Physics Investigation 4 Teacher Manual

Observation

An object falls much faster in air than in oil as oil is more viscous.

Problem

How does the viscosity (resistive force) of a medium affect the motion of an object?

Hypothesis

An object attains a terminal velocity in the fluid medium instead of continuously accelerating.

Aim :

To investigate the velocity of a marble falling in air and in a fluid medium respectively.

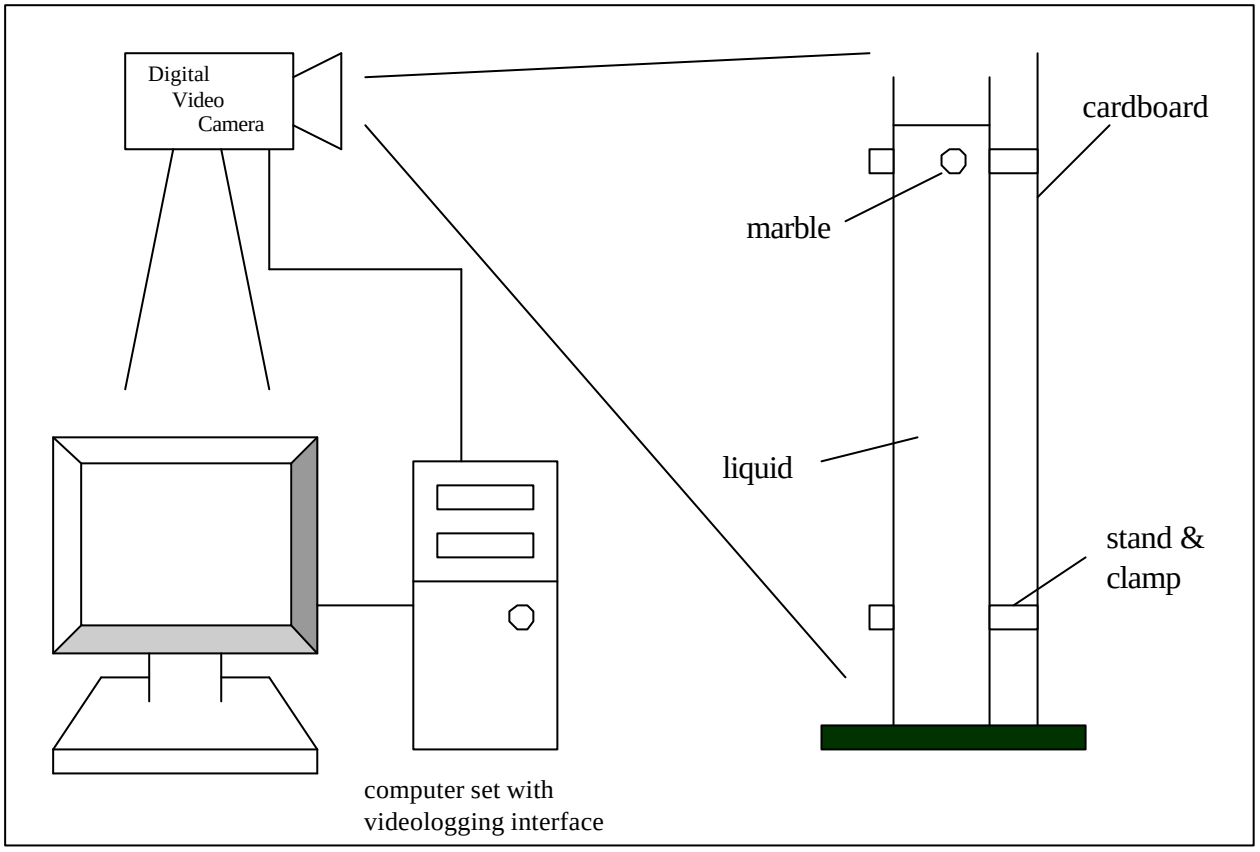
Principle

When an object falls "freely" in air, it moves with uniform acceleration ($10ms^{-2}$). If it falls in a fluid, there will be mainly three forces acting on it. They are its own weight, resistive force and upthrust by the fluid. Since the upthrust acting on a heavy object is much smaller than the other two, it can be assumed to be negligible and omitted for the purpose of this investigation. The equation of motion can be written as $W - f = ma$. (W - weight of object , f - resistive force , m - mass of object , a - acceleration.)

Equipment and Materials

- Visual logging interface X 1
- Desktop computer X 1
- Digital video camera X 1
- A painted marble X 1
- A black cardboard X 1
- Stand & clamp X 1
- Column of liquid X 1 (about 1m long)

Diagram of experimental set-up



Procedure

1. Connect the digital video camera to the computer;
2. Set up the apparatus as shown in the diagram above;
3. Switch on the digital video camera;
4. Choose '**Record**", and then '**Show Capture Window**" in the visual-logging program;
5. Choose '**Record**", and then choose '**Rapid Record**" and set the recording time limit to 2s. Set the radio button to 25 frames per second in the PAL/SECAM system;
6. Click '**Record**" in the capture window to start recording. At the same time, allow the marble to fall in air for about 50cm;
7. After the recording has stopped, choose "**Analysis**" and '**Video Object Trace**" in the menu bar;
8. Calibrate the screen by choosing the region to analyze the data, i.e. the position from where the ball starts to drop until the end of the motion. Enter the '**Y**" value, which

would be the distance the marble traveled. Leave the "**X**" value blank and then click "**Finish**";

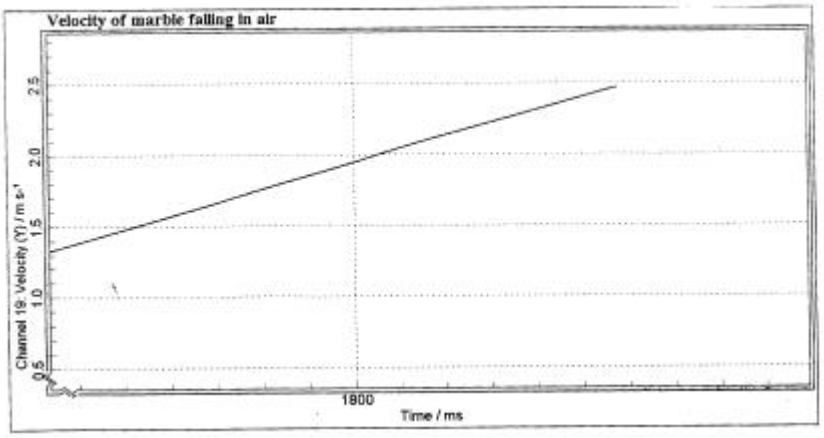
9. Click "**Fix Origin**" and move the crosshair on the marble, then click "**Finish**";
10. Calibrate the points by positioning the crosshair on the marble frame by frame;
11. Click "**Extra**" and choose the radio button – "**show Y value**" only. Check the box of "**Velocity**" only and then click "**Confirm**". Click "**OK**";
12. Plot the graphs of velocity and distance against time;
13. Repeat steps 4-12 for the marble falling in oil. Choose 5s interval for time of recording instead.

Precautions

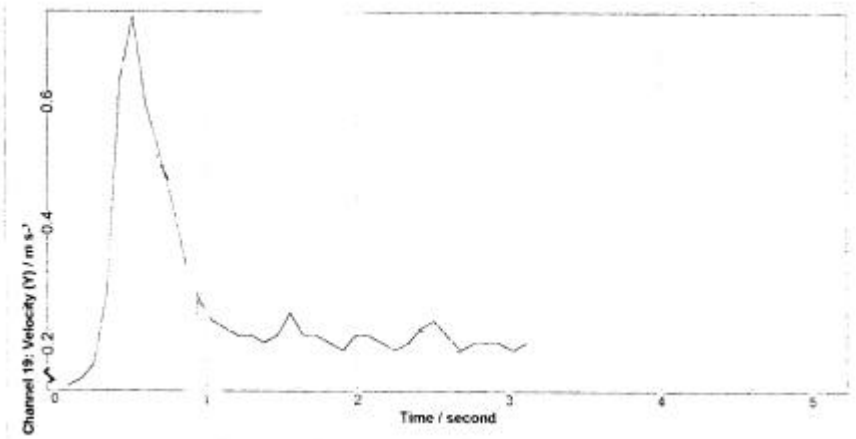
1. Make sure that the marble is dropped vertically;
2. The marble should not be too small. Otherwise, it will not be easily seen on the capture window;
3. A marble painted with a sharp colour is preferred so that it can be clearly seen on the screen;
4. Release the marble just a few mm above the oil surface to avoid the formation of bubbles on the marble or spilling oil out of the tube.

Results

Graphs obtained :



Velocity of marble falling in oil



Interpretation

In air, the marble fell with an increasing velocity, attaining a maximum velocity of 2.47 ms^{-1}.

When the marble was dropped into oil, it first moved with a higher velocity but slowed down gradually. After a short while, the marble did not accelerate, but had attained a terminal velocity of about $0.2ms^{-1}$. The terminal velocity of the marble was much smaller than the velocity of marble falling in air.

From the velocity-time graph in oil, when the velocity was high, the marble decelerated. The resistive force was greater than the weight. The velocity decreased gradually. Finally the velocity did not change. The resistive force was then the same as the weight. It showed that the resistive force increased with the velocity.

In air, the air resistance was much smaller. The resistive force was not large enough so that the marble continued to accelerate to a high speed.

Possible errors

1. Due to the limitation of the video capture card, the quality of the video image was not good. It was very difficult to mark the exact positions of the ball, which led to an error in calculating the speed of the marble;
2. Small air bubbles were formed on the marble, which hindered the motion of the ball.
3. As the video-datalogging system allowed the highest resolution of 25 frame per second only, i.e. 0.04s per image, it led to an error in studying the motion of a falling object in air, which lasted only for a second or less.

Improvement

1. A high quality capture is very essential in studying a fast motion using a videologger;
2. For further investigations, the relationship between the size of the ball and the terminal velocity can be studied.

Conclusion

The marble fell much slower in oil than in air due to the larger resistive force acting on the marble by oil. The marble had accelerated for a short while only and finally attained a terminal velocity when falling in oil.