SIR CHHOTU RAM INSTITUTE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

ENGINEERING MECHANICS (BT-419)

NOTES ON WEDGE FRICTION

You can also learn wedge friction by using following link

https://www.youtube.com/watch?v=UJC7hOKjscs&feature=youtu.be

The above link contains a lecture of Prof. Mahesh Panchagnula (IIT Madras) on wedge friction

7.3. Wedge Friction

A wedge is, usually, of a triangular or trapezoidal in cross-section. It is, generally, used for slight adjustements in the position of a body *i.e.* for tightening fits or keys for shafts. Sometimes, a wedge is also used for lifting heavy weights as shown in Fig. 7.10.

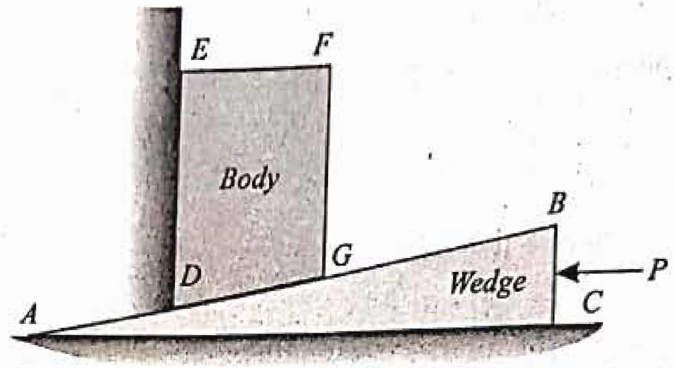


Fig. 7.10.

It will be interesting to know that the problems on wedges are basically the problems of equilibrium on inclined planes. Thus these problems may be solved either by the equilibrium method or by applying Lami's theorem. Now consider a wedge *ABC*, which is used to lift the body *DEFG*.

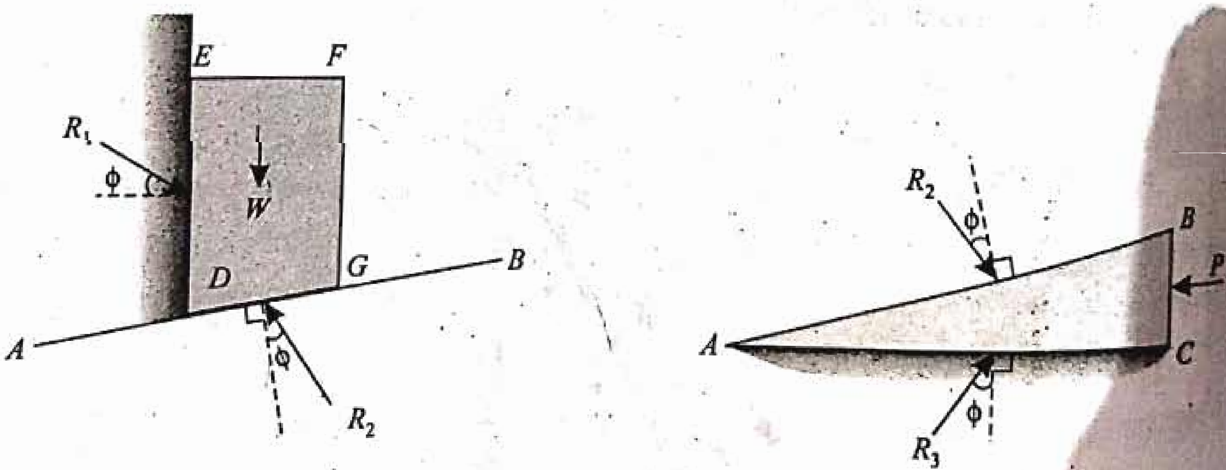
Let W = Weight fo the body *DEFG*,

P = Force required to lift the body, and

μ = Coefficient of friction on the planes *AB*, *AC* and *DE* such that

$\tan \phi = \mu$.

A little consideration will show that when the force is sufficient to lift the body, the sliding will take place along three planes *AB*, *AC* and *DE* will also occur as shown in Fig. 7.11 (*a*) and (*b*).



(*a*) Forces on the body *DEFG* (*a*) Forces on the wedge *ABC*

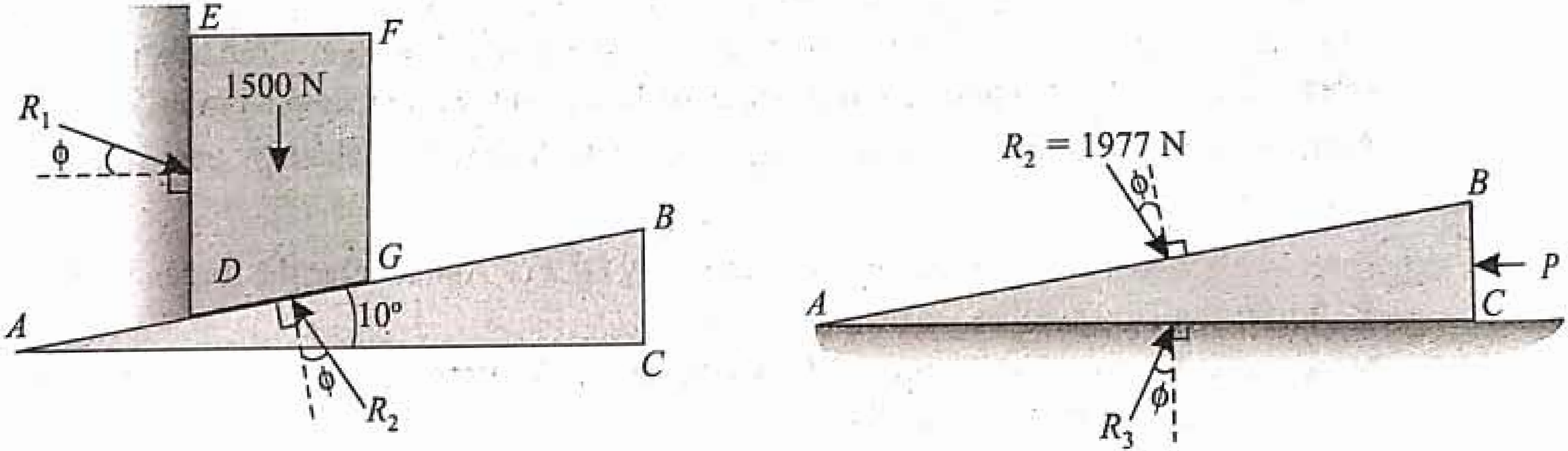
Fig. 7.11.

The three reactions and the horizontal force (P) may now be found out either by graphical method or analytical method as discussed below:

Graphical method

1. First of all, draw the space diagram for the body *DEFG* and the wedge *ABC* as shown in Fig. 7.12 (*a*). Now draw the reactions R_1, R_2 and R_3 at angle f with normal to the faces *DE*, *AB* and *AC* respectively (such that $\tan \phi = \mu$).

Analytical method



(*a*) Block *DEFG* (*b*) Wedge *ABC*

Fig. 7.14.

First of all, consider the equilibrium of the block. We know that it is in equilibrium under the action of the following forces as shown in Fig. 7.14 (*a*).

1. Its own weight 1500 N acting downwards.
2. Reaction R_1 on the face *DE*.
3. Reaction R_2 on the face *DG* of the block.

Resolving the forces horizontally,

$$R_1 \cos(16.7°) = R_2 \sin(10 + 16.7°) = R_2 \sin 26.7°$$

$$R_1 \times 0.9578 = R_2 \times 0.4493$$

or $$R_2 = 2.132\, R_1$$

and now resolving the forces vertically,

$$R_1 \times \sin(16.7°) + 1500 = R_2 \cos(10° + 16.7°) = R_2 \cos 26.7°$$

$$R_1 \times 0.2874 + 1500 = R_2 \times 0.8934 = (2.132\, R_1)0.8934$$

$$= 1.905\, R_1 \qquad ...(R_2 = 2.132\, R_1)$$

$$R_1(1.905 - 0.2874) = 1500$$

$$\therefore \quad R_1 = \frac{1500}{1.6176} = 927.3 \text{ N}$$

and $$R_2 = 2.132\, R_1 = 2.132 \times 927.3 = 1977 \text{ N}$$

Now consider the equilibrium of the wedge. We know that it is in equilibrium under the action of the following forces as shown in Fig. 7.14 (*b*).

1. Reaction R_2 of the block on the wedge.
2. Force (P) acting horizontally, and
3. Reaction R_3 on the face AC of the wedge.

Resolving the forces vertically,

$$R_3 \cos 16.7° = R_2 \cos(10° + 16.7°) = R_2 \cos 26.7°$$

$$R_3 \times 0.9578 = R_2 \times 0.8934 = 1977 \times 0.8934 = 1766.2$$

$$\therefore \quad R_3 = \frac{1766.2}{0.9578} = 1844 \text{ N}$$

and now resolving the forces horizontally,

$$P = R_2 \sin(10° + 16.7°) + R_3 \sin 16.7° = 1977 \sin 26.7° + 1844 \sin 16.7° \text{ N}$$

$$= (1977 \times 0.4493) + (1844 \times 0.2874) = 1418.3 \text{ N} \qquad \textbf{Ans.}$$

Example 7.7. *A 15° wedge (A) has to be driven for tightening a body (B) loaded with 1000 N weight as shown in Fig. 7.15.*

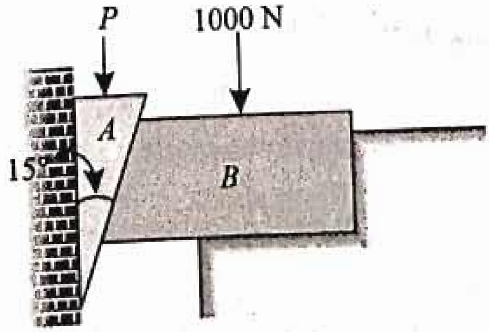
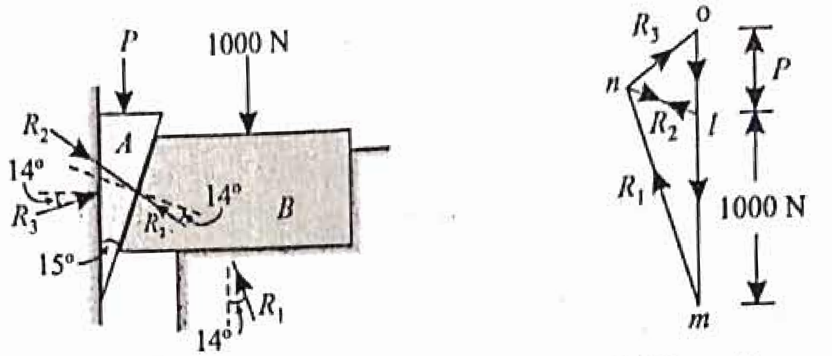


Fig. 7.15.

If the angle of friction for all the surfaces is 14°, find graphically the force (P), which should be applied to the wedge. Also check the answer analytically.

Solution. Given: Angle of the Wedge (α) = 15°; Weight acting on the body (W) = 1000 N and angle of friction for all the surfaces of contact (ϕ) = 14°.

Graphical solution



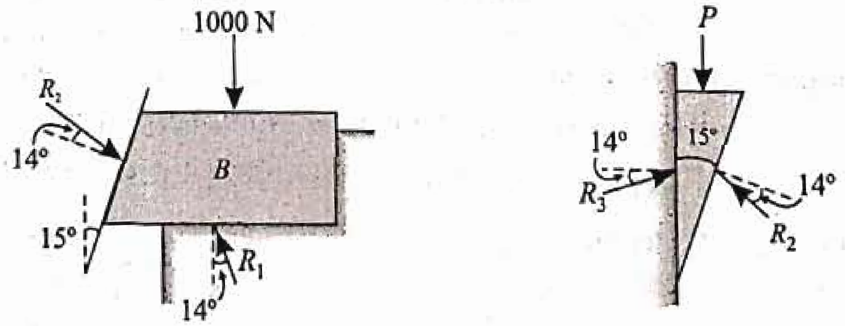
(*a*) Space diagram (*b*) Vector diagram

Fig. 7.16.

1. First of all, draw the space diagram for the body (B) and wedge (A) as shown in Fig. 7.16 (a). Now draw the reactions R_1, R_2 and R_3 at angles of 14° with normal to the faces.
2. Take some suitable point l and draw a vertical line lm equal to 1000 N to some suitable scale, representing the weight of the body. Through l draw a line parallel to the reaction R_2. Similarly, through m draw another line parallel to the reaction R_1 meeting first line at n.
3. Now through l draw a vertical line representing the vertical force (P). Similarly, through n draw a line parallel to the reaction R_3 meeting the first line at O as shown in Fig. 7.16 (b).
4. Now measuring ol to the scale, we find that the required vertical force, $P = 232$ N **Ans.**

Analytical check

First of all, consider equilibrium of the body: We know that it is in equilibrium under the action of the following forces as shown in Fig. 7.17 (a).



(*a*) Body *B* (*b*) Wedge *A*

Fig. 7.17.

1. Its own weight 1000 N acting downwards
2. Reaction R_1 acting on the floor, and
3. Reaction R_2 of the wedge on the body.

Resolving the forces horizontally,

$$R_1 \sin 14° = R_2 \cos (15° + 14°) = R_2 \cos 29°$$

$$R_1 \times 0.2419 = R_2 \times 0.8746$$

$$\therefore \qquad R_2 = \frac{0.8746}{0.2419} R_2 = 3.616 R_2$$

and now resolving the forces vertically,

$$R_2 \sin(15° + 14°) + 1000 = R_1 \cos 14°$$

$$R_2 \times 0.4848 + 1000 = R_1 \times 0.9703 = (3.616\,R_2)\,0.9703 \qquad = 3.51\,R_2 \qquad ...(\because R_1 = 3.616\,R_2)$$

or $$1000 = R_2\,(3.51 - 0.4848) = 3.0252\,R_2$$

$$\therefore \qquad R_2 = \frac{1000}{3.0252} = 330.6 \text{ N}$$

Now consider equilibrium of the wedge. We know that it is in equilibrium under the action of the following forces as shown in Fig. 7.17. (*b*) :

1. Reaction R_2 of the body on the wedge,
2. Force (P) acting vertically downwards, and
3. Reaction R_3 on the vertical surface.

Resolving the forces horizontally,

$$R_3 \cos 14° = R_2 \cos(14° + 15°) = R_2 \cos 29°$$

$$R_3 \times 0.9703 = R_2 \times 0.8746 = 330.6 \times 0.8746 = 289.1$$

$$\therefore \qquad R_3 = \frac{289.1}{0.9703} = 297.9 \text{ N}$$

and now resolving the forces vertically,

$$P = R_3 \sin 14° + R_2 \sin(14° + 15°)$$

$$= (297.9 \times 0.2419) + (330.6 \times 0.4848) = 232.3 \text{ N} \quad \textbf{Ans.}$$

EXERCISE 7.2

1. A block (A) of weight 5 kN is to be raised by means of a 20° wedge (B) by the application of a horizontal force (P) as shown in Fig. 7.18. The block A is constrained to move vertically by the application of a horizontal force (S). Find the magnitude of the forces F and S, when the coefficient of friction at the contact surfaces is 0.25.

   [Ans. 4.62 kN; 3.77 kN]

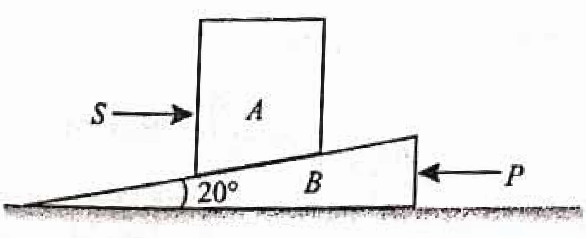


Fig. 7.18.

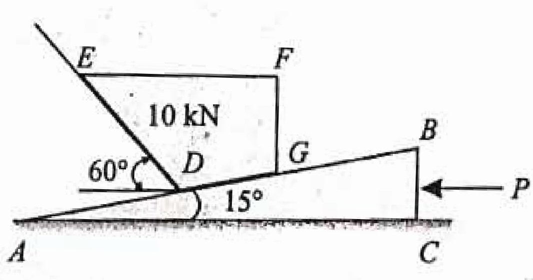


Fig. 7.19.

2. A block weighing 10 kN is to be raised against a surface, which is inclined at 60° with the horizontal by means of a 15° wedge as shown in Fig. 7.19.

   Find graphically the horizontal force (P) which will just start the block to move, if the coefficient of friction between all the surfaces of contact be 0.2. Also check the answer analytically. **[Ans. 6 kN]**