**QUESTION:**
A bus is moving downhill at a slope of 5° on a rainy day. At the moment when the speed of the bus is 30 km h−1 (8.33 m/s),the driver spots a deer 30 m ahead. He applies the brakes and comes to a stop. The deer is paralyzed by fear and does not move. Will the bus stop before reaching it or will it hit the deer? Do relevant calculations and draw appropriate force diagram. Take the coefficient of kinetic friction to be μk = 0.26

SOLUTION:
There are three forces, acting on a bus: normal force $\vec{F}_N$, the force of friction $\vec{F}_{fr}$ and the gravitational force $m\vec{g}$:
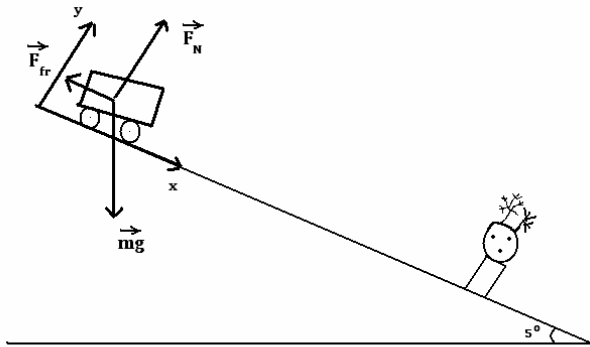
According to the Newton's second law of motion:
$$\vec{F} = m\vec{a}$$
$$\vec{F} = \vec{F}_N + m\vec{g} + \vec{F}_{fr}$$
Hence:
$$\begin{cases} -F_{fr} + mg\sin(5^o) = ma \ (\textit{the projection onto x axis}) \\ F_N - mg\cos(5^o) = 0 \ (\textit{the projection onto y axis}) \\ F_{fr} = \mu F_N \ (\textit{Amonton's law of friction}) \end{cases}$$

$$\begin{cases} -F_{fr} + mg\sin(5^o) = ma \\ F_N = mg\cos(5^o) \\ F_{fr} = \mu mg\cos(5^o) \end{cases} \Rightarrow \begin{cases} -\mu mg\cos(5^o) + mg\sin(5^o) = ma \\ F_N = mg\cos(5^o) \\ F_{fr} = \mu mg\cos(5^o) \end{cases} \Rightarrow$$

$$\Rightarrow \begin{cases} mg(\sin(5^o) - \mu\cos(5^o)) = ma \\ F_N = mg\cos(5^o) \\ F_{fr} = \mu mg\cos(5^o) \end{cases} \Rightarrow a = -g\left(\mu\cos(5^o) - \sin(5^o)\right)$$

The projection onto x axis of the acceleration of the bus is negative, because the bus decelerates. Hence, the bus travels:
$$s = \upsilon_0 t + \frac{at^2}{2} \text{ . Where } \upsilon = \upsilon_0 + at$$
When the bus stops,
$$\upsilon = 0$$
$$0 = \upsilon_0 + at$$
$$t = \frac{-\upsilon_0}{a} = \frac{\upsilon_0}{g\left(\mu\cos(5^o) - \sin(5^o)\right)}$$

Hence

$$s = v_0 t + \frac{at^2}{2} = v_0 \cdot \frac{v_0}{g\left(\mu\cos(5^o) - \sin(5^o)\right)} - \frac{\left(g\left(\mu\cos(5^o) - \sin(5^o)\right)\right)\cdot\left(\dfrac{v_0}{g\left(\mu\cos(5^o) - \sin(5^o)\right)}\right)^2}{2} =$$

$$= \frac{v_0^2}{g\left(\mu\cos(5^o) - \sin(5^o)\right)} - \frac{v_0^2}{2\cdot g\left(\mu\cos(5^o) - \sin(5^o)\right)}$$

$$s = \frac{v_0^2}{2\cdot g\left(\mu\cos(5^o) - \sin(5^o)\right)}$$

$$s = 20.6 \; m$$

This answer we can easily obtain without using the Newton's law of motion. According to the work-energy theorem

$$W = E_{k2} - E_{k1} + E_{p2} - E_{p1}$$

$$E_{k2} = 0$$

$$E_{k1} = \frac{mv_0^2}{2}$$

$$E_{p2} - E_{p1} = -mgh$$

$$h = s\cdot\sin(5^o)$$

$$W = F_{fr}\cdot s\cdot\cos(180^o) = -F_{fr}s$$

$$F_{fr} = \mu F_N = \mu mg\cos(5^o)$$

Hence

$$-\mu mg\cos(5^o)\cdot s = -\frac{mv_0^2}{2} - mg\cdot s\cdot\sin(5^o)$$

$$-mg\cdot s\cdot\sin(5^o) + \mu mg\cos(5^o)\cdot s = \frac{mv_0^2}{2}$$

$$s(-g\cdot\sin(5^o) + \mu g\cos(5^o)) = \frac{v_0^2}{2}$$

$$s = \frac{v_0^2}{2g\left(\mu\cos(5^o) - \sin(5^o)\right)}$$

$$s = 20.6 \; m$$

ANSWER:
But will travel 20.6 meters, and won't hit a deer.