMA} = \frac{495}{2.06}$

E_I = 240.21

Problem 3.4 Levers X, Y, and Z in Figure 3-6 represent three different lever systems. Identify which of these three lever systems is described in each of the statements below. Write the answers and justification for each selection in the spaces provided.

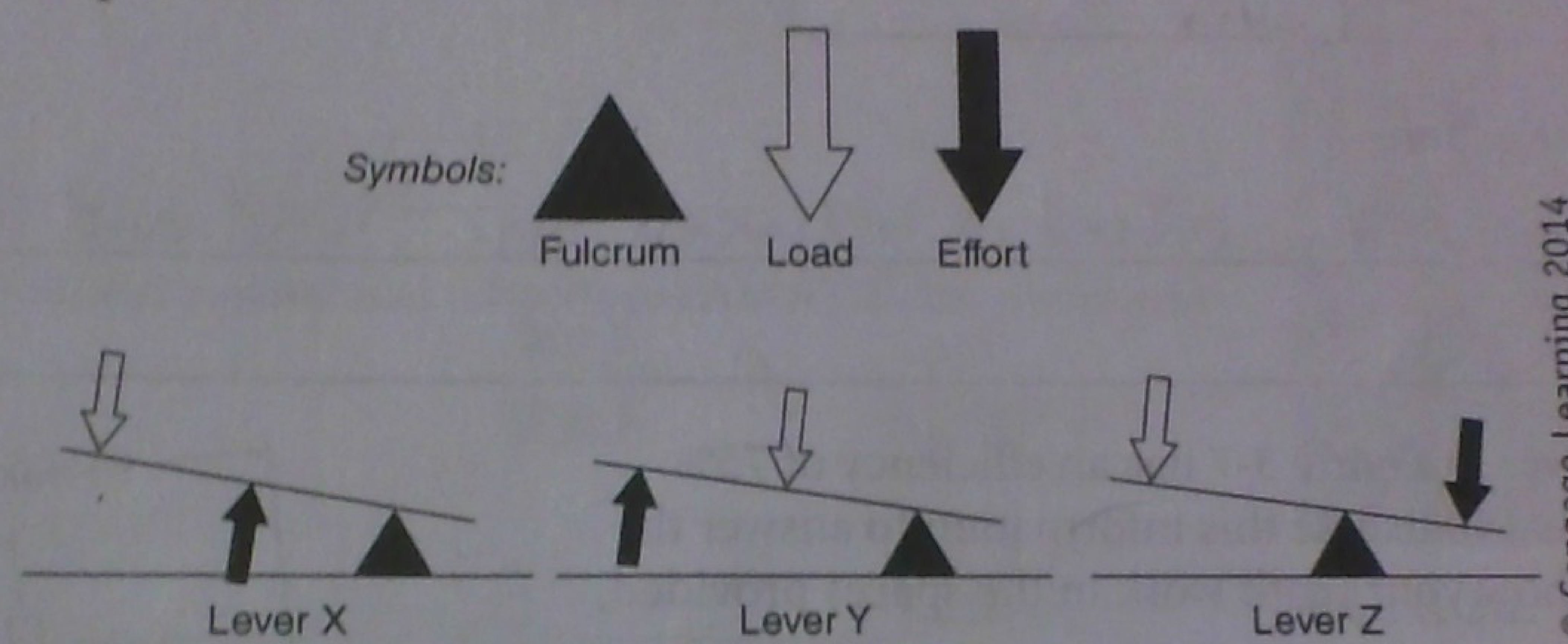

FIGURE 3-6 *Lever systems X, Y, and Z.*

1. This system represents a class of lever that always has a mechanical *disadvantage*.

Lever "X"

Explain your selection.

Lever X is a third-class lever, and third class levers have a mechanical advantage between 0 and 1. The effort always has to be more than the load.

2. This represents a class of lever that always has a mechanical *advantage*.

Lever "Y"

Explain your selection.

Lever Y is a 2nd-class lever, and 2nd-class levers always have a mechanical advantage

3. This is an example of a first-class lever.

Lever Z

Explain your selection.

The fulcrum is between the load and the effort. Also, the load and effort are both in the same direction.

4. This is an example of a second-class lever.

Lever Y

Explain your selection.

The load is between the effort and the fulcrum.

5. This is an example of a third-class lever.

Lever X

Explain your selection.

The effort is between the load and the fulcrum.

Problem 3.5 The lever in Figure 3-7 has an efficiency of 75%. The load on the lever is 150 lb. Use this information to answer the following questions. Show your math work in the spaces provided.

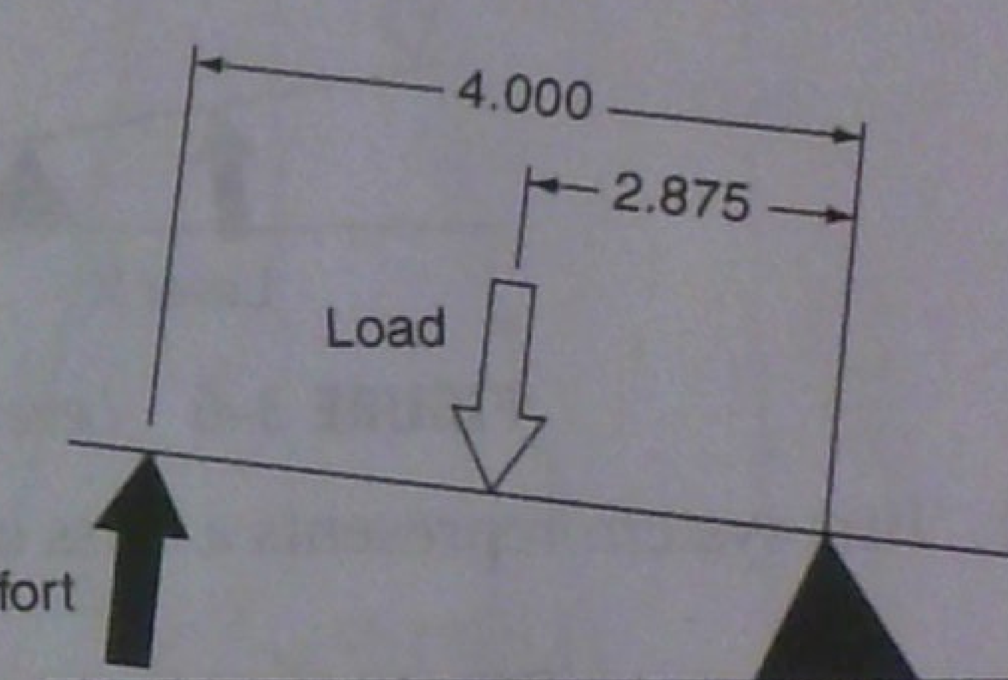

FIGURE 3-7 *A lever.*

1. Figure 3-7 is an example of what class of lever?

2nd Class

2. What is the ideal mechanical advantage (IMA) of the lever?

$IMA = \frac{4}{2.875}$

IMA = 1.391

3. What is the actual mechanical advantage (AMA) of this system?

$\eta = \frac{AMA}{IMA}$, $\eta(IMA) = AMA$

AMA = 1.04

4. What is the *ideal effort force* (E_1) that would be needed to move the lever in the absence of friction?

$\frac{L}{E_1} = IMA$ $\frac{L}{IMA} = E_1$

$E_1 = \frac{150}{1.391}$

E_1 = 107.836