Experiment 1-Air Track: Verification of Newton's Second Law of Motion

Apparatus Used: Tracking Camera, Air Track Setup, Slider, Air Pump to adjust air flow along the track on which the slider moves, weights which can be put on the slider and the pulley to adjust mass and force on the slider. The Videocom software interfaces between the air-track apparatus and the computer to collect and analyse data.

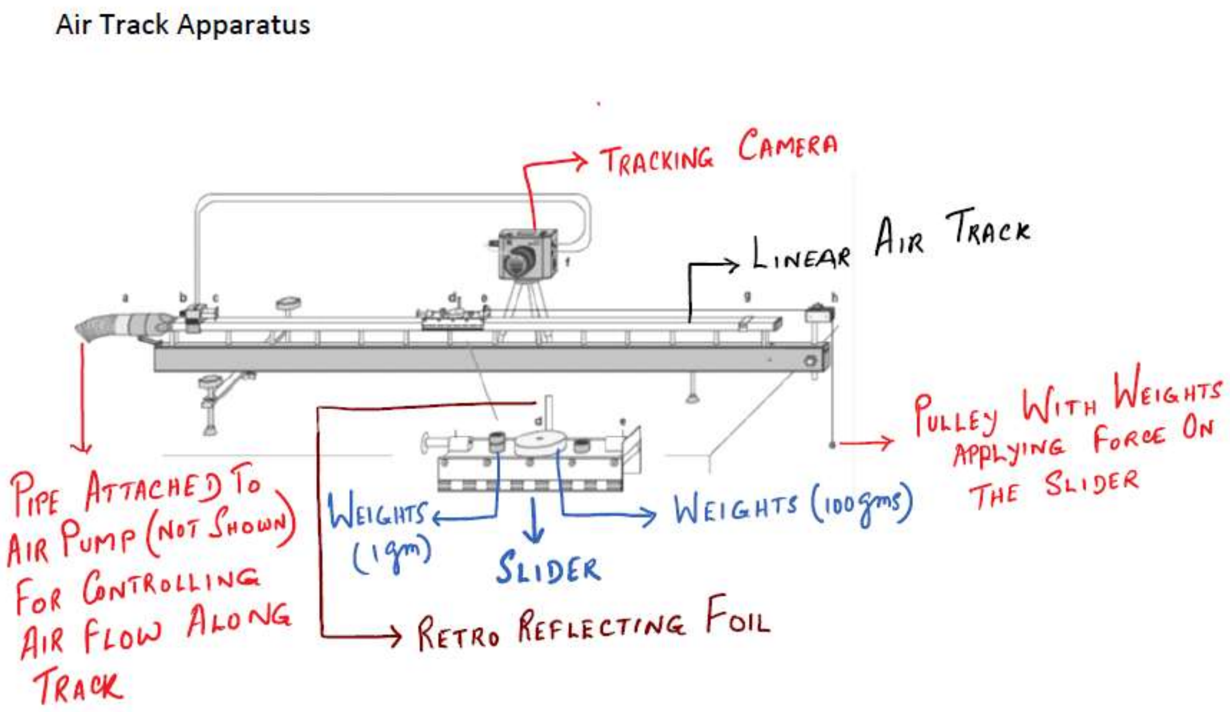

Fig.1

Objective: According to Newton's Second Law of Motion, ***F=ma***, where ***F*** is the force, ***m*** is the mass of the object and ***a*** is the acceleration of the object. To verify this law using the air-track system, we need to show that when the mass of the object is fixed, the acceleration of the object is proportional to the applied Force. Also, when the applied force is kept constant and the mass of the object is varied, the acceleration varies inversely with mass.

VideoCom Software

The VideoCom can operate in one of two main operating modes (motion recording and intensity measurement), each with a variety of functions (various time intervals for recording motions, and a choice of number of pixels when measuring intensities).The current operating mode is always indicated in LC display.

The MODE key toggles between operating modes in sequence.

The START/STOP key controls the recording of measured values in the connected computer; during motion recording, it switches the voltage at the holding-magnet sockets A off and on.

All of the VideoCom operating functions described above can also be completely controlled via software.

Fig. 2 shows a snapshot of the videocom software that you will see when you start the software.

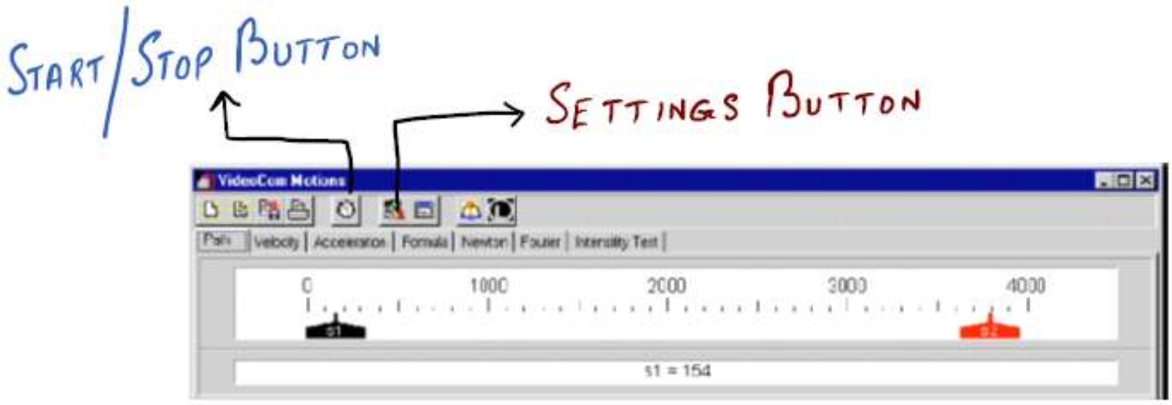

Fig.2

Setting up the Experiment

- Connect the two long black wires from the air-track apparatus to the corresponding wires attached to the camera by pushing the clips into the slots at the end of wires.
- Switch on power to the air pump located near one end of the air track.
- Power on the camera connected to one of the plug points. The camera is also connected directly to the PC on which the Videocom software is installed.
- Ensure that the distance covered by the slide along the air track is **1** m.

Make sure the slider position is detected by the camera both at the beginning and at the end of the motion when it hits the metal barrier placed on the air track. This can be done by placing the two sliders at two ends of the air track (separated by a distance of 1m) and adjusting the camera position to capture the light reflected by the Retroreflecting Foils attached to the sliders (see Fig.1) When motions are to be recorded, the camera looks for the reflections of the retroreflecting foil.

RetroReflecting Foil
The self-adhesive retroreflecting foil reflects incident light precisely into itself (triple-mirror principle). VideoCom distinguishes this reflection from the background by measuring its intensity and uses it to determine the position of the foil. The screwed-on LED flash is critical as a light source. The foil reflects the light back to precisely this point.

- To verify that the positions of both sliders are detected by the camera, click on the “Intensity Test” tab of the videocom software (shown in Fig.2)

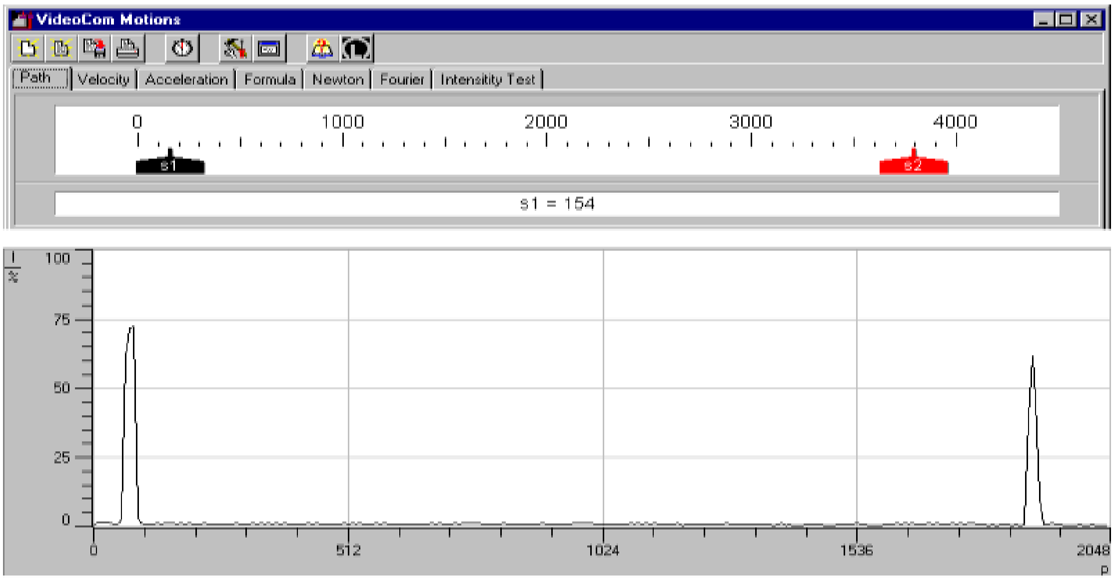

Fig.3

- The correctly aligned camera detects two reflections at the left and right edges of the motion even at the edge of the CCD (top: motion recording, bottom: intensity test). In this example, the intensity of the background is below 5 %, and the intensity of the reflections is greater than 25 %. The height of the peaks should be at least 5 times the background noise level.

> **Points to be noted while using VideoCom for recording motions**
> If it is not possible to adjust VideoCom because too few or too many reflections are detected (e.g. due to unfavorable lighting conditions), the software for evaluating motions allows you to display the measured intensities (intensity test). A typical intensity distribution shows a peak of at least 25% amplitude as well as max. 10 % background for each reflection (see Fig.3). Bare metal parts in VideoCom's field of view have no effect when they do not reflect light directly into VideoCom. If this problem should occur (e.g. from the rail of the linear air track), it can be solved by varying the height of VideoCom and thus the angle of incidence of the light flashes.

- Use the digital balance to determine the mass of the slider.
- The slider placed at the beginning of the track (the end near the pipe of the air pump in Fig.1) is held by means of a holding magnet. The slider can be released by pressing the START/STOP button in the videocom software window.
- The position of the slider at that end (determined by the position of the retroreflecting foil attached to it) should be calibrated to 0 while the position of the slider at the other end of the track should be calibrated to 1m.
- Calibrate the pixel spacing by specifying the positions of the two reflections along the path (in the software). (See "Path Calibration" section below)

> The **holding magnet** (near the end of the air pipe in Fig.1) is used for synchronizing the start of the motion and the measurement. Pressing the START/STOP button on the software window (Fig.2) demagnetizes the holding magnet thereby releasing the slider which was previously attached to the holding magnet.

Path calibration

- ❖ Equip both sliders with interrupter flags once more, move the first slider to the holding magnet, and put the second slider on the linear air track while the air supply is switched off so that the distance between the two interrupter flags is exactly 1 m.
- ❖ Enter the values 0 m and 1 m as positions of the two sliders in the register "Path Calibration" of the menu "Settings/Path Calibration".
- ❖ Click the button "Read Pixels From Display", and activate "Use Calibration".

- Remove the slider at the end of the track.
- Attach weights (use 1 gm weights) to the end of the pulley.
- Use the controls of the air pump to appropriately adjust air flow along the track.
- Press the START/STOP button to release the slider from the holding magnet.
- The trajectory (path tab), velocity (velocity tab) and acceleration (acceleration tab) are recorded by the videocom software as the slider moves towards the end of the track.
- Press the START/STOP again as soon as the slider hits the metal block at the end of the track to stop recording the motion. [**Note**: If you don't stop the recording by pressing the START/STOP button, the software will continue recording even after the slider has come to rest on being obstructed by the metal block at the end of the track. In that case, you will have to delete the spurious readings at the end which shows the position of the slider remains unchanged with time.]

Samples of the trajectory and acceleration curves from path data recorded by videocom are shown below.

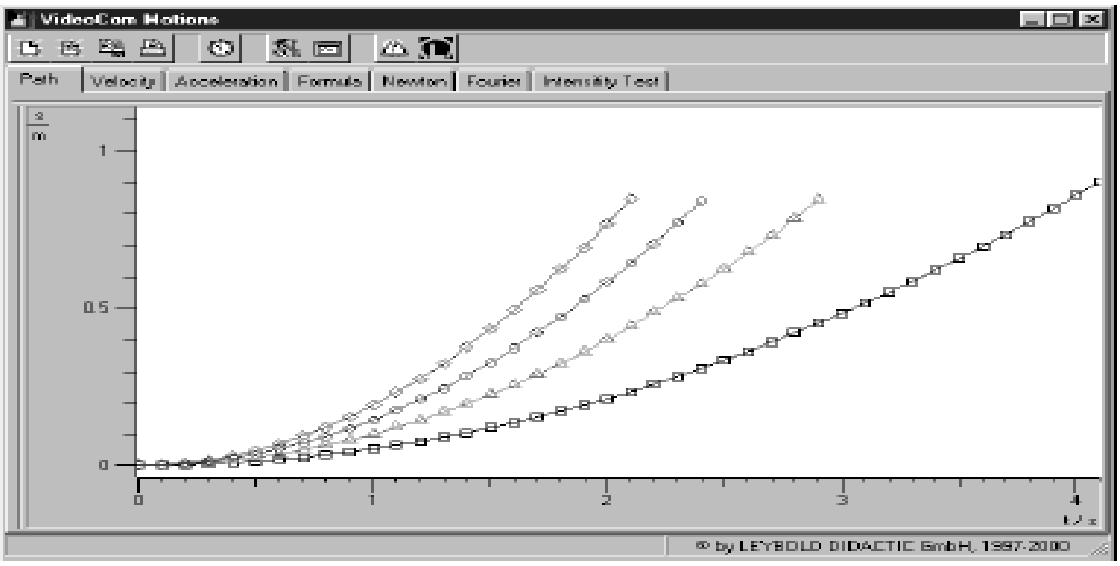

Fig.4: Trajectory for 4 different values of applied force when the mass is kept constant.

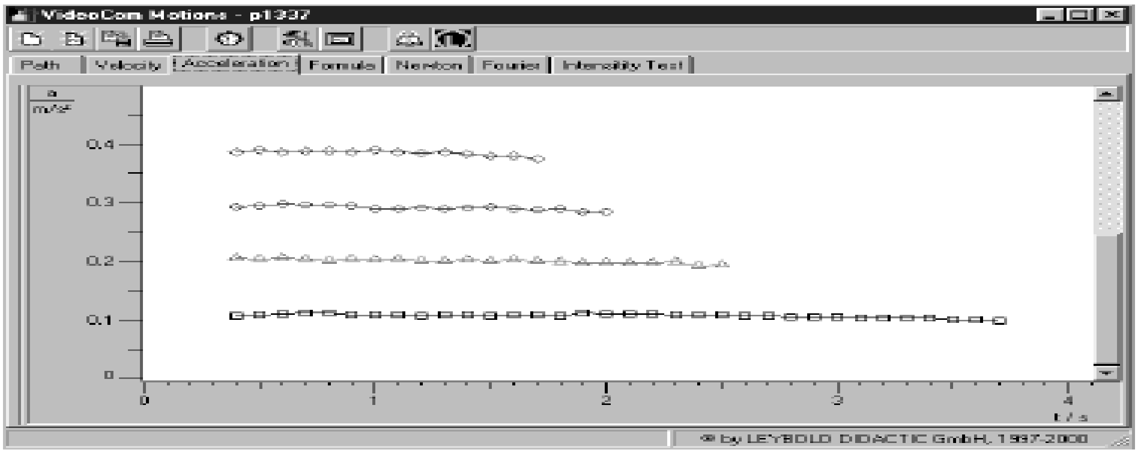

Fig.5: Acceleration for 4 different values of applied force when the mass is kept constant.

Experimental Measurements

Dependence of acceleration (*a*) on the applied force (*F*) for a fixed mass.

Keep the mass of the slider fixed and obtain the trajectory and acceleration of the slider by changing the applied force. The applied force can be changed by changing the mass attached to the pulley.

Repeat the experiment for at least 5 different values of the applied force.

Determine the acceleration for each value of force and plot a graph of ***F*** vs ***a***
Determine the slope from the graph. What does the slope of this graph represent?

Compare the mass of the slider obtained via experimental measurements with the mass determined by using the digital balance.

<u>Note</u>: Total mass (in Kg) that is subject to the applied Force (mg) is (m+M) where M is the mass of the slider. In order to keep the total mass (m+M) constant, you should place the 1gm weight removed from the pulley onto the slider. For example, if you start with m=4gms (4*1gm weights) on the pulley for the first set, in the next set, reduce m to 3gms but replace the 1gm weight removed from the pulley onto the slider. For the next set, reduce m to 2 gms and replace the 1 gm weight removed from the pulley onto the slider and so on. This ensures that (m+M) remains constant as required.

Dependence of acceleration (*a*) on the mass (*m*) of the slider for a fixed applied Force (*F*).

Keep the force on the slider fixed and obtain the trajectory and acceleration of the slider by changing the mass on the slider. The mass can be changed by placing metal disks each having a mass of **100** gms on the slider.

Repeat the experiment for at least 5 different values of slider mass.

Determine the acceleration for each value of mass and plot a graph of ***m*** vs **1/*a***
Determine the slope from the graph. What does the slope of this graph represent?

Compare the Force applied on the slider obtained via experimental measurements with the Force determined by measuring the mass attached to the pulley using the digital balance.

<u>Note</u>: Total mass (in Kg) that is subject to the applied Force (mg) is (m+M) where M is the mass of the slider.

Additional questions you need to think about:

- Why do you need to adjust the air-flow along the track?
- If you plot a graph of ***F*** versus ***a*** for fixed ***m***, what should the graph look like? Do you expect any non-zero intercepts on the ***a*** and ***F*** axis?
- How can you determine the acceleration of the slider from the trajectory (distance (***s***) vs time(***t***)) data?
- What is the geometric shape of the distance (***s***) vs time (***t***) graph?
- What should be the degree of the polynomial with which you can fit the ***s*** vs ***t*** data?