Activity 1.1.2 Simple Machines Practice Problems

Introduction

In the last activity, building and using simple machines and making measurements of forces and distances gave you concrete examples using mechanisms. Just from a good sketch, however, an engineer can deduce how a mechanism will transform forces and distances from input to output -- from effort to resistance. Making a good sketch of a mechanism and making accurate predictions based on your sketch of a mechanism are great problem solving skills that will help you design mechanisms for a particular task.

Procedure

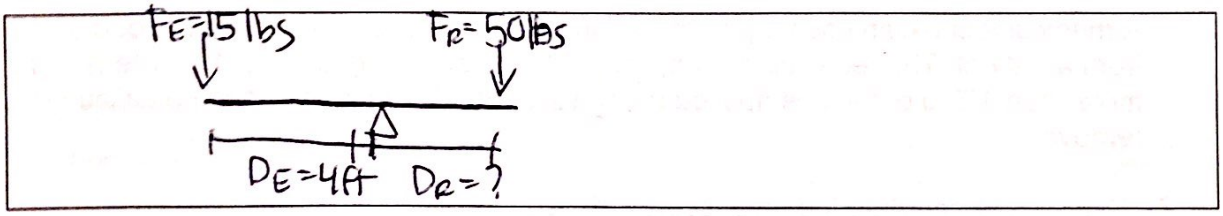
Answer the following questions regarding simple machine systems. Each question requires proper illustration and annotation, including labeling of forces, distances, direction, and unknown values. Illustrations should consist of basic simple machine functional sketches rather than realistic pictorials. Be sure to document all solution steps and proper units.

All problem calculations should assume ideal conditions and no friction loss.

Simple Machines – Lever

A first class lever in static equilibrium has a 50-lb resistance force and 15-lb effort force. The lever's effort force is located 4 ft from the fulcrum.

1. Sketch and annotate the lever system described above.



2. What is the actual mechanical advantage of the system?

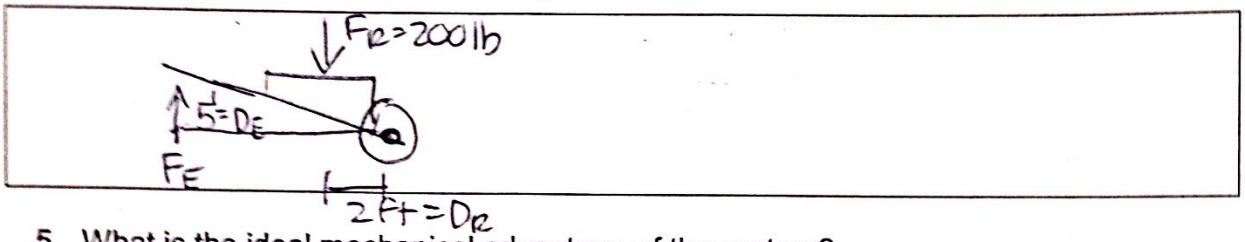
Formula	Substitute / Solve	Final Answer
$AMA = \frac{F_R}{F_E}$	$AMA = \frac{50\,lbs}{15\,lbs} = 3.33$	3.33

3. Using static equilibrium calculations, calculate the length from the fulcrum to the resistance force.

Formula	Substitute / Solve	Final Answer
$M_E = M_R$ $F_E \cdot D_E = F_R \cdot D_R$	$15lb \cdot 4ft = 50lb \cdot X$ $\frac{50X}{50} = \frac{60}{50}$	$X = 1.2ft$

A wheel barrow is used to lift a 200-lb load. The length from the center of the wheel to the center of the load is 2 ft. The length from the wheel to the effort is 5 ft.

4. Illustrate and annotate the lever system described above.



5. What is the ideal mechanical advantage of the system?

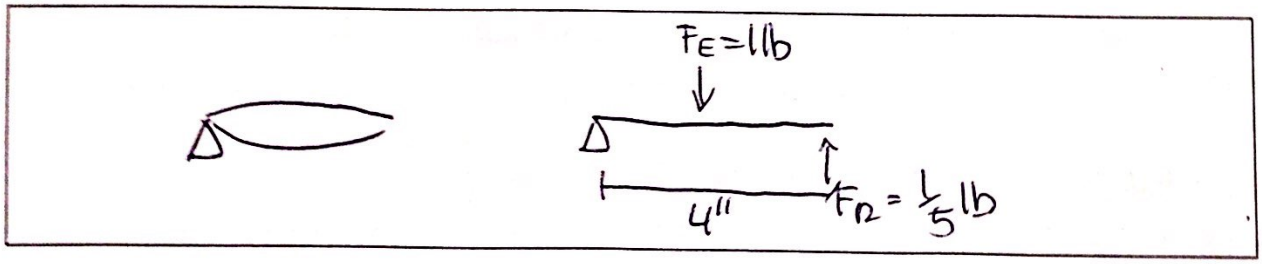
Formula	Substitute / Solve	Final Answer
$IMA = \frac{D_E}{D_R}$	$IMA = \frac{5ft}{2ft}$	$IMA = 2.5$

6. Using static equilibrium calculations, calculate the ideal effort force needed to overcome the resistance force in the system.

Formula	Substitute / Solve	Final Answer
$M_E = M_R$ $F_E \cdot D_E = F_R \cdot D_R$	$5ft \cdot F_E = 2ft \cdot 200lb$ $F_E = 80lb$	$F_E = 80lb$

A medical technician uses a pair of four-inch-long tweezers to remove a wood sliver from a patient. The technician is applying 1 lb of squeezing force to the tweezers. If more than 1/5 lb of force is applied to the sliver, it will break and become difficult to remove.

7. Sketch and annotate the lever system described above.



8. What is the actual mechanical advantage of the system?

Formula	Substitute / Solve	Final Answer
$AMA = \frac{F_R}{F_E}$	$AMA = \frac{0.200\ lb}{1.0\ lb}$	$AMA = 0.200$

9. Using static equilibrium calculations, calculate how far from the fulcrum the tweezers must be held to avoid damaging the sliver.

Formula	Substitute / Solve	Final Answer
$M_E = M_R$ $F_E \cdot D_E = F_R \cdot D_R$	$1.0\ lb \cdot D_E = 0.200\ lb \cdot 4\ in$	$D_E = 0.800\ in$

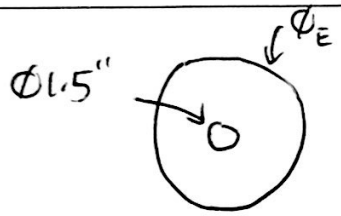
Simple Machines – Wheel and Axle

10. What is the linear distance traveled in one revolution of a 36-in.-diameter wheel?

Formula	Substitute / Solve	Final Answer
$C = \pi d$	$C = \pi(36.0\ in) = 113.0\ in$	$C = 113\ in$

An industrial water shutoff valve is designed to operate with 30 lb of effort force. The valve will encounter 200 lb of resistance force applied to a 1.5-in.-diameter axle.

11. Sketch and annotate the wheel and axle system described above.



$F_R = 200\ lb$

$F_E = 30\ lb$

12. What is the required actual mechanical advantage of the system?

Formula	Substitute / Solve	Final Answer
$AMA = \frac{F_R}{F_E}$	$AMA = \frac{200\ lb}{30\ lb}$	$AMA = 6.67$

13. What is the required wheel diameter to overcome the resistance force?

Formula	Substitute / Solve	Final Answer
$M_E = M_R$	$200\ lb \cdot 0.75\ in = 30\ lb \cdot d$	$D_E = 10\ in$

Simple Machines – Pulley System

Several times during a day, a construction crew lifts approximately 560 lb of material from a flatbed truck to a 32-ft rooftop. A block and tackle system with 50 lb of effort force is designed to lift the materials.

14. What is the required actual mechanical advantage?

Formula	Substitute / Solve	Final Answer
$AMA = \frac{F_R}{F_E}$	$AMA = \frac{560lb}{50lb}$	AMA = 11.2

15. How many supporting strands will be needed in the pulley system?

Formula	Substitute / Solve	Final Answer
IMA = # OF STRANDS	IMA = # OF STRANDS 11.2 = 12	12

A block and tackle system with nine supporting strands is used to lift a metal lathe in a manufacturing facility. The motor being used to wind the cable in the pulley system can provide 100 lb of force.

16. What is the mechanical advantage of the system?

Formula	Substitute / Solve	Final Answer
IMA = # OF STRANDS	IMA = 9	9

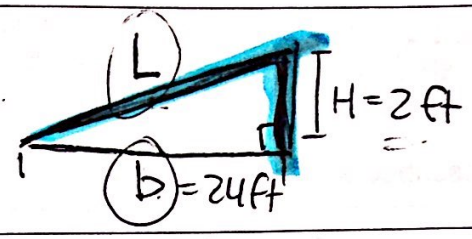
17. What is the maximum weight of the lathe?

Formula	Substitute / Solve	Final Answer
$IMA = AMA = \frac{F_R}{F_E}$	$\frac{9}{1} = \frac{F_R}{100} \rightarrow F_R = 900lb$	$F_R = 900lb$

Simple Machines – Inclined Plane

A civil engineer must design a wheelchair-accessible ramp next to a set of steps leading up to a building. The height from the ground to the top of the stairs is 2 ft. Based on ADA codes, the slope must be 1:12 or less. Slope is equal to the rise of the ramp divided by the run of the ramp.

18. Sketch and annotate the inclined plane described above.



slope = $\frac{\text{rise}}{\text{run}} = \frac{1}{12}$

19. Using the ADA code, what is the allowable minimum length of the ramp base?

Formula	Substitute / Solve	Final Answer
$\frac{\text{rise}}{\text{run}} = \frac{1}{12}$	$\frac{\text{rise}}{\text{run}} = \frac{1}{12} = \frac{2\text{ ft}}{b}$ $b = 24\text{ ft}$	24 ft

20. Using the known height and calculated base length, what is the length of the slope of the ramp?

Formula	Substitute / Solve	Final Answer
$a^2+b^2=c^2$	$a^2+b^2=c^2$ $2^2+24^2=c^2$ $\sqrt{c^2}=\sqrt{580}$ $c=24.08$	24.1 ft

21. What is the ideal mechanical advantage of the ramp?

Formula	Substitute / Solve	Final Answer
$IMA = \frac{L}{H}$	$IMA = \frac{24.08}{2} = 12.04$	IMA = 12:1

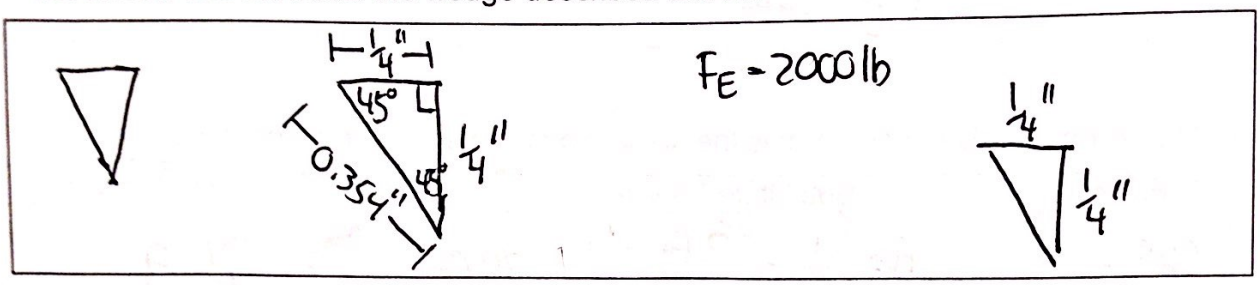
22. If a person and wheelchair have a combined weight of 185 lb, how much ideal effort force is required to travel up the ramp?

Formula	Substitute / Solve	Final Answer
$IMA = AMA = \frac{F_R}{F_E}$	$\frac{12}{1} = \frac{185\text{ lb}}{F_E}$ $\frac{12F_E}{12} = \frac{185}{12}$	$F_E = 15.41\text{ lbs}$

Simple Machines – Wedge

A hydraulic shear applies a 2000 lb force to a wedge. It is used to shear plate steel to rough size. The shear has a 1/4-inch-thick cutting blade with a 45° slope. (Note: 45°, 45°, 90° triangle)

23. Sketch and annotate the wedge described above.



24. What is the length of the slope?

Formula	Substitute / Solve	Final Answer
$a^2+b^2=c^2$	$0.25^2+0.25^2=c^2$	$c=0.354$ in

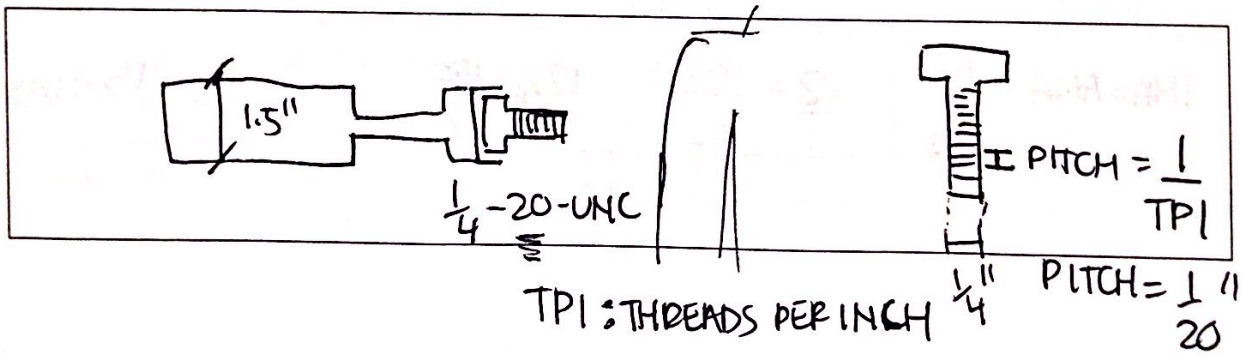
25. What is the ideal mechanical advantage of the wedge?

Formula	Substitute / Solve	Final Answer
$IMA=\frac{L}{H}$	$IMA=\frac{0.25''}{0.25''}$	1

Simple Machines – Screw

A 7/16 nut driver with a 1 1/2-inch-diameter handle is used to install a 1/4-20 UNC bolt into a robotic arm.

26. Sketch and annotate the screw system described above.



27. Determine the circumference where the effort is applied.

Formula	Substitute / Solve	Final Answer
$C = 2\pi r = \pi \cdot d$	$C = \pi \cdot d = \pi \cdot (1.5 in)$	4.71 in

28. Determine the pitch of the screw.

Formula	Substitute / Solve	Final Answer
$PITCH = \frac{1}{TPI}$	$PITCH = \frac{1}{20} = 0.05 in$	0.05 in

29. What is the mechanical advantage gained in the system?

Formula	Substitute / Solve	Final Answer
$IMA = \frac{C}{pitch}$	$IMA = \frac{4.71 in}{0.05 in} =$	94.2

30. How much force can ideally be overcome if 5 lb of force is exerted?

Formula	Substitute / Solve	Final Answer
$IMA = AMA = \frac{F_R}{F_E}$	$94.2 = \frac{F_R}{5lb}$	$F_R = 471 lb$