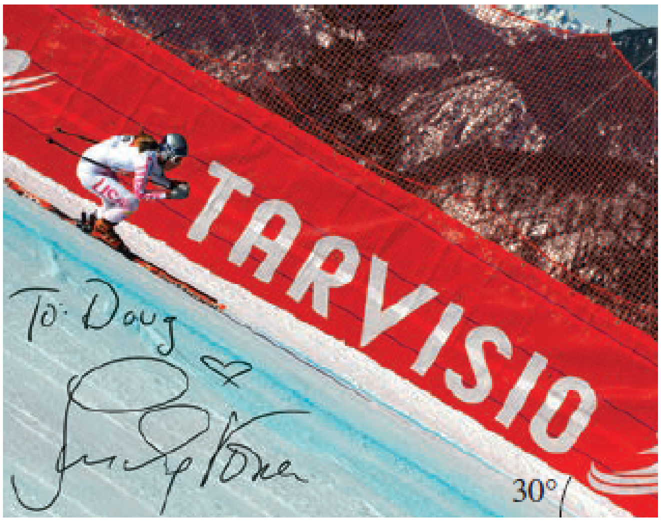
Subject Code	PHY 1	**Physics 1**
Module Code	7.0	**Applications of Newton's Laws of Motion**
Lesson Code	7.6	**Problem Solving on Inclined Planes**
Time Frame		30 minutes

Components	**Tasks**	**TA[1] (min)**	**ATA[2] (min)**
Target	By the end of this learning guide, the student should be able to: • apply Newton's second law of motion to solve word problems on an object along an inclined plane	1	
Hook	An object sliding down an incline, such as a hill or ramp, is an interesting application of Newton's second law of motion. While gravity propels the object to move, the object's acceleration is not along the vertical or along the line of action of gravity. Consider the following word problem. The skier in Figure 1 has begun descending the 30° slope. If the coefficient of kinetic friction is 0.10, what is her acceleration? (Giancoli, 2016)  ***Figure 1.*** *Skier descending a slope (Giancoli, 2016).*	2	

[1] Time allocation suggested by the teacher.
[2] Actual time allocation spent by the student (for information purposes only).

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How are we going to solve this problem?

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Given: μ_k=0.10 $\boldsymbol{\theta}$ = 30°
Required: a

Set the x-axis along the slope in the direction of the skier's motion and the y-axis perpendicular to it. Identify the forces acting on the skier. The free-body diagram, shown in Figure 2, consists of the weight of the skier, the normal force exerted by the slope, and kinetic friction. As the skier is descending on the slope, the kinetic friction is directed up the slope.

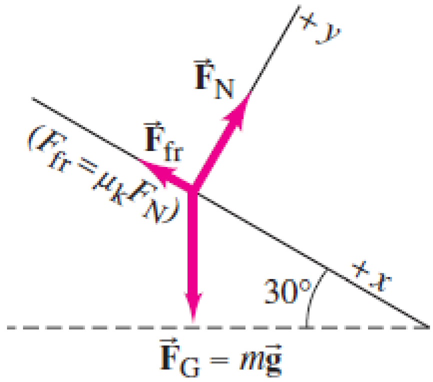

Figure 2. *FBD showing the forces kinetic friction (*$\boldsymbol{F_{fr}}$*), normal force (*$\boldsymbol{F_N}$*) , and weight or force of gravity (*$\boldsymbol{F_G = mg}$*). (Giancoli, 2016)*

***Equations and Solution*:**

Looking at the FBD, notice that weight ($\mathbf{F_G}$) can be resolved into its x- and y-components. See Figure 3 below. The components are drawn along the x- and y- axes as dashed lines:

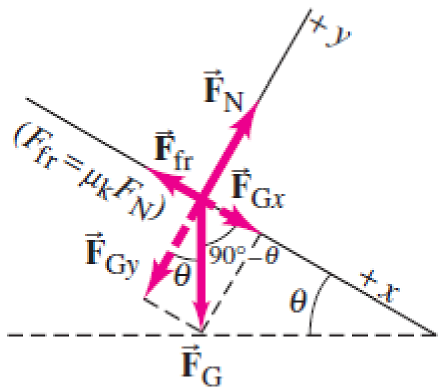

Figure 3. *Resolving the* $\boldsymbol{F_G}$ *into x and y components. (Giancoli, 2016)*

If we denote the angle of the incline as $\boldsymbol{\theta}$, the angle between F_G and +*x*-axis would be $\mathbf{90°-\boldsymbol{\theta}}$. Hence, the angle between F_G and the *y*-axis (or F_{Gy}) is also $\boldsymbol{\theta}$.

Applying the trigonometric functions, sine and cosine, we can obtain the components of F_G.

$$F_{Gx} = mg\sin\boldsymbol{\theta}$$
$$F_{GY} = mg\cos\boldsymbol{\theta}$$

Acceleration, $\mathbf{a_x}$, of the skier down the hill can be computed using Newton's second law in the x-direction:

$\sum F_x = ma_x$ Newton's Second Law

$F_{Gx} + (-F_{fr}) = ma_x$

Kinetic friction is negative since it is in the negative x-direction

$$mg\sin\boldsymbol{\theta} - \mu_k F_N = ma_x \qquad \textit{(equation 1)}$$

Applying Newton's second law in the y-direction:

$$\sum F_y = ma_y = 0$$

where we set $a_y = 0$ because there is no component of the motion along the *y*-direction (perpendicular to the incline).

$$F_N + (-F_{Gy}) = 0$$
$$F_N - mg\cos\boldsymbol{\theta} = 0$$

F_{GY} is negative, since it is in the negative y-direction

Thus, we can solve for $\mathbf{F_N}$:

$$F_N = mg\cos\boldsymbol{\theta} \qquad \textit{(equation 2)}$$

We can then substitute this (equation 2) to the value of F_N in equation 1:

$$mg\sin\boldsymbol{\theta} - \mu_k(mg\cos\boldsymbol{\theta}) = ma_x$$

There is m in each term which can be canceled out and substituting values of $\boldsymbol{\theta} = 30°$ and $\mu_k = 0.10$:

$$a_x = g\sin\boldsymbol{\theta} - \mu_k g\cos\boldsymbol{\theta}$$
$$= (9.8\text{m/s}^2)(\sin 30°) - (0.10)(9.8\text{m/s}^2)(\cos 30°)$$
$$= 4.1\ \text{m/s}^2$$

Answer: The acceleration is 4.1 m/s^2.
From the derived expression, note that the ***acceleration does not depend on the mass***.

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Write your answers with complete solutions on a clean sheet of paper. Follow your teacher's instructions regarding submission.

1. A block is attached to a spring scale as shown in Figure 4 below. If the block is in equilibrium, what is the reading in the scale in Newtons? (Serway, 2014)

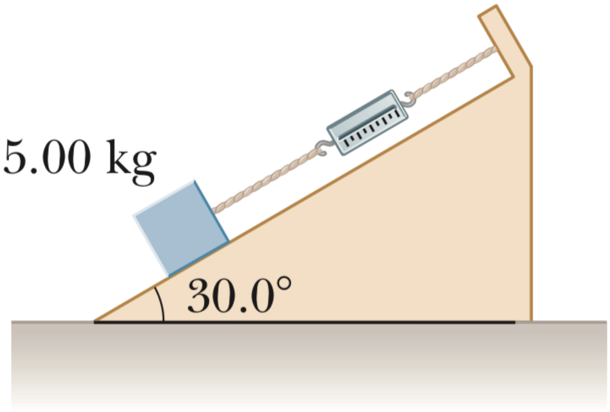
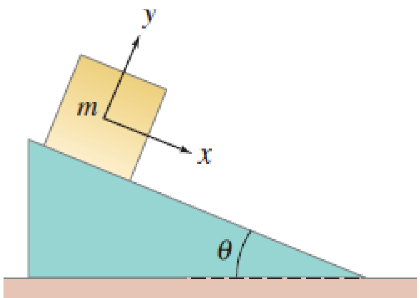


Figure 4. Block attached to a spring scale.

2. The block shown in Figure 5 below has mass m = 7.0 kg and lies on a fixed plane tilted at an angle θ = 22.0° to the horizontal, with $\mu_k = 0.12$. (a) Determine the acceleration of the block as it slides down the plane. (b) If the block starts from rest 9.30 m up the plane from its base, what will be the block's speed when it reaches the bottom of the incline?



(Giancoli, 2016)

Figure 5. Block on a frictionless incline.
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In solving word problems on inclined planes,

- Identify first the forces acting on the object and draw the FBD.
- Set one axis along the incline. Apply Newton's second law for this axis: Net force along this axis is equal to ma for accelerated motion; or equal to 0 if the object is at rest or moving at constant velocity.
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	• Set the other axis perpendicular to the incline. The motion, which is confined along the incline, won't have a component along this perpendicular axis. Hence, the net force on this perpendicular axis is zero. • Simplify and work with algebraic expressions before plugging in values.		

Reference:

1. Giancoli, D.C. (2016). *Physics: Principles with Applications* (Global ed.). Pearson Education.

2. Serway, R. A. and Jewett, J.W. - (2014) *Physics for Scientists and Engineers with Modern Physics* (9th ed.). Cengage Learning.

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