A new Applet Java about Frictional Force

Assunta Bonanno[1], Angela Milazzo[2]
Department of Physics – University of Calabria
I-87036 Arcavacata di Rende (CS)
Italy

Abstract

Frequently, the high school and university students meet many difficulties in the understanding of plane motion under the action of frictional force, because of its dependence either upon the roughness of touching surfaces and upon the force pressing one surface on the other.
Furthermore the understanding of difference between dynamic and static friction is conceptually difficult, since the former always opposes body's motion, while the latter is present until a body is in stationary condition.
The purpose of this new applet is to highlight such difference and to improve the understanding of limit angle concept by visualization and making interactive all parameters characterising a body motion in presence of frictional forces.

Keywords: Java, applet, frictional force, static friction, limit angle.

Introduction

Frequently, the high school and university students meet many difficulties in the Newton's Second Law[1] understanding, although the effects of natural forces are daily observed.
In particular, difficulties concerning plane motion increase considerably if the action of frictional forces[2,3,4] is present, because of its dependence either upon the roughness of touching surfaces[5] and upon the force pressing one surface on the other.
Furthermore the understanding of difference between dynamic and static friction (**Fad** and **Fas** respectively) is conceptually difficult, since the former always opposes body's motion, while the latter is present until a body is in stationary equilibrium and is contrary to the incipient motion due to the presence of force, **Fext**, acting on the body to move it.
Like all the constrain forces, the value of static friction isn't constant, but depends upon the magnitude of the **Fext**.
The static frictional force is expressed through the relation $F_{as} \le \mu_s N$ (where μ_s is the static friction coefficient[6,7,8,9] and **N** is the Normal force due to the constrain), so that the value $F_{as} = \mu_s N$ represents its maximum reachable value.
For example, in the case of a body moving on an rough horizontal plane, static friction value is, instant for instant, equal and opposite to horizontal component of **Fext** until this latter overcomes the limit value at which dynamic friction substitutes the static one, and the body start sliding on the rough horizontal plane.

---

1 e-mail: bonanno@fis.unical.it
2 e-mail: milazzo@fis.unical.it

One can treat the same problem by introducing the angle, Θ, between the direction of total constrain action, **Rt**, (obtained by the sum of **N** and **Fas**) and the normal to the plane, verifying that the increase of Θ derives from the rice of **Fas**.
It is known that the limit angle, Θ_ℓ, is experimentally equivalent to the angle of inclined rough plane at which the body start sliding and it is related to μ_s by the simple relation: $\mu_s = \text{tg}\,\Theta_\ell$.
Multimedia technologies[10,11], now, are valid instruments as educational resource in scientific matters teaching, and several web sites have been created for this purpose, like MERLOT [12] (Multimedia Educational Resource for Learning and on-line Teaching) proposing a great collection of educational materials.
The applets are the educational resources more widely used, because these are platform independent and allow an high degree of interaction.
About frictional force several applets[13,14] are available, and each of them presents valuable features, nevertheless few of them highlight the conceptual difference between the two types of frictional forces.
The purpose of this new applet[15,16] is to underline such difference by visualization and making interactive all parameters characterising a body motion on a rough plane.

An Applet Java about frictional force

The applets about frictional force, realised to focus difference between static and dynamic friction, illustrate a body motion both on a rough horizontal and on an inclined plane (applet-A and applet-B, respectively), which will be discussed separately in the following.
In the applet-B the limit angle concept is highlighted, while in the applet-A, **Fas** , **N** and gravitational force, **P**, are visualised and the user is allowed to apply an additional force, **Fext**, with variable orientation and magnitude, acting until the body start sliding,
Furthermore, in both virtual laboratories we made interactive the following parameters:

1. body mass;
2. static friction coefficient;
3. dynamic friction coefficient;

and it's possible the selection of other two buttons necessary to:

4. visualize the limit angle;
5. reset the screen and restart the animation.

-Applet A – Body motion on horizontal rough plane

The selection of parameters 2 and 3 permits the setting of static and dynamic friction coefficients value respectively, and thereby the body initial velocity, v_{in}, has been determined by the relation:

$$v_{in} = (\mu_s N - F_{ad})\frac{\Delta t}{m}$$

where m is body mass, and Δt is the time necessary to the body to pass from the rest to the motion state[17].

By choosing buttons 4, teachers are able to treat this argument by introducing the angle, Θ, formed between **N** and **Rt**.

In this applet we made interactive other two parameters:

6. inclination of **Fext**, respect to x-axes;
7. magnitude of **Fext** .

By varying magnitude and orientation of external force, one can observe the variation of **Rt** until this overcomes the limit value Θ_ℓ of Θ, at which the body start sliding on a rough horizontal plane.

The control panel (Fig.1, left side of applet) contains 5 sliders:

- **"mass setting"**: Changing body mass it's possible observe the variation of **Fad , Fas** maximum value and **N** magnitude.
  Students can understand that variation of body mass doesn't influence body acceleration.
- **"static friction coefficient setting"**: Its variation consents to change maximum value of static friction.
- **"dynamic friction coefficient setting"**: By varying this slider students can focus how this coefficient affects both dynamic friction and acceleration of body on the rough horizontal plane.
- **"inclination of external force setting"**: This slider consents to vary external force inclination.
- **"external force magnitude setting"**: Its variation permits to observe that static friction is equal and opposite to external force until this latter overcomes the maximum value of **Fas** and the body slides on rough horizontal plane under the action of **Fad** (Fig.1– Fig.2 respectively).

The choice of **"limit angle visualising"** checkbox allows teachers to treat the same argument by introducing the limit angle (Fig.1).

The button **"reset"** consents to clean the screen and restart the animation.

Furthermore in the right side of applet one can always visualise the numerical values (Fig.3) of:

a. **Fas** magnitude;
b. **Fext** magnitude, for which body start sliding;
c. **Fad** magnitude;
d. body initial speed;
e. maximum distance reached from the body.

-Applet B – Body motion on inclined rough plane

This applet is relative to body motion on an inclined rough plane, in addition to the other sliders relative to parameters from 1 to 5, the control panel (Fig.4,left side of applet) contains the slider consenting to vary plane inclination.

By modifying plane inclination, students can observe at stationary equilibrium, how static friction is equal and opposite to x-component of **P**, and how the body (under the only action of weight force) start sliding when inclined plane angle overcomes the value of Θ_ℓ, making easy the understanding of limit angle concept (Fig.4).

Furthermore at the right side of applet (Fig.4) it is possible to read the values of:

a. static friction;
b. the limit angle value to overcome, so that body start sliding;
c. dynamic friction.

Conclusion

We realised two java applets devoted to focus the difference between the static and dynamic frictional forces and to clarify the meaning of limit angle.

The presence of an additional force, **F**ext , with variable direction and magnitude highlights the behaviour of total constrain reaction, while the possibility of changing the slope of plane allows to connect the static friction coefficient with the inclination angle tangent.

References

[1] http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/newtltoc.html

[2] William M. Wehrbain, "**Frictional forces on an inclined plane**", Am. J. Phys. 60 (1), January 1992.

[3] R. E. Vermillion and G.O.Cook, "A **particle sliding down a movable incline: An experiment**", Am. J. Phys., Vol.56, No.5, May 1988.

[4] John F. Goehl, "**Effect of frictional force on time of motion**", Am. J. Phys., July 1983.

[5] J. Krim, "**Friction at macroscopic and microscopic length scales**", Am. J. Phys., Vol.70, No.9, September 2002.

[6] J.Ringlein and M.O.Robbins, "**Understanding and illustrating the atomic origin of friction**" , Am. J. Phys., Vol.72, No.7, July 2004.

[7] J.Krim, "**Friction at the atomic scale**" Sci. Am. 275, 74-80 (1996).

[8] Gerald E. Hite, "**The sled rice**", Am. J. Phys., Vol.72, No.8, August 2004.

[9] Timothy J. Folkerts, "**Exploring factors affecting measurements of the static coefficient of friction: An application of fractional factorial experiment design** ", Am. J. Phys., Vol.72, No.10, October 2004.

[10] A. Bonanno,"**La Multimedialità come strumento per l'apprendimento modulare ed interdisciplinare delle Scienze. Un esempio di Lezione Multimediale: Le onde elastiche**" -

[11] C. Costabile e R. Santarossa , "**Formazione della conoscenza con le nuove tecnologie**", *Convegno Internazionale – Didattica in ambito scientifico con le nuove tecnologie – Maggio 2003*

[12] http://www.merlot.org/Home.po

[13] http://www.phy.ntnu.edu.tw/java/friction/friction.html

[14] http://www.sc.ehu.es/sbweb/fisica/dinamica/rozamiento/estatico/estatico.htm

[15] http://www.fis.unical.it/~milazzo/Attrito/appletA.htm

[16] http://www.fis.unical.it/~milazzo/Attrito/appletB.htm

[17] M.Urbakh, J.Klafter, D.Gourdon & J.Israelachvili, "**The nonlinear nature of friction**" , *Nature, vol.430, 29 Luglio 2004.*

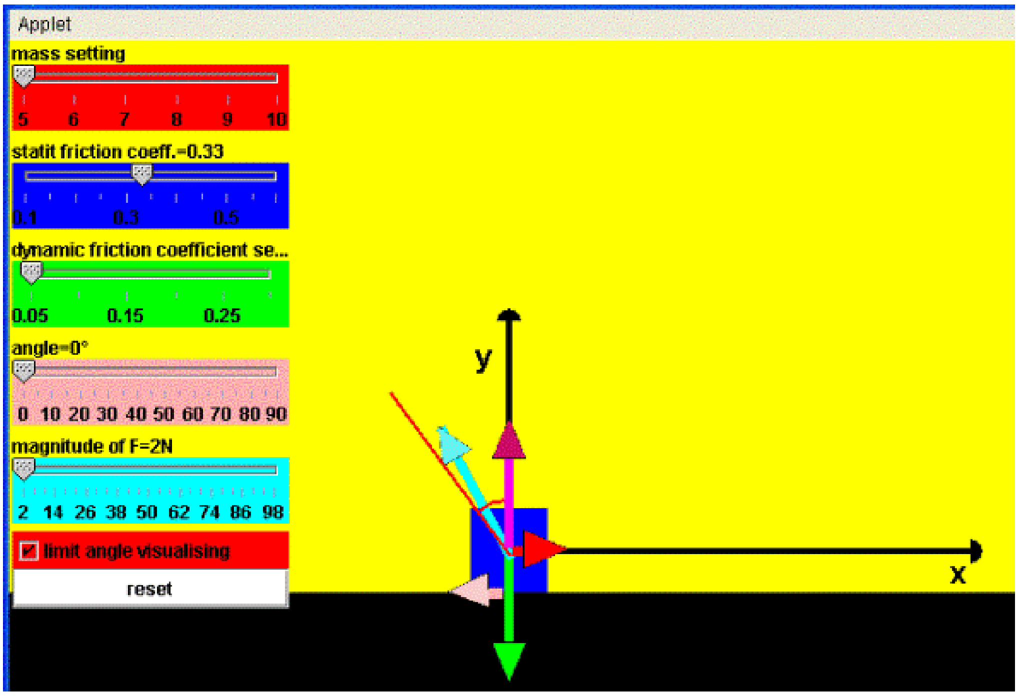

Fig.1
The picture shows at the left side of applet the control panel by which it's possible to set the parameters involved in body motion. At the centre of figure is showed the body in stationary condition. The static friction is represented by a pink arrow, **Fext** by the red one, **P** and **N** forces are represented in green and magenta colours respectively. The total constrain reaction is the cyan arrow and limit angle is in red colour.

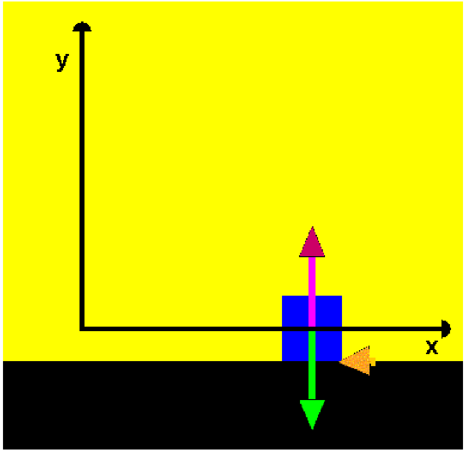

Fig. 2
The figure shows a body's motion under the action of dynamic friction (orange arrow).

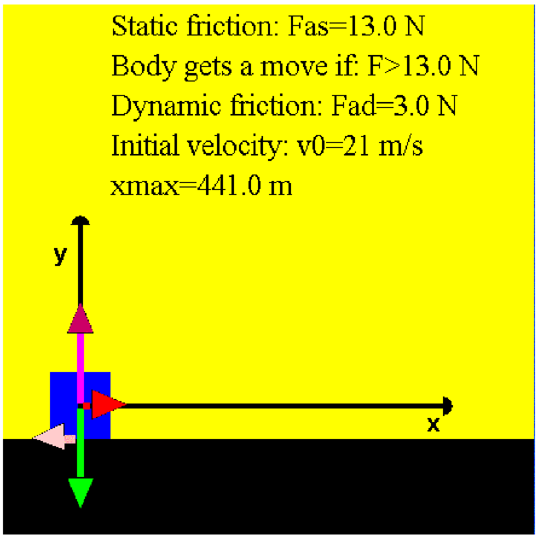

Fig. 3
The picture shows the possibility to visualise the numerical values of kinematic and dynamic quantities.

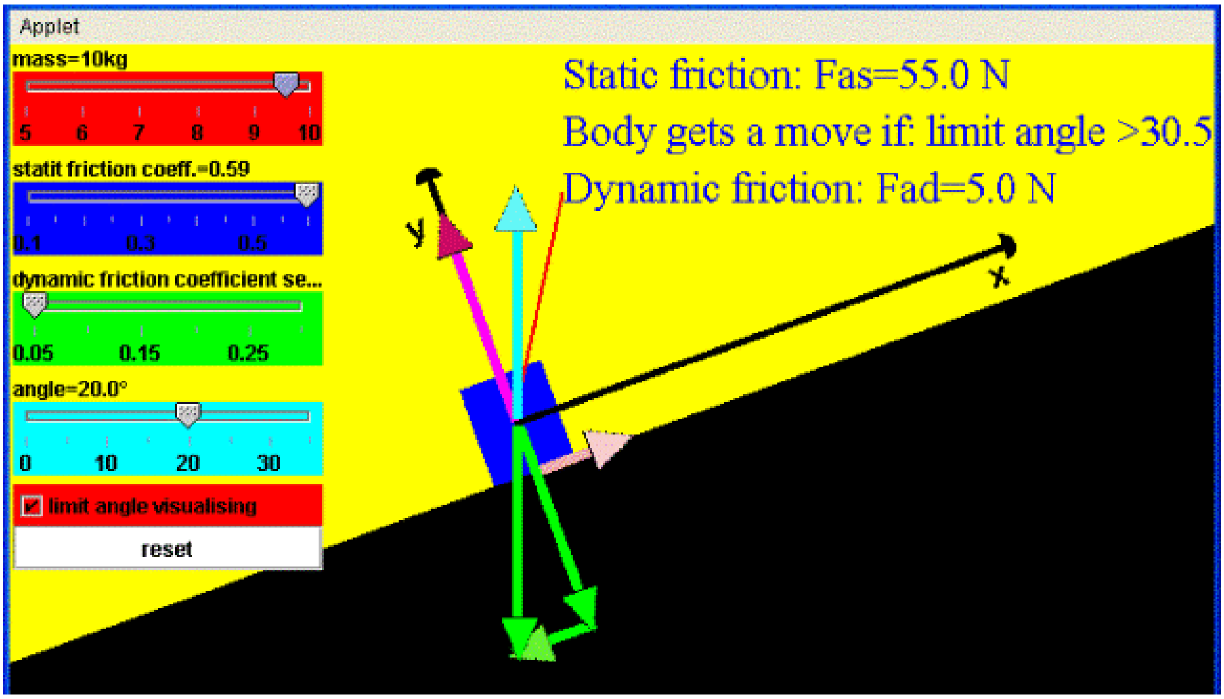

Fig.4
The picture shows the sliders to set the involved parameters. The cyan slider permits to vary plane inclination. It's evident the x-component of **P** (green arrow), the limit angle (red line) and the values of involved parameters at the right side of applet.