No 1 FORCE and GRAVITY

Gerald Foley Given at CTC 7 June 2010

1. This is the first of my talks on easy engineering and mechanics.
2. The reason for dealing with these rather than the more exciting anatomy or psychology is that an awful lot of what happens in the human body, especially the bones and muscles, is made clearer, by looking at it in terms of the underlying engineering or mechanics.
3. Some knowledge of these basic engineering and mechanical concepts helps us understand what is happening in the body as it moves and goes through its various activities. It also helps us understand how and why it can go wrong in these activities. It gives us an additional perspective on how we do our job as Alexander teachers.
4. Another reason for knowing something about these ideas is that they are commonly used in writings about the AT – in the works of Alexander himself, and in other writers. The question of balance is an issue which is extremely important in our work. What do we mean when we say we are in a state of balance and how do we achieve this state? What are we doing when we are putting ourselves into a nicely balanced monkey?
5. A very clever young man who trained with me called Jason had a PhD in particle physics. One of the things we used to discuss was the construction of a monkometer. This would measure the muscle forces being applied throughout the body and show you on a computer screen a read-out which would tell you how close you were to the perfect monkey.
6. Walter used to recommend the book *Understanding Balance* written by his physiologist friend TDM Roberts. They were both very interested in equestrianism which is very much a question of balance. If you want to get anywhere in this book, you need to know some of the engineering ideas I am going to be discussing.
7. Today I am going to begin with the basic engineering concept of **FORCE.** In everyday language, we use the word force in a variety of ways. We might say of a singer that he or she was forcing their voice on the top notes. We might say of someone that she has a very forceful personality. We might say, I forgot my key and I had to use force to open the window and let myself in. We might talk of the futility of trying to solve political and social problems by the use of force.

8. All of these words convey something of the basic concept of force but are fairly imprecise and often have an emotional or moral value attached to them. In general, force is usually seen as something negative.
9. In engineering, this is certainly not the case. We do not think of force being a good or bad thing. One could reasonably argue that force is the most basic engineering concept of all.
10. Engineering could even be defined as the constructive conscious control of forces in structures and buildings. Human activity and balance, the use of the self, also depend on the control and organisation of the various forces occurring in the muscles and the bony structure of the skeleton.
11. In engineering, the word force has a very precise and restricted meaning. A force, is a push or a pull acting at a particular point.
12. If I push against a wall, we say I am applying a force to the wall at that point. If I pull on a rope attached to a hook in the wall, I am applying a force through the rope to the hook and through the hook to the wall.
13. Engineers find it convenient to use an arrow to represent a force. The arrow shows the direction in which the force is acting. I can exert an upward, downward or sideways force. Or I can exert it at an angle.
14. The arrow also can be used to show the precise point at which the force is acting. This point is called the point of application of the force.
15. And, of course, forces can vary in magnitude or strength. I can have a large force or a small force – a big or small push or a big or small pull.
16. We can look at all kinds of examples of forces acting on things. Someone pushing against a wall, rockets pushing the shuttle into space, birds pulling worms out of the ground, a pianist's fingers pressing the keyboard and so on.
17. But the force I particularly want to look at today is the downward force which we call weight. If I hang this piece of metal from my finger, I experience a downward pull on that finger.
18. The reason I feel this downward pull, is that everything on the earth is being pulled downwards by the force of gravity. More precisely, everything is being pulled towards the centre of the earth.

19. If I put the weight on top of my hand, it is still attracted towards the centre of the earth and pushes my hand down.

20. And of course my hand is being pulled down. I resist the pull by tightening the muscles in my arm. If I stop tightening them, my hand falls downwards.

21. When we say one thing is heavier than another, we mean the pull of gravity on the one is greater than on the other. That, in practice, means it is exerting a greater downward force on whatever is supporting it.

22. When we say an elephant is heavier than a mouse, we mean that if an elephant stands on you, it exerts a much greater downward force on you than if a mouse were standing on you. Two telephone directories exert a greater downward force than one.

23. We measure force using a variety of units. The easiest to envisage are the ones used to measure weight. The most common unit is the kilogram or for the more old-fashioned among us, the pound. Engineers use units such as the Newton which is about a tenth of a kilogram.

24. When you stand on the weighing scales, the reading on the dial is the downward force you are exerting on the scales. If I come along and push down on your head, the reading on the scales will go up. This is not because you have become heavier but because I have applied an additional downward force through you on to the scales. Forces can add up.

25. Next, I would like to show something engineers are quite fond of using – called a force diagram. Here is a piece of wood resting on two supports. If I put a weight on it, or as an engineer might say, apply a force here at the mid point, the supports at each end exert an upward force. The total upward force is equal to the total downward force and if the weight is in the middle, then the force in each support is exactly half that of the downward force.

26. If the weight in the middle is 10 kg then the upward force pushing against it in each support is 5 kg. And if I move the weight towards one of the supports, the amount supported by the near one increases and the further one decreases. If I put it at the quarter point, for example, the near support carried 7.5 kg and the far one carries 2.5 kg.

27. The next thing I want to look at is the concept of equilibrium or what is sometimes called the balance of forces.

28. Let us imagine I have got something which moves extremely easily – a little trolley thing on very freely running wheels. If I apply a force to it, it moves in the direction of the force. If I then apply an equal force in the opposite direction it stops moving. The two forces balance each other out. We say the object is in equilibrium under the forces acting on it.

29. The same is true if I push or lean against a wall. The wall resists the pressure I am putting it – if it did not, it would fall over. This is what the expression action and reaction are equal and opposite means. We can show this with an arrow representing the force on the wall and an equal and opposite arrow resisting the push.

30. Now imagine someone standing on the floor with the force of gravity pulling them towards the centre of the earth. Under normal circumstances, the floor prevents this happening. The floor, in other words, resists the downward force I am putting on it. I am pushing down with my feet and the support provided by the floor is in an upward direction.

31. This is sometimes hard to get one's mind around. The floor doesn't really feel as if it is pushing upward. One way of thinking about it is to imagine that instead of standing on the floor, someone is supporting my feet on their hands. In this case, it is quite clear that the weight is acting downwards and the support is acting upwards.

32. It is worth mentioning here the difference between the weight of a thing and the mass of a thing. This is a very important distinction to people who want to be very precise, as you will find if you look at TDM Roberts' book on balance.

33. In broad terms, the weight of a thing is the downward force it exerts on whatever is supporting it. The mass of a thing is the amount of stuff in it.

34. So I can take a 1 kg bag of sugar and the force it exerts on my hand is 1 kg. If I take the same bag of sugar to the moon, the amount of sugar, its mass, will remain the same but its weight will be a sixth of what it is here.

35. So if you are giving AT lessons on the moon, you will need to be very careful when taking the head because it weighs a sixth of what it does here. If you apply the amount of force you would use here, for example to lift the head to slip another book under it, you could very easily dislocate the person's neck.

36. But for most of us earthbound creatures, we don't need to worry. The weight of a thing, the downward force it exerts on whatever is supporting it, is pretty constant no matter where you are on the surface of the earth.

37. Finally, I want to come closer to home and think about the skeletal muscles, of which there are about 600 in the body. You remember they have a belly which contracts so that the tendons extending from the belly pull on the bones to which they are attached.

38. From the engineering point of view, muscles are force generators. When they contract they exert a pulling force at their point of attachment. They don't push; they only pull.

39. It's an interesting thought, to which we will come back later, that all the movements of our limbs and other bits of our body are a result of muscles tightening to exert a pulling force on their points of attachment and then releasing. Inhibition means not tightening, not exerting a pulling force.

40. You may have heard the expression anti-gravity muscles and wondered what magical powers they might have. The expression goes back at least to Sir Charles Sherrington about whom I will have a lot to say when we are talking about the neurophysiology of the AT.

41. The anti-gravity muscles are those which keep us sitting or standing upright against the downward force or pull of gravity. They prevent us collapsing in a disorderly heap.

42. Another name for them is the postural muscles.

43. Because these muscles are in action all the time, it is pretty important that they do not get tired. This brings us back to the whole issue of red and white muscle fibres.

44. The red fibres do get tired quickly. They can continue exerting a force for a long time. This is why they are called non-fatiguable. These are the fibres in the postural muscles which keep them going against the pull of gravity which never stops.

45. The white fibres are stronger and act more quickly but they tired quite quickly.

46. We get postural problems when we stand or sit in ways which depend on the white fibres because gravity never stops but the white fibres, no matter how strong they are in the beginning, get tired very quickly.

47. We could obviously talk a great deal more about all of this but I think it is enough for today. We have covered a number of very fundamental ideas.

48. We looked at the basic concept of a force, which is a push or a pull. It has a direction, up, down, or sideways. It has a point of application. And it has a magnitude; it can be big or small. And we have also looked at the principle of equilibrium, in which action and reaction are equal and opposite.

49. And we have begun to apply an engineering perspective to the way the skeletal muscles do their various jobs in the different parts of the body.