Name: ________________ Class: _______

Work, Mechanical Advantage, and Efficiency

1. A container has a mass of 36 kg. How much does the container weigh?

$m = 36\ kg$
$g = 9.8\ {}^{N}/_{kg}$
$F_W = ?$

$F_W = mg$
$F_W = 36 \times 9.8$
$F_W = 352.8\ N$

∴ The container weighs 352.8 N.

2. If you were to lift the container, and place it on the back of a truck, 115 cm high, how much work would you do?

$F_W = 352.8\ N$
$d = 115\ cm$
$d = 1.15\ m$
$W = ?$

$W = Fd$
$W = 352.8 \times 1.15$
$W = 405.72\ J$

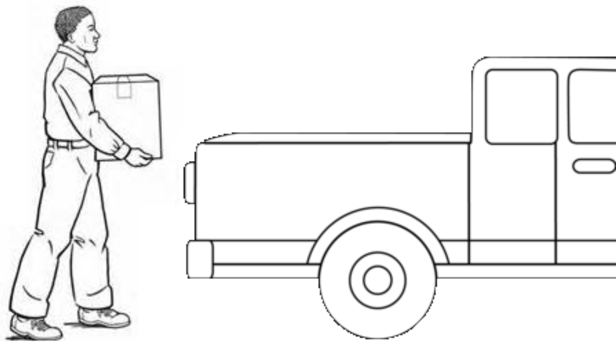
∴ It should take 405.72 J of work to put the container in the truck.

3. If it was a windy day, and it took you 450 J of energy to get the container to the back of the truck, how efficient were you?

$W_i = 450\ J$
$W_o = 405.72\ J$
$Eff = ?$

$Eff = \frac{W_o}{W_i}$
$Eff = \frac{405.72}{450}$
$Eff = 0.9016$
$Eff = 90.16\ \%$

∴ The process was about 90 % efficient.



4. For the lever shown below, what effort force would be needed to raise the load?

$d_L = 37\ cm$
$d_E = 126\ cm$
$F_L = 283$
$F_E = ?$

$\frac{d_L}{d_E} = \frac{F_E}{F_L}$

$\frac{37}{126} = \frac{F_E}{283}$

$0.294 = \frac{F_E}{283}$

$F_E = 0.294 \times 283$

$F_E = 83.1\ N$

$\therefore$ It should take 83.1 N to lift the load.

5. What is the mechanical advantage of this lever?

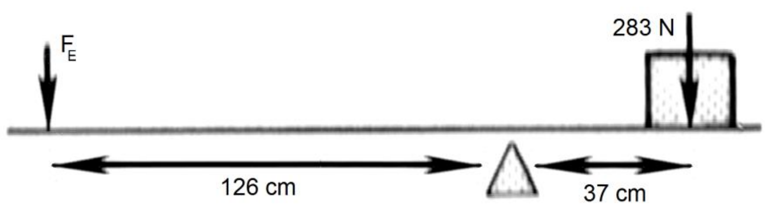
$d_L = 37\ cm$
$d_E = 126\ cm$
$IMA = ?$

$IMA = \frac{d_E}{d_L}$

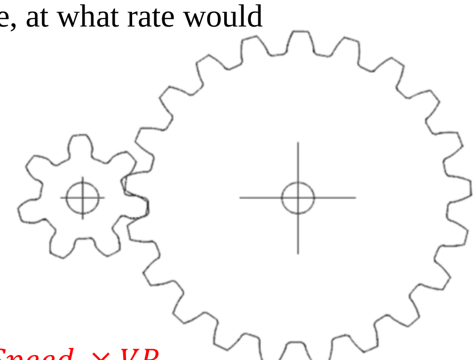
$IMA = \frac{126}{37}$

$IMA = 3.405$

$\therefore$ The mechanical advantage of the lever should be about 3.4.



6. If the larger gear below is turned at a rate of 60 rotations per minute, at what rate would the smaller gear turn?



<u>Velocity Ratio</u>

$\#Driver\ Teeth = 21$
$\#Follower\ Teeth = 7$
$VR = ?$

$VR = \frac{\#Driver\ Teeth}{\#Follower\ Teeth}$

$VR = \frac{21}{7}$

$VR = 3$

$\therefore$ The small gear turns 3 times faster.

<u>Follower Speed</u>

$Driver\ Speed = 60\ RPM$
$Follower\ Speed = ?$
$VR = 3$

$Follower\ Speed = Driver\ Speed \times VR$

$Follower\ Speed = 60 \times 3$

$Follower\ Speed = 180\ RPM$

$\therefore$ The smaller gear would turn at 180 RPM.

7. For each of the following three simple machines:
   a. What is the ideal mechanical advantage?
   b. How much force, ideally, would be needed to move the object?

<u>Weight of Box</u>

$m = 12\ kg$

$g = 9.8\ {}^{N}/_{kg}$

$F_W = ?$

$F_W = mg$

$F_W = 12 \times 9.8$

$F_W = 117.6\ N$

∴ The container weighs 117.6 N.

<u>Ideal Mechanical Advantage</u>

$h = 1.6\ m$

$l = 3.9\ m$

$IMA = ?$

$IMA = \frac{l}{h}$

$IMA = \frac{3.9}{1.6}$

$IMA = 2.4375$

∴ The ideal mechanical advantage is about 2.4.

<u>Effort Force</u>

$F_L = 117.6\ N$

$F_E = ?$

$IMA = 2.4375$

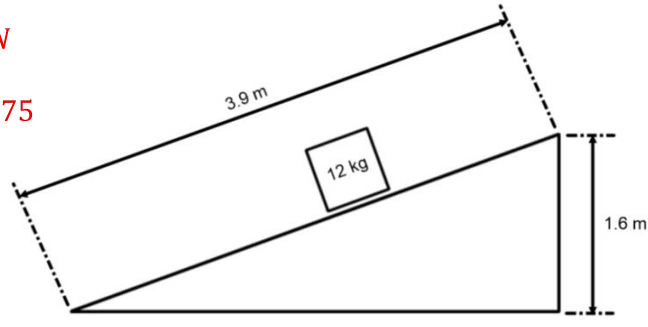
$IMA = \frac{F_L}{F_E}$

$F_E = \frac{F_L}{IMA}$

$F_E = \frac{117.6}{2.4375}$

$F_E \cong 48.246\ N$

∴ It should take about 48.2 N to move the box.



<u>Ideal Mechanical Advantage</u>

$r_w = 28\ cm$

$r_a = 6.5\ cm$

$IMA = ?$

$IMA = \frac{r_w}{r_a}$

$IMA = \frac{28}{6.5}$

$IMA \cong 4.308$

∴ The ideal mechanical advantage is about 4.3.

<u>Effort Force</u>

$F_L = 156\ N$

$F_E = ?$

$IMA = 4.308$

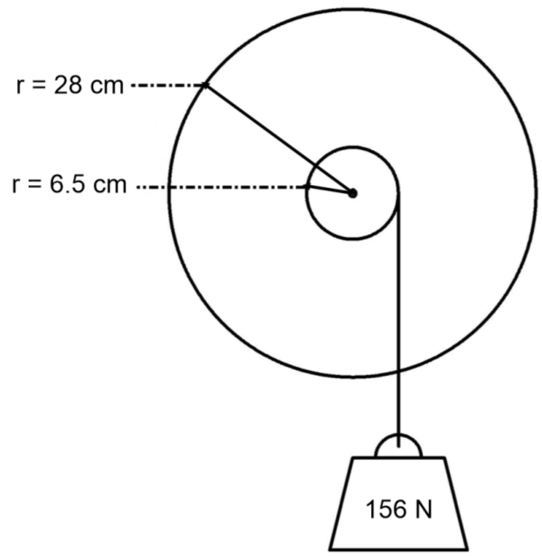
$IMA = \frac{F_L}{F_E}$

$F_E = \frac{F_L}{IMA}$

$F_E = \frac{156}{4.308}$

$F_E \cong 36.214\ N$

∴ It should take about 36.2 N to lift the load.



<u>Ideal Mechanical Advantage</u>

$Support\ Ropes = 6$

$Pulled\ Ropes = 1$

$IMA = ?$

$IMA = \frac{\#\ Support\ Ropes}{\#\ Ropes\ Pulled}$

$IMA = \frac{6}{1}$

$IMA = 6$

∴ The ideal mechanical advantage is 6.

<u>Effort Force</u>

$F_L = 3240\ N$

$F_E = ?$

$IMA = 6$

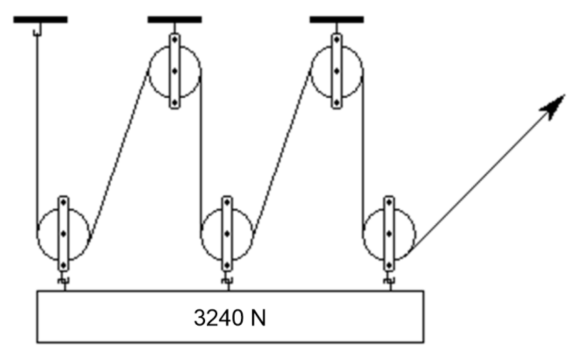
$IMA = \frac{F_L}{F_E}$

$F_E = \frac{F_L}{IMA}$

$F_E = \frac{3240}{6}$

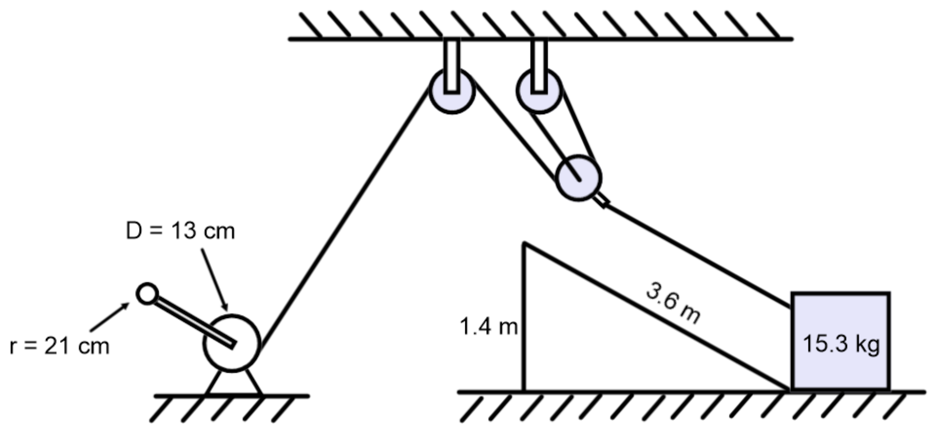
$F_E = 540\ N$

∴ It should take 540 N to lift the load.



8. The following system combines a variety of simple machines. The box is to travel up a ramp. There is a cable used to raise the box up the ramp, that cable moves through a variety of pulleys. The pulley system is attached to a winch.
   a. What is the mechanical advantage of this system?
   b. How much force, ideally, should you need to use to move the box?
   c. If the box moves to the top of the ramp by turning the crank arm with a force of 15 N, how efficient is the system?

* Note, this is a level 4 question, do what you can, but understand that not all students will be able to get a full solution. However, everyone should attempt it.



<u>IMA - Ramp</u>

$h = 1.4\ m$
$l = 3.6\ m$
$IMA_R = ?$

$$IMA_R = \frac{l}{h}$$
$$IMA_R = \frac{3.6}{1.4}$$
$$IMA_R \cong 2.571$$

<u>IMA - Pulleys</u>

$Support\ Ropes = 3$
$Pulled\ Ropes = 1$
$IMA_P = ?$

$$IMA_P = \frac{\#\ Support\ Ropes}{\#\ Ropes\ Pulled}$$
$$IMA_P = \frac{3}{1}$$
$$IMA_P = 3$$

<u>IMA – Winch (W&A)</u>

$D_W = 21 \times 2$
$D_W = 42\ cm$
$D_a = 13\ cm$
$IMA_W = ?$

$$IMA_W = \frac{D_w}{D_a}$$
$$IMA_W = \frac{42}{13}$$
$$IMA_W \cong 3.231$$

<u>IMA - System</u>

Because the three simple machines are used one after the other, they need to be multiplied, as each simple machine applies its mechanical advantage to the next.

$$IMA_S = IMA_R \times IMA_P \times IMA_W$$
$$IMA_S = 2.571 \times 3 \times 3.231$$
$$IMA_S \cong 24.923$$

∴ The ideal mechanical advantage of the system is about 24.9.

<u>Load Force (Straight Lift)</u>

$m = 15.3\ kg$
$g = 9.8\ {}^{N}/_{kg}$
$F_W = ?$

$$F_W = mg$$
$$F_W = 15.3 \times 9.8$$
$$F_W = 149.94\ N$$

∴ To lift the container without the system it would take 149.94 N.

Question 8 Continued

Effort Force

$F_L = 149.94\ N$
$F_E = ?$
$IMA = 24.923$

$$IMA = \frac{F_L}{F_E}$$
$$F_E = \frac{F_L}{IMA}$$
$$F_E = \frac{149.94}{24.923}$$
$$F_E \cong 6.016\ N$$

∴ It should take about 6.0 N to lift the load with the system.

Actual Mechancial Advantage

$F_L = 149.94\ N$
$F_E = 15\ N$
$AMA_S = ?$

$$AMA_S = \frac{F_L}{F_E}$$
$$AMA_S = \frac{149.94}{15}$$
$$AMA_S = 9.996$$

System Efficiency

$IMA_S = 24.923$
$AMA_S = 9.996$
$Eff_S = ?$

$$Eff_S = \frac{AMA}{IMA}$$
$$Eff_S = \frac{9.996}{24.923}$$
$$Eff_S \cong 0.401$$
$$Eff_S \cong 40\%$$

∴ The system is 40% efficient.