ORTHOLETTER

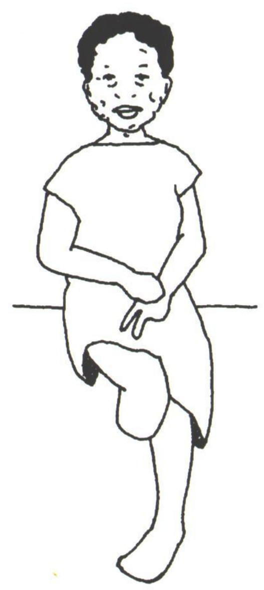
A NEWSLETTER ON ORTHOPAEDIC TECHNOLOGY IN DEVELOPING COUNTRIES

Number 4*

What is Hansen's Disease (Leprosy)?

Through many hundreds of years, leprosy has been one of the world's most terrifying diseases. The infected people, having deformed faces and extremities, were often considered as having been punished by some higher power and they were isolated from the rest of the society and sent to leper colonies. Though it is today known that the disease is only slightly infectious and that it can be cured, the fear and the social rejection are still a reality.

The treatment of the disease consists of two parts; medical treatment to cure the infection and, equally important, actions to prevent secondary disabilities. Physiotherapy, surgery and technical orthopaedic services play an important role in this work. The provision of proper orthopaedic footwear to prevent blisters in insensitive feet is one of the steps to help patients return to the community and lead a normal life. ....**page 2**



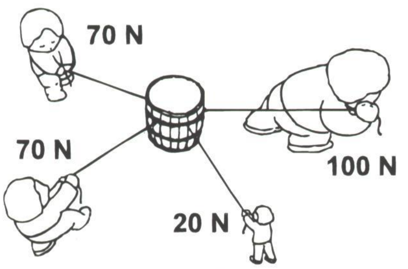
Hansen's Disease (Leprosy)

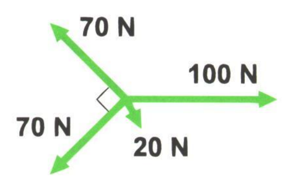
Training in Hansen's Disease: ALERT

The All Africa Leprosy and Rehabilitation Training Centre, ALERT, in Ethiopia, was created in the 1960s to provide services for medical care and rehabilitation of patients with Hansen's disease. The centre plays an important role in international leprosy research and it provides various training courses. It also accommodates an orthopaedic workshop where the working methods are principally based on local materials. ....**page 5**

Biomechanics in Prosthetics and Orthotics (2)

In the first part of *Biomechanics in Prosthetics and Orthotics*, some fundamental definitions in mechanics were described. Among other things we saw that *forces* can be represented by *vectors* and thus visualised. In this, the second part, we will utilise this fact when we learn how to add forces together. This will be done *graphically*, which means that vectors are drawn to a chosen scale in a diagram.





The forces as seen from above (Scale: 1 cm = 50 N)

Problem. The boys are pulling the barrel in different directions and with various forces. In what direction will the barrel move? (The frictional force between the barrel and the floor can be neglected.) A solution will be presented in the next issue.

There are various problems in mechanics to which graphical methods can be applied. Look at the figure on the left, for example; in what direction is the barrel likely to move if it is acted upon by the forces? To know exactly, we will have to replace the four forces with *one single force* that has exactly the same effect on the barrel as the others acting together. Such a single force is called a *resultant,* and one of the basic problems in statics is to find the resultant of two or more forces. Before you solve this particular problem, you can learn more about forces and how they can be treated graphically. We will also see how *equilibrium problems* are approached by the drawing of a *free body diagram* and we will learn *the first condition for equilibrium*. ....**page 6**

* Corresponding to Issue 2 - 1994

Biomechanics in Prosthetics and Orthotics (2)

Force analysis

Force systems

As was shown in the first part, bodies on earth are acted upon by *the force of gravity*, which is a force that pulls the bodies *downwards*. Clearly, since few bodies are actually falling, most of them are also acted upon by a force which is directed *upwards*. This is usually the *reaction force* of the floor or the ground (figure 1).

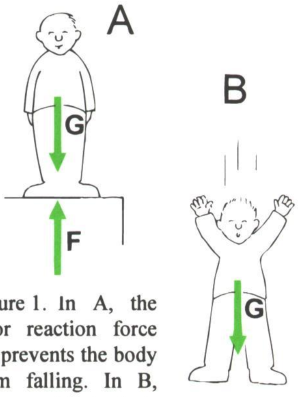


Figure 1. In A, the floor reaction force (F) prevents the body from falling. In B, however, the body is no longer acted upon by the floor and, consequently, the force of gravity (G) causes it to fall.

In real life many bodies are also acted upon by other forces that may have various directions. When two or more forces are acting on an object, the group of forces is called a *force system*. Depending on how the forces are arranged, force systems can be divided into different types. The three main arrangements are:

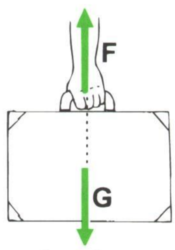


Figure 2. *Linear force system*. The downward force (the gravitational pull, G) is opposed by an equal upward force (F) exerted by the hand (otherwise the suitcase would fall). The two forces share the same action line.

1. **Linear force system**, in which all forces occur along the same action line. Many well-known force situations belong to this category, such as a suitcase held in the hand (figure 2) or a tug-of-war (figure 3).

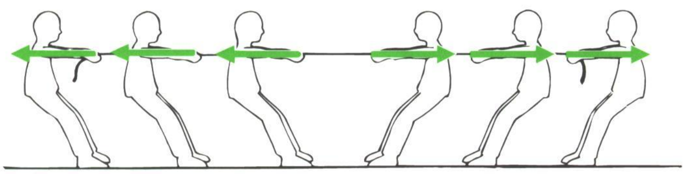


Figure 3. Tug-of-war. When the two teams are pulling the rope in opposite directions their forces are acting along the same line, thus representing a *linear force system*.

2. **Parallel force system**, in which all forces are parallel and occurring in the same plane but not along the same action line. This type may be represented by two children balancing on a see-saw (figure 4).

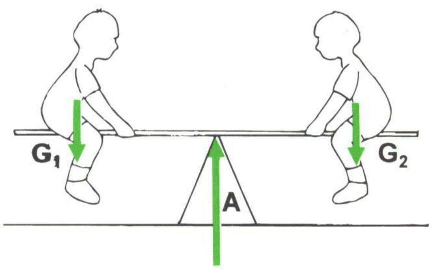


Figure 4. *Parallel force system*. The children exert downward forces (G_1 and G_2) which must be opposed by the upward force (A) at the axis of the board. All forces are parallel.

3. **Concurrent force system**, in which all forces meet at the same point. Traction devices may provide examples of this arrangement of forces (figure 5).

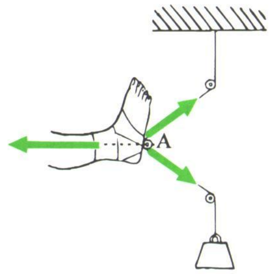


Figure 5. Leg traction, as performed in the picture, represents a *concurrent force system*. All forces are acting through point A.

When the forces cannot be covered by any of the above mentioned three types alone the arrangement is called a *general force system*.

Composition of forces

Many forces may be acting on a body simultaneously. Sometimes it is necessary to know the final effect of all the forces, or the *resultant*, which is the simplest force that can produce the same effect as all the forces acting together. The process of adding two or more force vectors together is called *composition* of forces.

It is easy to see that two forces in a linear force system can be replaced by one single force; if the forces are acting in the *same direction*, the resultant will be equal to the *sum* of the two forces (figure 6); if they are acting in *opposite directions*, the resultant will be equal to the *difference* between the two forces (figure 7). In a similar way, we may also calculate the resultant for a linear force system consisting of several forces (figure 8).

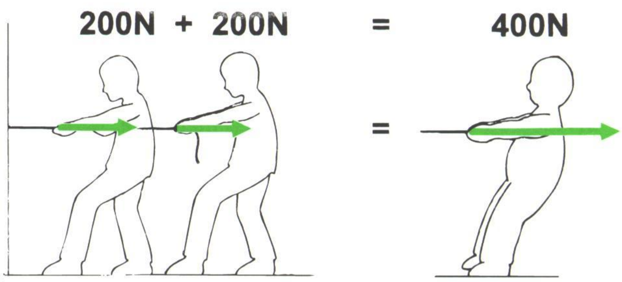


Figure 6. If two forces are acting in the same direction in a linear force system, the resultant may be determined by *addition* of the forces.

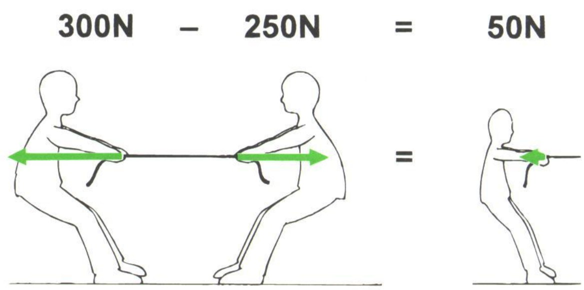


Figure 7. If the forces are acting in opposite directions, the resultant may be determined by *subtraction*.

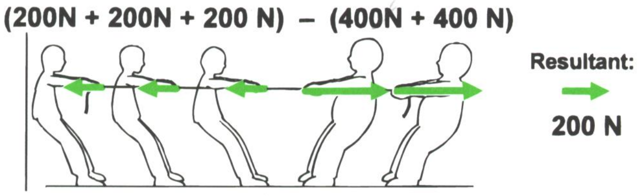


Figure 8. If there are more than two forces present, the resultant for the whole system is found by first adding the forces in each direction and then taking the difference between these two sums. Thus, in the figure we will get -200 N, which means that the resultant (R) is 200 N and directed to the right. Consequently, the team pulling in that direction will win!

In a concurrent force system, with two or more forces acting at the same point but forming an angle with each other (figure 9), it is no longer possible to determine the resultant by using the basic algebraic summation described above. There are, however, other, *graphic* methods. If there are only two forces, either the *parallelogram method* (figure 10) or the *triangle method* (figure 11) may be used. Where more than two forces are involved, the triangle method can be extended to the *polygon method* (figure 12).

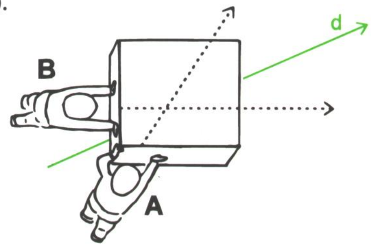


Figure 9. When two forces are acting on an object in different directions, it will move in a third direction (d), which corresponds to the direction of the resultant of the two forces.

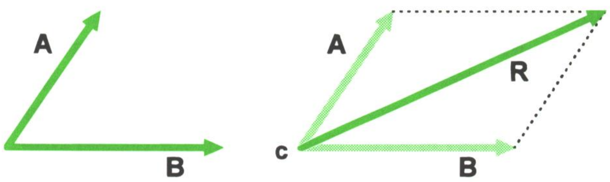


Figure 10. To determine the resultant with the *parallelogram method*, the two forces (A and B) are drawn to a chosen scale, with the correct angle between them, letting the length of the vectors represent the magnitude of the forces. Now the other two sides of the parallelogram can be constructed. (As we can understand from the name of this method, these sides should be *parallel* to the two sides represented by the vectors.) A line drawn from the initially selected point (c) to the opposite corner of the parallelogram gives the resultant force (R). The magnitude of the resultant is determined by measuring its length. It will have exactly the same effect on the object as the two original forces combined.

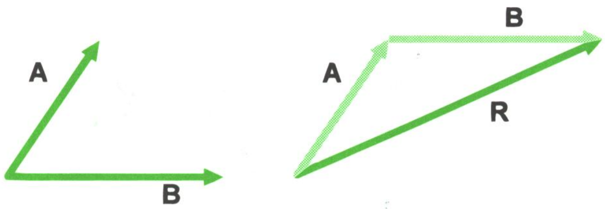


Figure 11. In the *triangle method*, one of the two force vectors is first drawn to a chosen scale and in its original direction. The other is then drawn from the tip of the first, also to the chosen scale and following its original direction. The resultant vector (R) is found by joining the tail of the first vector to the head of the last. Note that the result is the same as when using the parallelogram method (figure 10); it is a matter of convenience which method to use.

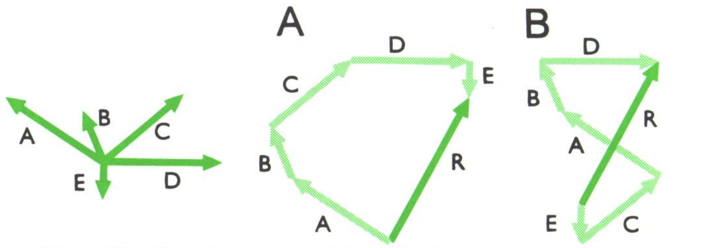


Figure 12. *The polygon method* is used when more than two forces are involved. Here the vectors are placed end to end in the same manner as in the triangle method. The resultant (R) is found by joining the tail of the first vector to the head of the last. Note that the order in which the vectors are added is of no importance; the resultant in A is the same as in B.

Resolution of forces

As we have just seen, any pair of concurrent forces has a resultant. Consequently, it must also be true that any *single* force can be considered to be the resultant of a pair of concurrent forces. When solving problems in mechanics, it is sometimes useful to replace a single force by two *components*, i.e. two forces that have the same effect on the object as the original force. This is called *resolution* of a force and is exactly the reverse process of composition (figure 13).

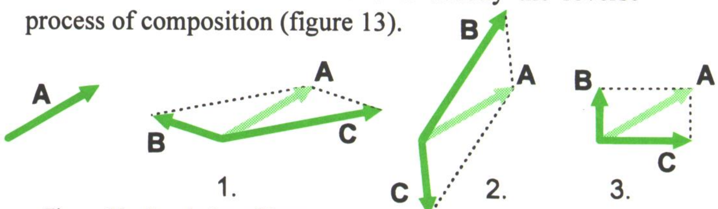


Figure 13. *Resolution of force*.
From the force (A), two components (B and C) are constructed to produce a parallelogram. As we can see, this may be done in different ways. In fact, there is no limit to the magnitude or direction of the vectors; the only criterion is that they should make up the sides of a parallelogram in which the original force forms the diagonal. In biomechanical problems, however, it is often convenient to make a rectangular resolution (number 3).

Solving problems in statics

There are two general problems which form the basis for the subject of statics. The first type of problem involves *finding the resultant*. We have already seen how this can be done graphically and we are able to solve problems like the one on the front page.

The other basic problem is called the *equilibrium problem*. In this type we study objects that are known to be at rest (in equilibrium) while acted upon by various forces. Some of these forces are usually known; their magnitude and direction, or one of them, is given to us in the presentation of the problem. To find a solution, however, we have to determine the *unknown forces*. As an example, we will now see how the following equilibrium problem can be graphically solved:

Problem. A tug-of-war competitor (figure 14) has a weight of 800 N. What will be the magnitude and direction of the *floor reaction force* if he is pulling the rope with a force of 400 N?

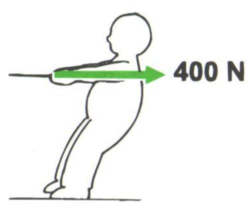


Figure 14.

Solution. When solving a statics problem like this, the first step should always be to draw a figure that shows *all* of the forces that are acting on the object concerned (also those that are unknown, like the floor reaction force in our problem). Such a figure, or a *free body diagram*, will help us to visualise the problem and give us an idea of how to approach it. The basic principle when making the diagram is that all surrounding bodies should be removed from the object and replaced by forces in such a way that these give the same effect on the object as the removed bodies had. The following figure shows how this is done in our particular problem:

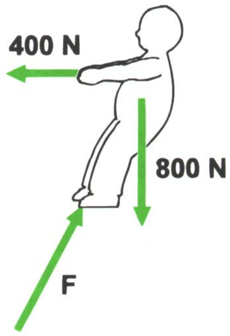


Figure 15. A *free body diagram* showing all the forces acting on the tug-of-war competitor. When this is compared with the original drawing (figure 14), we will find that the following changes have been done:

1. The force of gravity has been applied to the approximate location of the body's centre of gravity.
2. The rope has been removed and replaced by a force vector. Since we know that the man is pulling the rope with a force of 400 N to the right, it must also be true that *the rope is acting upon the man* with the same force but in the *opposite direction*. (According to Newton's third law, every action must have an equal and opposite reaction.) Therefore, when the rope is removed from the body, it must be replaced by a force of 400 N that is pulling the man *to the left* (otherwise he would fall backwards!).
3. The floor has also been removed and replaced by a force (F), which is in fact the floor reaction force that we will determine. Since this force is not yet known, we must here assume its direction and magnitude. It is easy to see that it must be directed upwards and backwards, since the body, influenced by the other forces, would otherwise fall or move forward .

Once we have made the free body diagram and studied it, we can draw the following conclusion; since the body is at rest and since there are only three forces acting on it, the floor reaction force (F) must completely balance the other two forces. This means that it must be equal in magnitude to the *resultant of the two forces*, and opposite in direction. Thus, by graphically finding this resultant (figure 16) and by measuring its length, we can completely determine the floor reaction force; it is 900 N and directed as shown in figure 17.

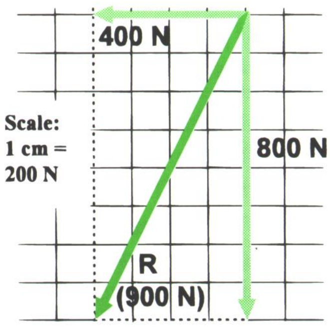


Figure 16. The resultant is found by composition of the two forces. Note that this work must be done very accurately and preferably on squared paper.

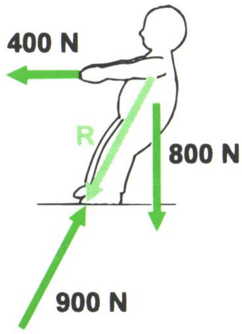


Figure 17. The reaction force of the floor is 900 N and directed opposite the resultant of the other two forces.

Conditions for equilibrium

In the example above we could assume that the body, being at rest, is acted upon by forces that completely balance each other, or, in other words, that the sum of the forces is equal to zero:

$$\Sigma F = 0$$

This is called *the first condition for equilibrium* and should always be considered in statics problems. Note, however, that this condition *alone* is not enough to describe the state of equilibrium. There are in fact situations where an object may not be at rest though the sum of the forces is zero. Therefore, also a *second condition for equilibrium* must be considered. This will be introduced in the next part of *Biomechanics in Prosthetics and Orthotics*. (The second condition for equilibrium would not have influenced the solution of the problem above, since, as we will see, all *concurrent* force systems are in fact bound to satisfy this condition.)

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