Conversation with Aristotle

Aristotle's ideas of motion using simple demonstrations, told in the context of a dialogue between Aristotle and his most famous student, the young Alexander the Great, surely one o the most famous student-mentor relationship in history. Alexander was a student of Aristotle for three years. We are describing his last meeting with the Master, when he was 16 years old , at the age when he was asked by his father, Phillip of Macedonia, to represent him at home while he went to war. In this last meeting Alexander thanks Aristotle for his wisdom and mentorship in philosophy in general, but is finally interested in the physics of motion and forces, in preparation for his military role in the future.
We are in Greece, in the fourth century, BC.

Aristotle appears. He walks back and forth in deep thought. Alexander approaches him.

Aristotle:
Greetings my young friend.

Alexander:
Greetings, Master.

Aristotle:
This is a sad day for me, Alexander, because I understand that this may be our last meeting.

Alexander:
Yes, Master. My father, King Phillip has asked me to represent him at home while he is away in battle.

Aristotle:
Well, my son –if I can call you that, we have accomplished much in the last three years. I have seen you grow not only in your knowledge of the doctrines of Morals and Politics and the rules of logic, but philosophy in general.

Alexander:
Yes, you may call me son, after all, King Phillip gave me life, but you have taught me how to live well.

Aristotle:
Thank you, Alexander. I am very pleased.
He looks reflective and then continues.

But there is one part of my philosophical work that we have neglected so far. That is, we have not discussed the phenomena of nature around us, such as motion, force, light sound etc.

Alexander:

Yes. Now that I may be going into battle soon myself, I would like to come to understand your ideas about the workings of nature, or what you call physics. I may be able to apply them in defeating my enemies.

Aristotle:

In anticipation of your visit I have been thinking about motion and forces around us. The Motion of a leaf falling, a javelin being thrown, the motion of a cart, etc…Motion in general is an inexhaustibly deep subject. I am glad that you wish to discuss motion and forces with me.

Alexander:
Yes, I do. It is bewildering, I know. But you have clearly categorized motion in general, that much I know.. Especially, you have separated the laws of motion in the heavens and those that govern motion on Earth, *terrestrial* motion and *celestial* motion.
Stops for a moment and then adds:

I would also like to know more about levers and forces so that my engineers can construct effective war machines.

Aristotle:
Yes. But let us only talk about motion on Earth and forces. We can discuss celestial motion sometime in the future, I hope.
Aristotle takes a stone and a feather. He looks at Alexander and then asks:

Which of these will fall to the ground first, the stone or the feather?

Alexander:
Surely, the stone will fall faster… .

Aristotle:
Alright.
He drops the stone and the feather. As expected, the stone reaches the ground first.
Then Alexander then takes a small piece of wood.

Alexander:
He looks at Aristotle and says:

I have here a small piece of light wood. The stone is clearly many times heavier than the wood. Do you agree?
He gives these to Aristotle. Aristotle smiles and hands them back to the Alexander. The Alexander drops these and they seem to fall to the ground at the same time.

This simple demonstration suggests that all heavy objects fall at the same rate, don't you think Aristotle:
I am not convinced about that. I think if we went to a high tower and dropped these objects, then the stone would hit the ground first.

Alexander:
That may be so. However, you cannot say that if we had two objects, say two spheres made of different metals, but of the same size, and one twice as heavy as the other, the heavier one would fall twice as fast.

Aristotle:
Well, maybe not. But I have observed heavier than water objects fall through water."
He picks up two metallic spheres.

Let's place these in the water and allow them to fall.
He walks over to a glass container and lets the spheres fall through the water.

Now observe them as they fall through the water.

Alexander:
It looks like the heavier falls much faster.

Aristotle:
You see. Clearly, heavier objects fall faster in water.

Alexander:
Very impressive. But then, imagine an object falling toward the earth if there were no air. Don't you think that then a feather and a stone would reach the ground at the same time?

Aristotle:
No! That is impossible!

Alexander:
But why?

Aristotle:
Because if there were no air, we would have a vacuum above the earth. And…, I believe that vacuum cannot exist!

Alexander:

Aristotle, why do you believe a vacuum cannot exist?

Aristotle:
Then any small force could make an object move at an infinite speed because there exists no more resistance against the movement. And to have motion we need a force. Therefore, vacuum is impossible.
Alexander:
Yes, I can see that. But his is only true if we say 'the greater the push force the greater the speed and also "the less the resistance force the greater the speed for a given push force.

Aristotle:
Exactly. The question then is: 'What is the cause of motion of a freely falling object or a projectile like a javelin after it is thrown?'.

Alexander:
According to your physics, first, 'for an object to move you need a force' and secondly, there are two kinds of forces, *natural* and *violent*. A natural force is the force that pulls objects toward the center of the earth and a violent force is a force like the one that propels a javelin.

Aritotle:
Very good. So, a freely falling object needs no explanation but the motion of a javelin does.

Alexander:
Where does the motive force for the javelin come from?

Aristotle:
Again we have to invoke the principle that vacuum cannot exist. As the javelin moves through the air, the air behind the javelin rushes in to fill the momentary vacuum produced. This action of the air provides the pushing force.

Alexander:
But, surely, there must be an air resistance that opposes this force, Aristotle.

Aristotle:
Yes. But the push force of the air rushing in is greater.

Alexander:
I would be interested to know how you would explain this motion.
The Alexander produces a pendulum and shows Aristotle how the attached mass moves back and forth.

Aristotle
He studies the motion and then smiles:

This is a very interesting motion. It seems to be a combination of free fall and constrained

motion. Therefore I would say that it is partly natural and partly violent motion."

Alexander:
I have to go soon, But before I go I would like to hear your ideas how forces are related to the action of levers.

Aristotle:

You must some day come and join us in my Academy. Perhaps you can continue to study of the motion? , what did you call it…, the pendulum?.

Alexander:

The motion of the pendulum reminds me of a description of a ram that was used by my father King Phillip,

He shows Aristotle a picture of this war machine.

One of my father's engineers, Pephasmenos, fixed up a pole and suspended a cross piece there from, and thus swinging it backwards and forwards, is able to produce heavy blows that can bring down large walls. Another engineer, Chalcedonian, added a base to it of timber moveable on wheels, and covered it with a roof on upright and cross pieces: on this he suspended the ram, covering it with bulls' hides, so that those who were employed therein battering the walls might be secure from danger.

Aristotle:

He studies the ram.

You are right, Alexander, this is an unnatural motion produced by the effect of the earth' natural motion, constrained by the ropes, just like the pendulum. I can imagine the destructive power of such a device.

Alexander:

Master, I would also like know more about how a projectile like an arrow or a rock propelled by a trebuchet moves. You have partly given an answer to that question.

He shows Aristotle a picture of a trebuchet.

My first question is: How are the forces acting on a beam distributed?

Aristotle:

The motion of the rock hurled from this device is similar to the motion of a javelin thrown by a warrior, which we discussed earlier: Since there must be a force that moves the javelin in a

horizontal direction, I believe that that force is produced by the air rushing in behind the javelin.

Alexander:

But I know from experience that when I ride a horse at a high speed the air around me and it pushed me back.

Aristotle:

Yes. The air rushing in to replace the momentary vacuum created by the javelin's presence produces a push and the air in front of the javelin causes a resistance.

Alexander:

I see. But the motion of a projectile like a javelin or a stone does not seem to be a straight-line motion: it is surely curved, as I have observed such motion.

Aristotle:

You may have been deceived by your eyes, Alexander.

Alexander:

I would also want to know at what angle the projectile must be hurled to get a maximum distance for a given initial speed.

Aristotle:

I think it must be ½ a right angle.

Alexander:

That makes sense, Master. But don't you think one should actually be able to show by testing what the maximum distance would beAristotle:

Well, you could test that in the field. These things go beyond my physics.

He stops for a while and then continues.

Alexander:

What I mean, Master, is that your ideas of projectile motion should be tested, exactly the way you showed me the laws of the lever and that a heavy sphere falls faster than an identical light sphere in water?

Aristotle:

He smiles and then changes the subject

I just want to make a last comment before you go, Alexander. You remember that I argued that the task of the Greeks to rule and educate and look after other people, who are not capable of more than performing basic tasks and occupying the role of servants. You will probably become

a great warrior and conquer many lands.

Alexander:

Mater, I think I will try to be more open-minded and accepting. I will try to allow locals to govern lands, even allow them to marry women of royal blood in faraway kingdoms. I believe that would be wiser than assuming that they are only able to be servants, incapable of higher thinking.

Aristotle:

He looks thoughtful and shakes his head.

He then smiles and looks at Alexander.

Is it true, Alexander, that you sleep with a dagger and Homer's Iliad under your pillow?

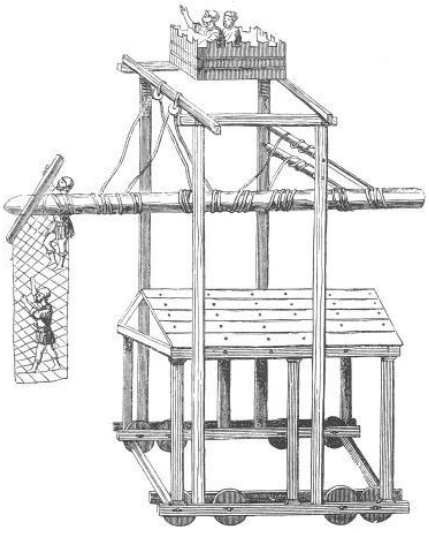
Alexander:

Yes, it is. The dagger is there to protect me from sudden attempts on my life, and the Iliad to nurture my soul and inspire me in coming battles. Your teachings, are, of course, in my head and my heart.

But I must go, Master. I hope to see again soon.

Aristotle:

You have my blessing, my son. You have learned much, use it well.



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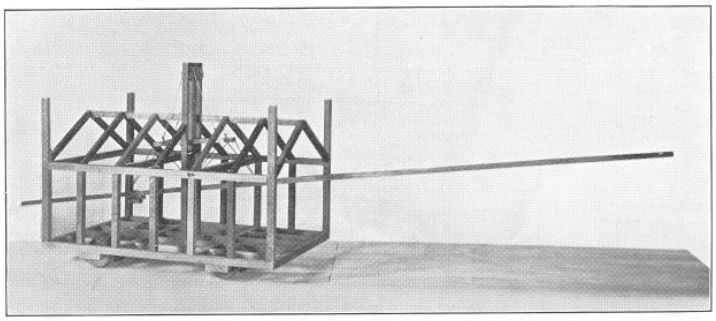

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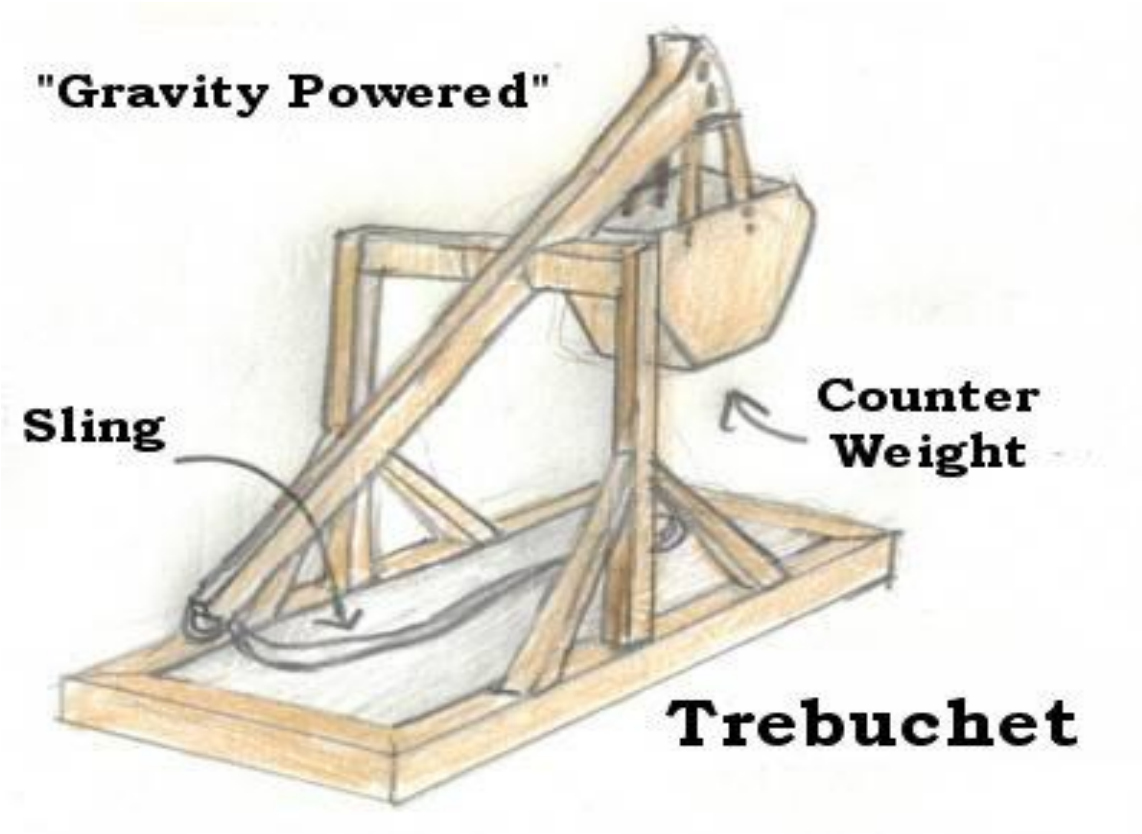
HEGETOR'S RAM AND TORTOISE

1. From a MS. of the sixteenth century (Wescher's *Poliorcétique des Grecs*).
2. From a model made by A. A. Howard.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