# Use of Indigenous elements in teaching introductory Physics courses

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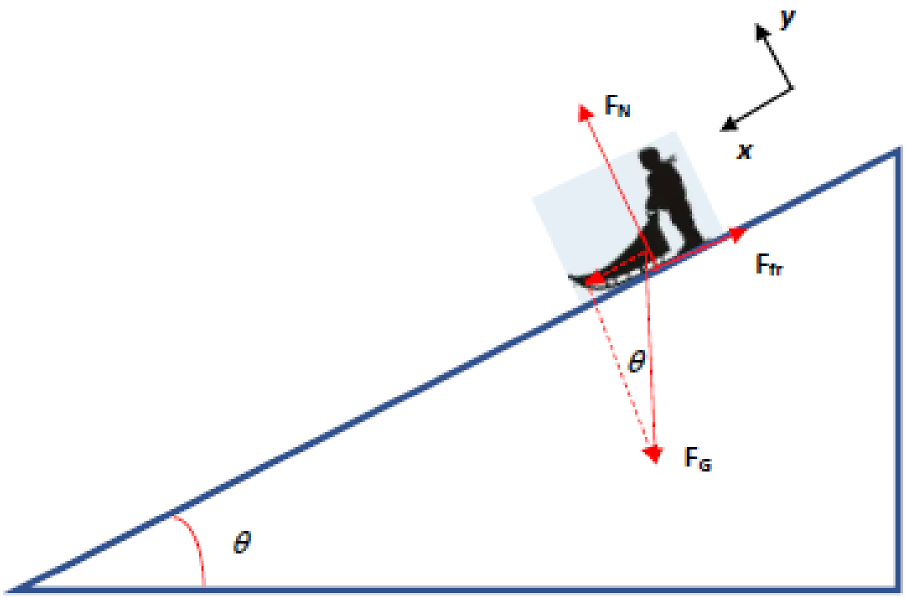
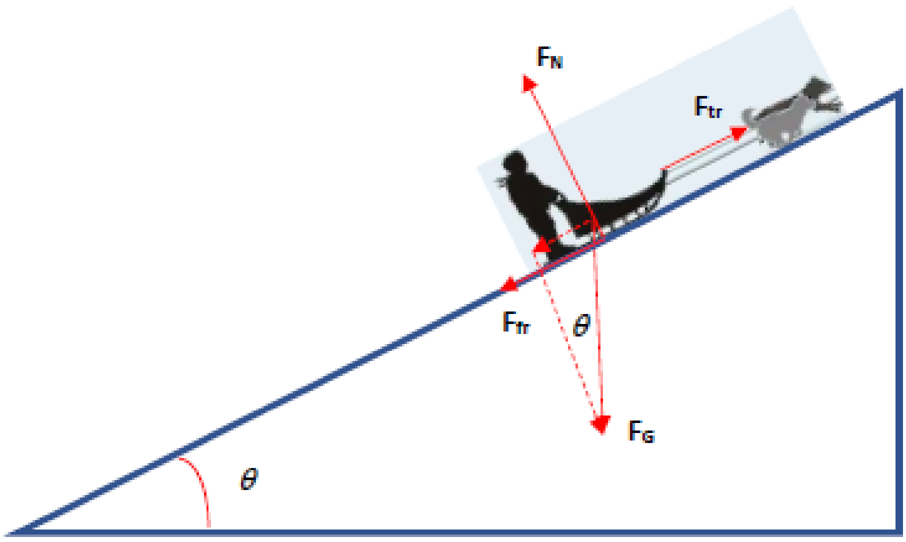
# Example. Friction. Dog Sled

Dogsledding is one of the winter adventures of Indigenous youth in North Saskatchewan. Observation of some dogsledding activities can help us to understand the role of the friction force in the motion along the inclined surface.

(a) A 36-kg boy on a 14-kg sled is moving down along an 8˚-inclined hill at a constant velocity. Find the coefficient of friction between the surface and the sled. Is this friction static or kinetic?

(b) The boy used dogs to get back to the top of the hill. The traction force of the tethered dogs is 500 N. Find the acceleration of the boy on the sled.



# Example. Friction. Dog Sled (cont.)

**Solution**

(a) While the boy the sled is moving down, three forces are acting on the system sled-boy: the gravity force $\mathbf{F}_G$, the normal force $\mathbf{F}_N$ and the friction force $\mathbf{F}_{fr}$. Because the system is moving, we have to consider the friction as kinetic. The net force is zero, since the system is moving at the constant velocity. We can apply Newton's First Law to this system:

$$\mathbf{F}_G + \mathbf{F}_N + \mathbf{F}_{fr} = \mathbf{0} \qquad (1)$$

We choose the ***x***-axis along the slope with positive direction pointing down the slope, and ***y***-axis along the normal to the slope, as it is shown on the diagram (Fig. ). Referring to previous sections we can determine $\mathbf{F}_G = m\boldsymbol{g}$ and $|\mathbf{F}_{fr}| = |\mu_S \mathbf{F}_N|$, where *m* is the total mass of the boy and sled: $m = 36\text{ kg} + 14\text{ kg} = 50\text{ kg}$ As one can see, both, the normal force and the coefficient of kinetic friction are unknowns. Therefore, we need two equations for finding unknowns. Writing ***x*** and ***y*** components of Newton's First Law would lead us to the solution:

$$mg\sin\theta - \mu_S F_N = 0 \qquad (2a)$$

$$-mg\cos\theta + F_N = 0 \qquad (2b)$$

Now we can find the value of the normal force from the equation (2b):

$$F_N = mg\cos\theta \qquad (2c)$$

Let's use (2c) in (2a) for finding the coefficient of the kinetic friction:

$$mg\sin\theta - \mu_S mg\cos\theta = 0$$

$$\mu_S = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta = \tan(8^\circ) = 0.14$$

Answer: 0.14

(b) In this part Newton's Second Law will include the traction force of the tethered dogs, $\mathbf{F}_{tr}$:

$$\mathbf{F}_G + \mathbf{F}_N + \mathbf{F}_{fr} = m\boldsymbol{a} \qquad (3)$$

The values of the normal force and the coefficient of the kinetic friction were determined in part (*a*). This is why it will be enough to write only the ***x*** component of the equation (3):

$$mg\sin\theta + \mu_S F_N - F_{tr} = ma \qquad (3a)$$

Using (2*c*) in (3*a*) we get:

$$mg\sin\theta + \mu_S mg\cos\theta - F_{tr} = ma \qquad (3b)$$

Now we can find the acceleration:

$$a = \frac{mg\sin\theta + \mu_S mg\cos\theta - F_{tr}}{m}$$

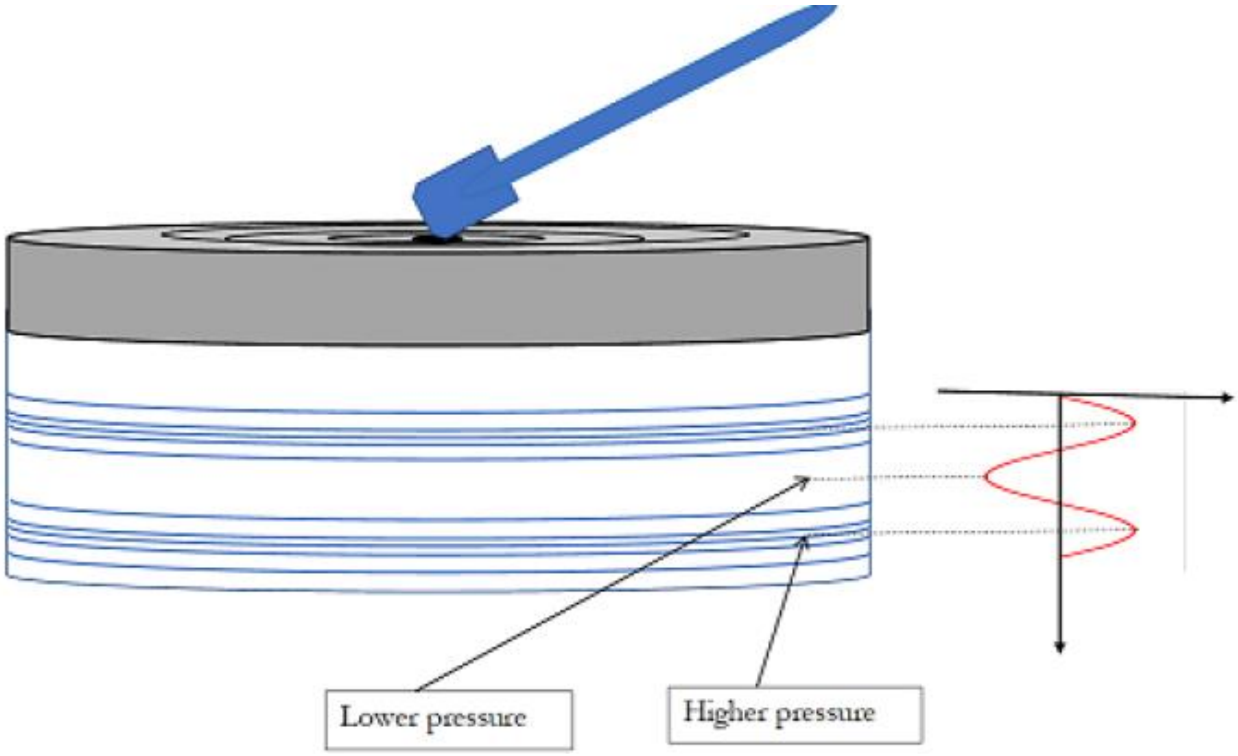
$$= \frac{(50\text{ kg})(9.8\frac{\text{m}}{\text{s}^2})(\sin 8^\circ) + (0.14)(50\text{ kg})\left(9.8\frac{\text{m}}{\text{s}^2}\right)(\sin 8^\circ) - 500\text{ N}}{50\text{ kg}} = -8\,\frac{\text{m}}{\text{s}^2}$$

Answer: 8 m/s$^2$

**Thinking exercise**: Interpret the negative sign of the acceleration.

# Example. Sound Waves. Drum

Many nations use the drum as a musical instrument. But drums are not just music makers, they can hold great cultural and symbolic meaning. Indigenous knowledge Keepers distinguish between hand drums and Pow Wow drums. The PowWow drums are larger than hand drums and usually a group of people perform on these drums. To learn more about one drum makers knowledge about hand drums visit the video on our website. The drum maker in the video has noticed some correlation between the physical parameters of drums and the sound generated from them. For instance, he noticed that depending on how far you strike the drum from the edge, you get a different pitch. Also, that a change in hide thickness, diameter of the drum, hardness of the striker and the surrounding air humidity all affect the sound of the drum.
Below we will analyze the physical properties of sound generated by drums. Physically, a hand drum can be considered as a cylindrical shell, which surrounds a column of air closed from one end by stretched skin (Figure below).




The skin behaves as a membrane. When we strike the drum by a drumstick, the hide starts vibrating at the point of striking. The vibration travels generating waves in all directions from the point of struck toward the rim. The rim rebounds waves repeatedly. In other words, the drum surface vibrates back and forth setting up standing waves. The vibration of the drum surface creates alternating regions of higher and lower pressure in the air column.

# Example. Sound Waves. Drum (cont.)

The Pow Wow drums can be considered as a cylindrical shell surrounding a column of air closed from both ends. These drums are played by drum groups consisting of five or more singers. All group members strike the drum. In terms of physics, this means that five or more sound waves are generated on the surface of the drum. Analysis of the interaction of these waves requires more advanced mathematical apparatus and will not be carried out within this book.

# Example. Heat Flow. Tipi

Indigenous People once lived in tipis. A traditional tipi is a cone-shaped dwelling, with a flap for a door, no windows, and usually covered by a bison skin. Indigenous People used a bonfire to heat their place. For safety reasons, they did not fan the bonfire when they slept. However, the tipis kept them warm the whole night even in the coldest of weather. Let us analyze, why this was possible. A traditional Indigenous tipi was built of about 4-mm bison skin with the fur intact. Indigenous people were able to keep the inside temperature at 18°, while the temperature outside was as cold as −15°. Let us calculate the rate of the heat flow through the circular piece of a 5-mm sick fur-covered bison skin with a diameter of 80 cm, assuming that the heat flows perpendicular to the surface. The thermal conductivity of the fur-covered bison skin is 0.050 J/(s×m°C).

**Solution**

Since the temperature inside of the tipi is higher than the outside temperature, the heat flows from inside to outside. Considering that the heat flow is perpendicular to the wall surface, we can find the rate of the heat flow using the equation

$$\frac{Q}{t} = kA\frac{T_1 - T_2}{L}$$

Given: $L = 0.05$ m, $T_1 = 18°$C, $T_2 = 18°$C, $T_2 = -15°$C, $d = 0.8$ m, $k = 0.050\ \frac{\text{J}}{\text{s} \times \text{m} \times° \text{C}}$

First, we must determine the area of the fur-covered bison skin:

$$A = \frac{\pi d^2}{4} = \frac{\pi\,(0.8\text{ m})^2}{4} = 0.50\text{ m}^2$$

Now we can calculate the heat loss through the bison skin:

$$\frac{Q}{t}|_{skin} = 0.050\ \frac{\text{J}}{\text{s} \times \text{m} \times° \text{C}} \times 0.50\text{ m}^2 \times \frac{18°\text{C} - (-15°\text{C})}{0.05\text{ m}} = 17\ \frac{\text{J}}{\text{s}}$$

Currently, brick is largely used in the construction of houses. The thermal conductivity of brick is 0.84 J/s × m ×° C. The typical thickness of a brick wall is 0.23 m. The heat loss through this fragment of the brick wall can be calculated as

# Example. Heat Flow. Tipi (cont.)

$$\frac{Q}{t}|_{brick} = 0.84 \ \frac{\mathrm{J}}{\mathrm{s} \times \mathrm{m} \times^{\circ} \mathrm{C}} \times 0.50 \ \mathrm{m}^2 \times \frac{18^{\circ}\mathrm{C} - (-15^{\circ}\mathrm{C})}{0.23 \ \mathrm{m}} = 60 \ \frac{\mathrm{J}}{\mathrm{s}}$$

$$\frac{\frac{Q}{t}|_{brick}}{\frac{Q}{t}|_{skin}} = \frac{60 \ \frac{\mathrm{J}}{\mathrm{s}}}{17 \ \frac{\mathrm{J}}{\mathrm{s}}} \approx 3.5$$

$$answer \approx \boxed{3.5}$$

As one can see, the fur-covered bison skin is approximately 3.5 better as an insulator than the brick, which is why less energy is needed to keep the tipi warm.