PHYSICS 534

ANSWERS

EXERCISE-16 **Friction**

DALEN

Nils Dalen received the Nobel prize for physics in 1912 for his work on automatic gas flow regulators.

A very important concept in physics is friction. Friction is a force caused by two surfaces in contact. Because friction is a force, it is a vector. As such, it has both magnitude and direction and its unit is the "newton". Note that the term "friction" refers to the resistance to movement of solid objects. For fluids, the term "viscosity" is used to indicate frictional force.

Friction causes energy to be transformed into heat and sound. Since we cannot use the energy which friction transforms into heat and sound, we say that friction causes energy loses. Real systems are systems which have friction. Ideal systems are systems which do not have friction. Ideal systems do not exist in nature. However, by pretending that they do exist, the system under study becomes easier to understand and is known as an ***ideal*** or ***frictionless*** system.

There are three types of frictional forces:

- Static friction (offers the greatest frictional force)
- Kinetic friction (also known as sliding friction)
- Rolling friction (offers the least frictional force)

The formula for friction is: $f = kF_N$

where: f is the frictional force (in newtons)
k is the "coefficient" of friction (a constant always less than one)
F_N is the normal force (in newtons)

↳ ***Note***: Because the coefficient of friction is a ratio between the force of friction and the normal force, it has no units. That is, the unit for frictional force (the newton) cancels with the unit for the normal force (the newton).

★ ***IMPORTANT***: It is very important to realize that the formula for friction gives us the ***maximum*** frictional force. However, just like the maximum strength of a table, the actual frictional force for any situation will depend upon the applied force.

☝ ***Remember***: Friction is a force that always acts in a direction ***opposite*** the motion of an object and therefore has a negative value.

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1. Define ***friction*** and explain whether it is good or bad.

Friction is a force caused by two surfaces in contact.

2. In what ***direction*** do frictional forces act?

Opposite the direction that an object moves.

3. What is an ***ideal*** system and what importance does it have?

An ideal system is a system having no friction (and therefore no energy loss).

4. What is a ***real*** system and how does it differ from an ideal system?

A real system is a system with friction (and therefore energy loss).

5. What becomes of the energy lost to friction?

It is lost (unrecoverable) as heat and sound.

6. Define ***coefficient of friction*** and state its unit.

The coefficient of friction is a ratio between the force of friction and the normal force. It is a number without any units (the units cancel out).

7. Can the coefficient of friction ever be greater than 1.00? Explain.

No, the coefficient of friction cannot be greater than one. If it were greater than one then a real system would gain energy (which is impossible) rather than lose energy.

8. Briefly define the three types of frictional forces.

Static friction: Between two surfaces which are not moving.
Kinetic friction: Between two surfaces which are sliding.
Rolling friction: Between a rolling object and a surface.

9. A block of aluminum having a mass 14 kg slides on a steel surface. If the coefficient of sliding friction is 0.47, find the force of friction. [65.8 N]

$$f = kF_N = (0.47)(140\ N) = 65.8\ N$$

Note: It is understood that the direction of the frictional force is opposite the direction of the movement of the object and is therefore not specified in the answer.

10. How much force is needed to drag a 50 kg block of ice across a floor if the coefficient of friction is 0.05? [25 N]

$$f = kF_N = (0.05)(50\ kg) = 25\ N$$

11. Using a horizontal force of 40 newtons, how heavy a box could you drag across a floor where the coefficient of friction is 0.40? [100 N]

Note: When objects are pulled or pushed, it is understood that they move at constant velocity. As such, $F_R = 0$, thus the applied force equals the frictional force. In this problem, $F_A = 40\ N$ $(\therefore f = 40\ N)$.

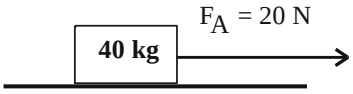
$\because\ f = kF_N$

$$\therefore\ F_N = \frac{f}{k} = \frac{40\ N}{0.4} = 100\ N$$

12. For each of the following systems, assume that the coefficient of friction is 0.2. ***Do not*** assume, however, that the systems are at rest. For each case, draw and calculate: a) The normal force b) The frictional force c) The resultant force

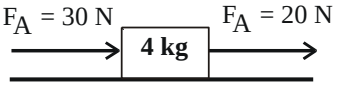
Note: For each case, use the formula $f = KF_N$ to calculate the fricntional force (f).

(a)



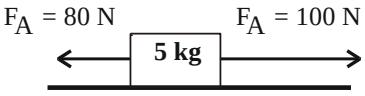
F_N = **400 N**
f = **20 N**
F_R = **0**

(b)



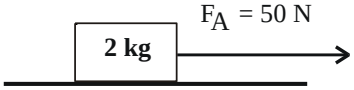
F_N = **40 N**
f = **8 N**
F_R = **42 N E**

(c)



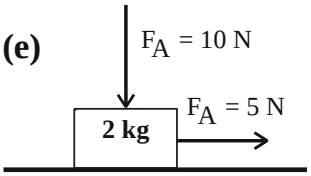
F_N = **50 N**
f = **10 N**
F_R = **10 N E**

(d)



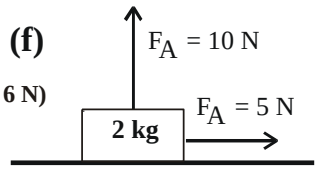
F_N = **20 N**
f = **4 N**
F_R = **46 N E**

(e)



F_N = **30 N**
f = **5 N (max = 6 N)**
F_R = **0**

(f)

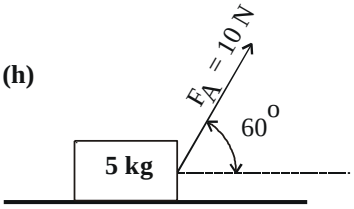


F_N = **10 N**
f = **2 N**
F_R = **3 N E**

(g)

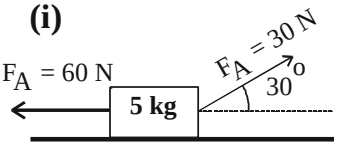
F_N = **20 N**
f = **4 N**
F_R = **0**

(h)



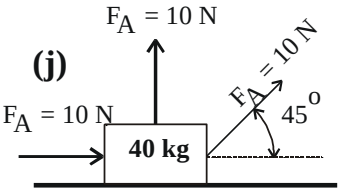
F_N = **41 N**
f = **5 N (max = 8 N)**
F_R = **0**

(i)



F_N = **35 N**
f = **7 N**
F_R = **27 N W**

(j)



F_N = **383 N**
f = **17 N (max = 77 N)**
F_R = **0**