

THE INCLINED PLANE – A SIMPLE MACHINE

LAB MECH14

From *Laboratory of Elementary Physics, Westminster College*

INTRODUCTION

Our industrial world makes much use of the principles of mechanics as exemplified in simple machines. Simple machines are defined in two principle categories, the inclined plane and the lever. The lever further, includes the pulley and the wheel-and axle and the inclined plane also includes the screw and the wedge.

The applications of simple machines generally provide some benefit or advantage for doing work. In this experiment a car moving on an incline or ramp will be considered as a simple machine, which has many applications in our world, such as a truck hauling freight up a hill or using a ramp to load a heavy object on the back of a truck.

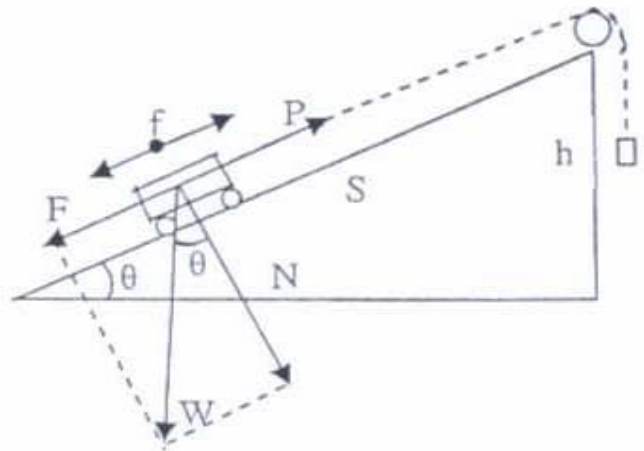
The car and its load, W due to its weight, is pulled up the tilted plane at approximately constant velocity by a hanging weight, P_u . The magnitude of the hanging weight is then adjusted, now identified as P_d , so that the car moves down the tilted plane, again with approximately uniform motion. The actual mechanical advantage, AMA, is defined as the ratio of the load, W , lifted to the force pulling it up the plane. Thus we have

$$AMA = W/P_u. \quad (1)$$

The theoretical mechanical advantage TMA, is defined as the ratio of the load lifted to the force, F' , that would be required to pull it up the plane (so parallel to the plane) if there were no friction, so

$$TMA = W/F'. \quad (2)$$

Let F be the force of the gravitational mass or weight W component down the plane equal and in opposite direction of F' . P_u and P_d differ in magnitude from each other and from F' or F because of force of friction f . The force of friction acts opposite to the direction of the motion so parallel to the plane.



For the ideal case of no friction, the work done by force F' in pulling the load up the plane of length s is $F's$ which equals the work done in lifting the weight, W , to a height of h , so we write

$$F' s = Wh \quad (3)$$

and so
$$W/F' = s/h = \text{TMA}. \quad (4)$$

Note these quantities as indicated on the diagram. Defining angle of tilt as θ , in terms of trigonometry, it follows that

$$\sin \theta = h/s \quad (5)$$

which from equation (4), gives

$$\text{TMA} = 1/\sin \theta.$$

The TMA can also be determined from experimental data: P_u , P_d , and f ; according to

$$P_u = F + f \quad (6) \quad \text{and} \quad P_d + f = F. \quad (7)$$

Then by combining equations (6) and (7) by addition, we have

$$P_u + P_d = 2F \text{ or } F = (P_u + P_d)/2. \quad (8)$$

This value of F is also the magnitude of F' , so by equation (4) TMA can be obtained. The coefficient of friction, k , is defined as the ratio of the force of friction to the normal force N , that is, the component of the weight W perpendicular to the tilted plane, so

$$k = f/N \quad (9)$$

with $N = W \cos \theta$.

By subtracting equation (7) from equation (6) we obtain

$$P_u - P_d = 2f \text{ or } f = (P_u - P_d) / 2. \quad (10)$$

The efficiency of a machine, E , is defined as the ratio of the amount of work done by a machine to the amount of work put into the machine, that is

$$E = W_h / P_u s. \quad (11)$$

PURPOSE

The purpose of this experiment is to experimentally study the mechanical advantage of an inclined plane as a simple machine and to obtain a value of its efficiency.

MATERIALS

adjustable tilt inclined plane with pulley	meter stick
car	string
masses (to include several small masses)	wood blocks
mass hanger	protractor
balance	calculator
C-clamps	

PRELIMINARY QUESTIONS

1. State some additional (beyond those already mentioned in this write-up) examples of practical applications of the inclined plane as a simple machine.
2. Discuss the maximum work output of an inclined plane as it compares to the work input.
3. Explain why a screw can be thought of as an inclined plane.

PROCEDURE

1. A Data Table is provided for reporting your various basic data and results.
2. Set the tilt of the plane at an angle of about 15° with the horizontal. To obtain a good angle value; with respect to the sine function, measure the total length and corresponding vertical height of the plane.
3. Place the car with a desirable load on the incline.
4. Put masses on the mass hanger so that the car moves up the plane with approximately uniform motion. Record this force up the plane of these masses as P_u .
5. In a similar manner find P_d , the force down the plane, with an appropriate choice of masses.
6. Now set the tilt at about 25° and repeat the procedures steps 3-5.

DATA TABLE

Trial	Tilt angle (deg)	Car mass (kg)	Load mass (kg)	Weight car + load (N)	Force up P_u (N)	Force down P_d (N)
1						
2						
Trial	Force F (N)	Friction force f (N)	AMA	TMA	Efficiency (total weight)	Efficiency (load weight)
1						
2						

ANALYSIS

1. With equation (8), find F for each of the tilts; also for each find f with equation (10).
2. For each tilt compute AMA, TMA, and efficiency E considering W the weight of the car and load. Now considering the useful work done as lifting the mass load placed on the car, compute the efficiency for the two tilts noting that W in equation (11) is now only the weight of the mass load added to the car.
3. How does conservation of energy apply to this system? Draw a force diagram for the car moving up the plane and one for it moving down the plane, clearly showing the forces acting on the car. Why is it important that the speed of the car be approximately uniform? How does the mechanical advantage vary with the inclination of the plane?