Work and Machines

1) Work – Force applied through a distance on something.

2) Calculations (Work)

$W = (F)(d)$

W = Work = Joules – J

F = Force = Newtons – N

d = distance = meters – m

Example #1

$W =$ _____ $F = 200\bar{}\ N$ $d = 10\bar{}\ m$

$W = (F)(d) = (200\bar{}\ N)(10\bar{}\ m) = 2000\bar{}\ Nm = \boxed{2000\bar{}\ J}$

Example #2

$W = 500\bar{}\ J$ $F =$ _____ $d = 5.00\ m$

$500\bar{}\ Nm$

$W = Fd$

$\frac{W}{d} = \frac{Fd}{d}$

$F = \frac{W}{d} = \frac{500 Nm}{5.00 m} = \boxed{100\bar{}\ N}$

Example #3

$W = 80.0\ J$ $F = .200\ N$ $d =$ _____

$= 80.0\ Nm$

$\frac{W}{F} = \frac{Fd}{F}$ $d = \frac{W}{F} = \frac{80.0 Nm}{.200 N} = \boxed{400\bar{}\ m}$

3) Power – rate at which work is done.

4) Calculation (Power)

$$P = \frac{W}{t} = \frac{(F)(d)}{t}$$

P = Power	= Watt =	W
W = Work	=	J
t = second		s
F = Force		N
d = distance		m

Example #1

$P =$ ____ $W = 650\ J$ $t = 10.0\ s$

$$P = \frac{W}{t} = \frac{650\ J}{10.0\ s} = 65.0\ \frac{J}{s} = 65.0\ W$$

Example #2

$P = .456\ W$ $\quad .456\ \frac{J}{s}$ $\quad W =$ ____ $\quad t = 10.0\ s$

$$P = \frac{W}{t}$$

$$t\,P = \frac{W}{t}\,t$$

$$W = (t)(P) = \left(10.0\ s\right)\left(.456\ \frac{J}{s}\right) = \boxed{4.56\ J}$$

Example #3

$P = 60.0\ W$ $\quad 60.0\ \frac{Nm}{s}$ $\quad F = \_\_\_\_$ $\quad d = 10.0\ m$ $\quad t = 5.00\ s$

$$P = \frac{Fd}{t}$$

$$\frac{t}{d}\,P = \frac{Fd}{t}\,\frac{t}{d}$$

$$F = \frac{(t)(P)}{d} = \frac{(5.00\ s)\left(60.0\ \frac{Nm}{s}\right)}{10.0\ m} = \boxed{30.0\ N}$$

Example #4

$P = 100.0\ W$ $\quad 100.0\ \frac{Nm}{s}$ $\quad F = 50.0\ N$ $\quad d = 2.00\ m$ $\quad t = \_\_\_\_$

$$P = \frac{Fd}{t}$$

$$\frac{t}{P}\,P = \frac{Fd}{t}\,\frac{t}{P}$$

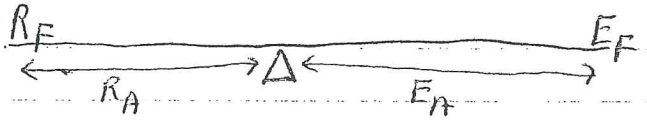
$$t = \frac{Fd}{P} = \frac{(50.0\ N)(2.00\ m)}{100.0\ \frac{Nm}{s}} = \boxed{1.00\ s}$$

5) Machine – device that makes work easier.

6) Simple machine – device that does work with one movement or motion.

7) 6 simple machine – lever, wheel and axle, pulley, inclined plane, wedge, screw.

8) Work done by machines



Resistance Force = R_F (Load)
Resistance Arm = R_A
Effort Force = E_F (lift)
Effort Arm = E_A
Work (Resistance) = W_R
Work (Effort) = W_E

Balance

$W_R = W_E$

IF Work = (Force)(distance)

$W_R = W_E$

$(R_F)(R_A) = (E_F)(E_A)$

or

$(F_{out})(d_{out}) = (F_{in})(d_{in})$

W_R = Work output = W_o

W_E = Work input = W_I

9) Calculation (Work on lever)

$R_F = 60\,N$ $R_A = 4m$ $E_A = 6m$ $E_F =$ _____

$\frac{R_F R_A}{E_A} = \frac{E_F E_A}{E_A}$ $E_F = \frac{(R_F)(R_A)}{E_A} = \frac{(60\,N)(4m)}{6m} =$ **40 N**

10) Obeying the Law of Conservation of energy:

Work output = Work input (Balanced)

or

Work input $\geq$ Work output

Effort side — Resistance or load side

11) Actual Mechanical Advantage - (AMA) = Resistance Force or Output force divided by the effort force or Input force.

$$AMA = \frac{R_F}{E_F} \quad \text{or} \quad AMA = \frac{F_{out}}{F_{in}}$$

12) Calculation (AMA)

$R_F = 10.0\,N$ $E_F = 2.0\,N$ $AMA =$ ____

$$AMA = \frac{R_F}{E_F} = \frac{10.0\,N}{2.0\,N} = 5.0$$

13) Ideal Mechanical Advantage (IMA) = mechanical advantage of a machine without friction.

1) lever $IMA = \frac{E_A}{R_A}$ 2) Wheel and axle $IMA = \frac{D_W}{D_A}$ (D_W ← diameter wheel, D_A ← diameter axle)

3) Pulley IMA = # OF bearing ropes 4) Inclined plane $I = \frac{L_P}{H_P}$ (L_P – length, H_P – height)

5) Wedge $IMA = \frac{L_W}{T_W}$ (L_W – length, T_W – Thickness) 6) Screw $IMA = \frac{L_T}{L_S}$ (L_T – length threading, L_S – length screw)

14) Efficiency – ratio of work out to the work input in percentage.

$$EFF = \frac{W_O}{W_I} \times 100\% \qquad EFF = \frac{R_F R_A}{E_F E_A} \times 100\%$$

$$EFF = \frac{AMA}{IMA} \times 100\%$$

15) Calculation (Efficiency) (Exampl. #1)

$AMA = 4 \quad IMA = 10 \quad EFF = \_\_\_\_$

$$EFF = \frac{AMA}{IMA} \times 100\% = \left(\frac{4}{10}\right)(100\%) = \boxed{40\%}$$

(Exampl. #2)

$W_O = 6\,J \quad W_I = 12\,J \quad EFF = \_\_\_\_$

$$EFF = \frac{W_O}{W_I} \times 100\% = \frac{6}{12} \times 100\% = \boxed{50\%}$$

(Exampl. #3)

$R_F = 10.0\,N \quad R_A = 2.00\,m \quad E_F = 4.00\,N \quad E_A = 6.00\,m \quad EFF = \_\_\_\_$

$$EFF = \frac{R_F R_A}{E_F E_A} \times 100\% = \frac{(10.0\,N)(2.00\,m)}{(4.00\,N)(6.00\,m)} \times 100\% = \boxed{83.3\%}$$

(Exampl. #4)

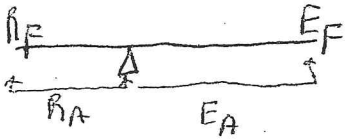
$EFF = 5.50\% \quad W_O = 9.50 \quad W_I = \_\_\_\_$

$$EFF = \frac{W_O}{W_I} \qquad W_I = \frac{W_O}{EFF} = \frac{9.50}{.0550} = \boxed{173}$$

16) Lever – device that has a bar that pivots on a fulcrum.

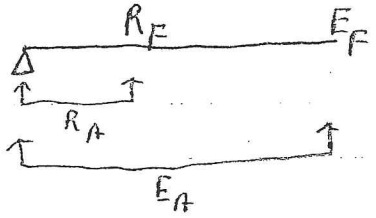
17) 3 Classes of Levers:

1st Class



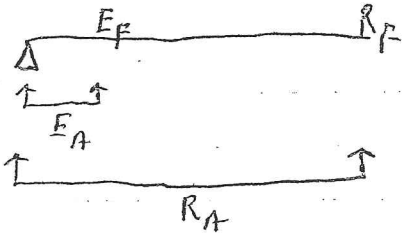
$IMA = \frac{E_A}{R_A}$

2nd class



$IMA = \frac{E_A}{R_A}$

3rd Class

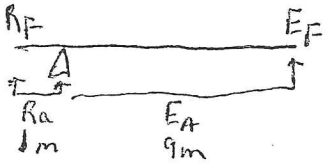


$IMA = \frac{E_A}{R_A}$

18) Calculation (Mechanical advantage)

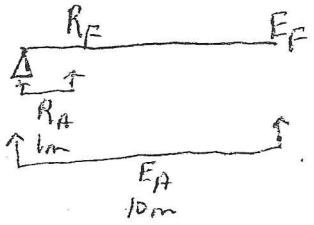
Example #1 Which has a greater mechanical advantage, a 1st class or 2nd class lever 10.0 m long and the resistance arm 1.00 m from the load?

1st Class



$IMA = \frac{E_A}{R_A} = \frac{9m}{1m} = \boxed{9}$

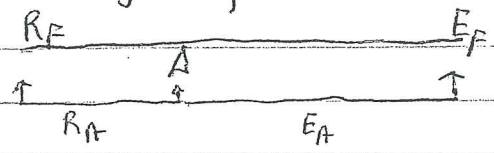
2nd Class



$IMA = \frac{E_A}{R_A} = \frac{10m}{1m} = \boxed{10}$

✓

19) Center of gravity on levers:



$W_R = W_E$

$(R_F)(R_A) = (E_F)(E_A)$

Given $R_F = 1000N$ $R_A =$ ____ $= X_m$ $E_A =$ ____ $= 10m - X_m$ $E_F = 100N$ lever $= 10m$

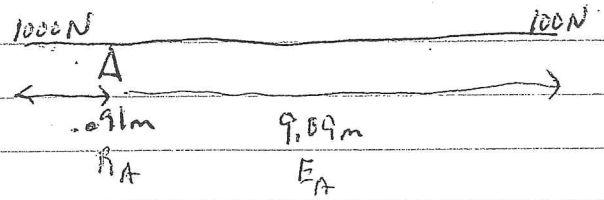
$R_F R_A = E_F E_A$

$(1000N)(X_m) = (100N)(10m - X_m)$

$100XNm + 1000XNm = 1000Nm - 100XNm + 100XNm$

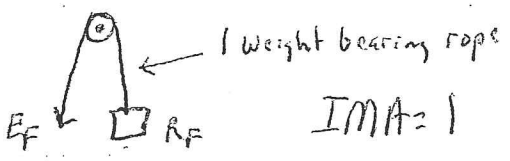
$1100XNm = 1000Nm$

$X = \frac{1000\,Nm}{1100\,Nm} = .91$



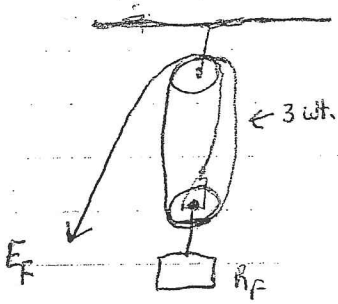
20) Pulley – Type of lever using wheels and axle with ropes or chains.

Example #1 Fixed pulley



IMA = 1

#2 Multiple pulleys

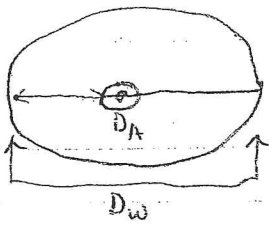


IMA = 3

Note: It takes less force to move the load but you have to move a greater distance of rope.

21) Wheel and axle – Type of lever using a wheel rotating on axle

Example #1



$$IMA = \frac{D_W}{D_A}$$

$D_W = 10.0\text{ cm}$ $D_A = 1.00\text{ cm}$ $IMA =$ _____

$$IMA = \frac{D_W}{D_A} = \frac{10.0\text{ cm}}{1.00\text{ cm}} = \boxed{10}$$

22 Inclined plane - device with a sloping surface.

Example #1

(A)

$IMA = \frac{L_p}{H_p} = \frac{5m}{1m} = 5$

(B)

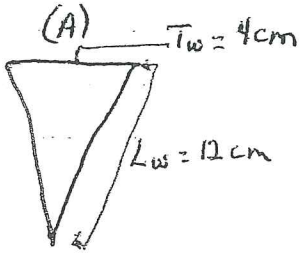
$IMA = \frac{L_p}{H_p} = \frac{10m}{1m} = 10$

Note: Plane A is 2 times harder to go up
Plane B is 2 time farther to travel.
What you gain in force advantage you lose in distance travelled!

23 Wedge - (device) a type of inclined plane.

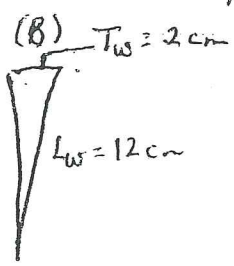
Exampl.

(A)



$IMA = \frac{L_w}{T_w} = \frac{12\,cm}{4\,cm} = 3$

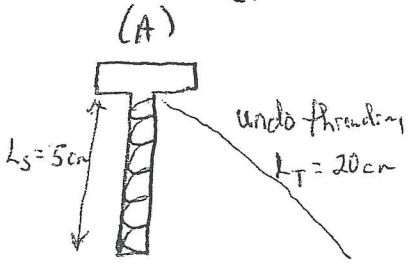
(B)



$IMA = \frac{L_w}{T_w} = \frac{12\,cm}{2\,cm} = 6$

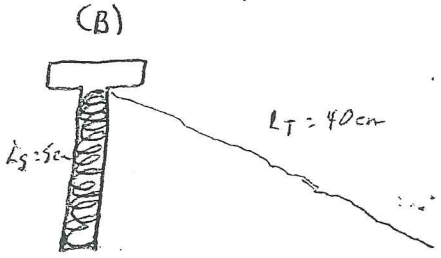
24 Screw - (device) a spiraled inclined plane.

(A)



$IMA = \frac{L_T}{L_s} = \frac{20\,cm}{5\,cm} = 4$

(B)



$IMA = \frac{L_T}{L_s} = \frac{40\,cm}{5\,cm} = 8$

25) Compound - device made up of 2 or more simple machines working together.

Problems

1) How much work is done when 425 N of force is applied for 60.0 m?

2) How much power is needed to do 675 J of work in 5 seconds?

3) How long will take to move 755 N of force on an object for 5000.0 m using 75.0 W of power?

4) How much weight can be lifted using a 10.5 m bar with the fulcrum .500 m from the load and the effort force being 25.0 N using a 1st class lever?

5) What is the mechanical advantage of a device lifting 4000 N using 200 N of force?

6) What is the mechanical advantage a wedge that is 400 cm long and 10.0 cm thick on one end?

7) What is the efficiency of a pulley system with 4 weight bearing ropes lifting a 6000 N load using 3000 N of effort?