Physics 200 **Unit 3** Name: Key

Friction, Physics Diagrams, Circular Motion, and Gravitation

Part 1: Friction

1. The symbol that I will try to use for friction is f What is friction?

A force that resists the sliding of two forces across one another.

2. The force of friction between two surfaces is determined by two things:
   - The types of materials that are in contact. Every pair of materials that are in contact has its own coefficient of friction (symbol = μ) that is proportional to the strength of the friction between them.
   - The perpendicular force that these surfaces exert on each other, which is known as the Normal Force (F_N)

3. When there is relative motion between objects in contact, the friction is called Kinetic friction. The symbol for its "coefficient" is μ_K.

4. When there is no motion between objects in contact, the friction is called Static friction. The symbol for its "coefficient" is μ_S.

4. According to the table, which type of friction is stronger?

Static Friction

System	Static Friction μ_s	Kinetic Friction μ_k
Rubber on dry concrete	1.0	0.7
Rubber on wet concrete	0.5-0.7	0.3-0.5
Wood on wood	0.5	0.3
Waxed wood on wet snow	0.14	0.1
Metal on wood	0.5	0.3
Steel on steel (dry)	0.6	0.3
Steel on steel (oiled)	0.05	0.03
Teflon on steel	0.04	0.04
Bone lubricated by synovial fluid	0.016	0.015
Shoes on wood	0.9	0.7
Shoes on ice	0.1	0.05
Ice on ice	0.1	0.03
Steel on ice	0.04	0.02

Table 6.1 Approximate Coefficients of Static and Kinetic Friction

6. Write the equation for the magnitude of static friction.

$$f \leq \mu_S F_N$$

7. Write the equation for the magnitude of kinetic friction.

$$f = \mu_K F_N$$

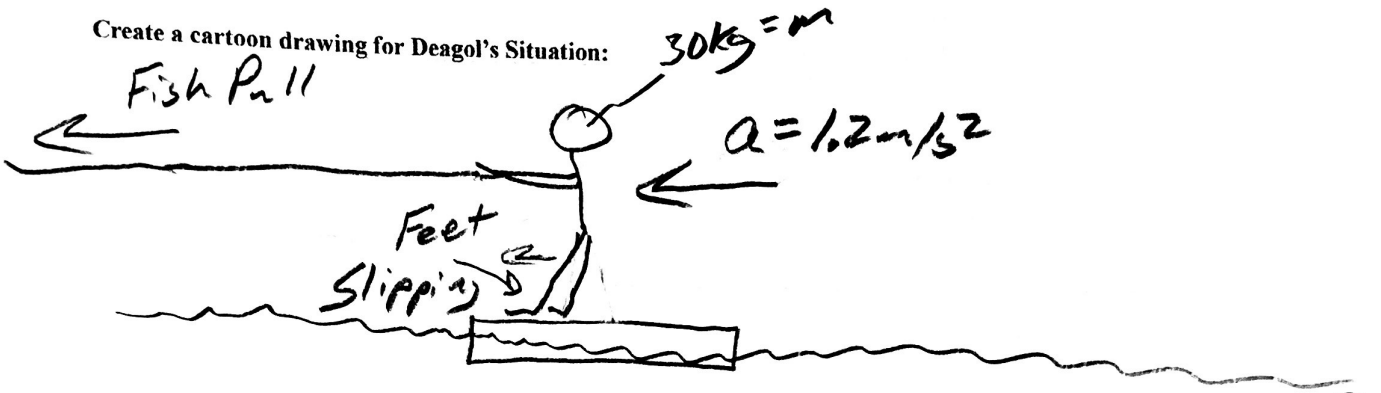
Part 2: Physics Diagrams

Practice each of these types of drawings by creating one of each for this scenario:

> *A 30kg hobbit-like creature named Deagol is standing on a raft on the River Anduin. He is fishing with a simple line and hook, and he is trying to pull in a very large fish. Deagol is pulling the fishing line rightward with a force of 200N, but the fish is too strong, and he is slipping leftward toward the edge of the raft. Deagol is accelerating to the left at a rate of 1.2m/s². What is the coefficient of friction between Deagol's feet and the raft?*

Cartoon Drawing: This is an informal drawings showing objects, their motions, and their surroundings. It provides context for better understanding the System Schema and Free-Body diagrams. You should include accelerations here, if you know them, and you might also want to show net force.

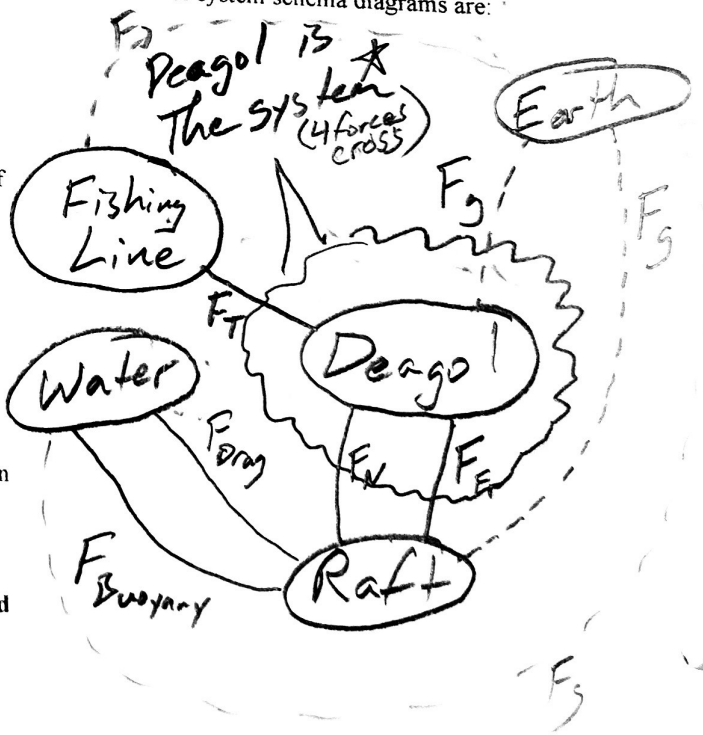
Create a cartoon drawing for Deagol's Situation:



System Schema Diagram: This diagram shows interactions between objects that exert 3rd Law pairs of forces on one another. It is used to identify systems and external forces acting on each system. The rules for system schema diagrams are:

- Write the names of entities/objects that are interacting (i.e. exerting force on one another), and circle each of them. **Leave out air unless drag is specifically mentioned**.
- For each force of interaction between objects, connect the objects with a line. Label the line with the name of the force. Use solid lines for contact forces (e.g. Normal force) and dotted or dashed lines for non-contact forces (e.g. gravity, electric force, or magnetism).
- Keep in mind that some entities may interact with multiple forces, so they should be connected with multiple lines.
- Circle the System you are choosing to analyze with a dotted, dashed, or wavy line – something different than the other circles. In physics, the system is whatever part of the Universe you choose to examine.

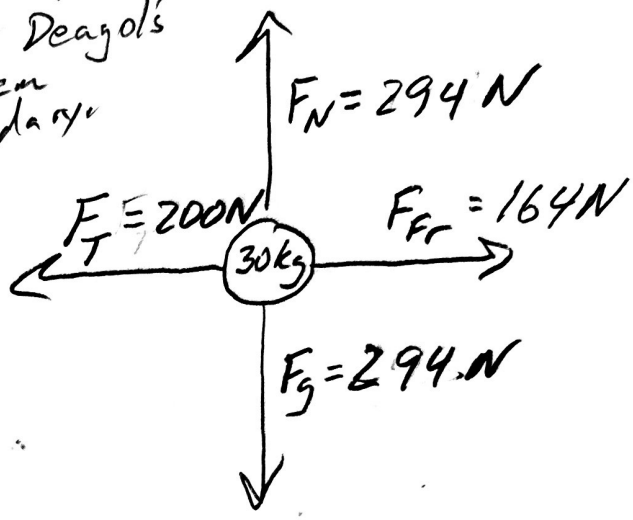
In the space on the right, create a System Schema based on the cartoon. Deagol is the system we are analyzing.



Free-Body Diagram: This is a simple diagram showing the external forces acting on an object (or system). This diagram shows the individual forces that can be added together to give the net force, but it does not include net force.

- Use a box or a circle (with mass inside, when known) to represent the center of mass.
- Show all individual external forces (not net-force, and not internal forces – that do not cross the system boundary in the system schema)
- Draw force vectors as arrows with tails starting at the box and heads pointing outward.
- Label each force vector with the abbreviated name of the force and its magnitude (if known) with correct units.

* From previous page -- 4 forces cross Deagol's system boundary.



In the space on the right, us the System Schema to create a Free-Body Diagram showing all of the forces acting on the system of Deagol. Include only forces whose lines crosses the system boundary.

Solve the problem: Use Newton's Laws to fill in the missing parts of the Free-Body Diagram. Write the two different equations for net force and set them equal. Then use the kinetic friction formula to find the coefficient of friction between Deagol's feet and the raft.

$$F_g = mg = 30kg(9.8\,m/s^2) = 294N$$

2nd Law $\Rightarrow \sum F = ma = 30kg(-1.2\,m/s^2) = -36N$

Vector Sum $\Rightarrow \sum F = F_{Fr} - 200N$

$$F_{Fr} - 200N = -36N$$

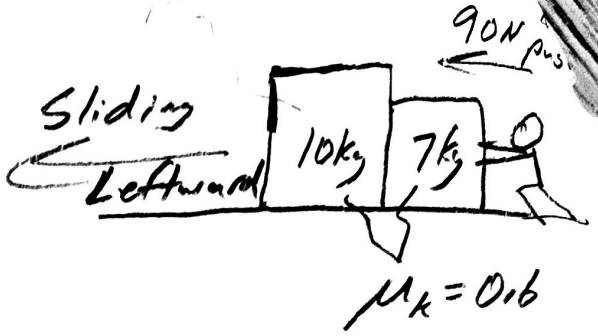
$$F_{Fr} = 164N$$

$$F_{Fr} = \mu_k F_N \Rightarrow 164N = \mu_k(294N)$$

$$\boxed{\mu_k = 0.558}$$

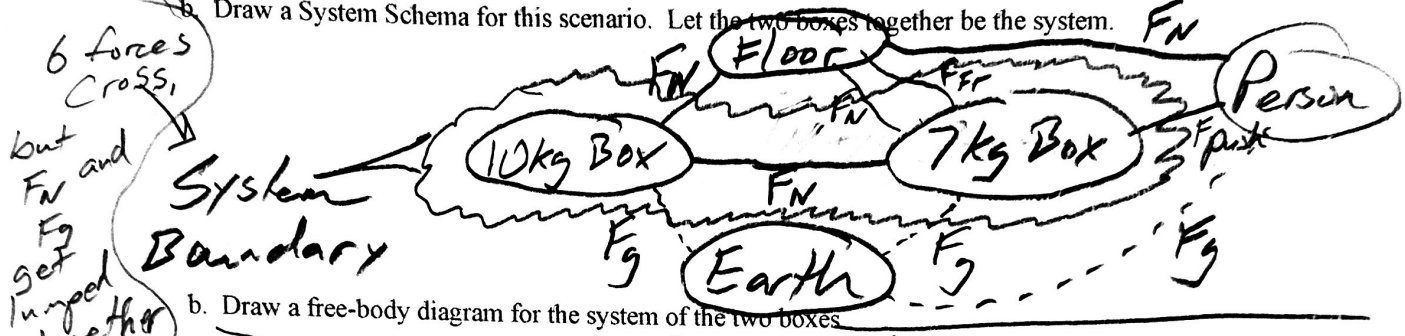
Practice Problems:

1. Someone is pushing a 7kg box leftward across the floor by applying a leftward push of 90N. In front of the 7kg box (to its left) is 10kg box that is being pushed leftward by the 7kg box. The floor is level. The 10kg box is frictionless, but the μ_k of the 7kg box against the floor is 0.6.

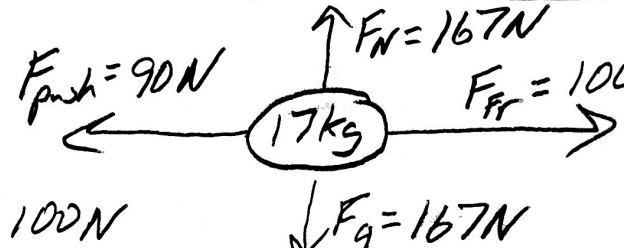


a. Draw a cartoon of this situation in the space to the upper right.

b. Draw a System Schema for this scenario. Let the two boxes together be the system.



b. Draw a free-body diagram for the system of the two boxes.



$F_{Fr} = \mu_k F_N$

$= 0.6(167N) = 100N$

$F_g = mg = 17kg(9.8m/s^2) = 167N$

c. Write two equations for the net force acting on the boxes and solve for their acceleration.

$\Sigma F = ma = 17kg(a)$

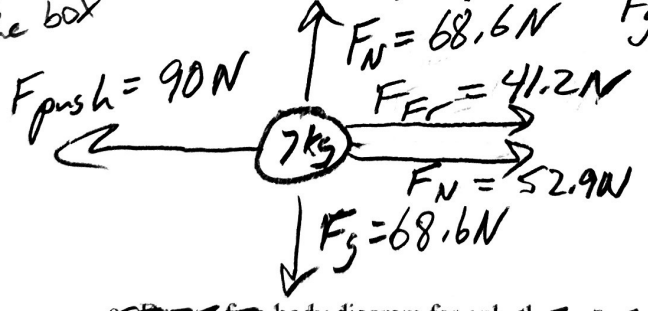
$\Sigma F = 100N - 90N = 10N$

$\Rightarrow 17kg(a) = 10N$

$a = 0.588 m/s^2$

d. Draw a free-body diagram for the system of the 7kg box. [Hint: reconsider the system schema, with only the 7kg box circled as the system.]

* 5 forces connect to the box



$F_g = mg = 7kg(9.8m/s^2) = 68.6N$

$\Sigma F = ma = 7kg(0.588 m/s^2)$

$= 4.12N$

~~e. Draw a free-body diagram for only the system of the 10kg box.~~

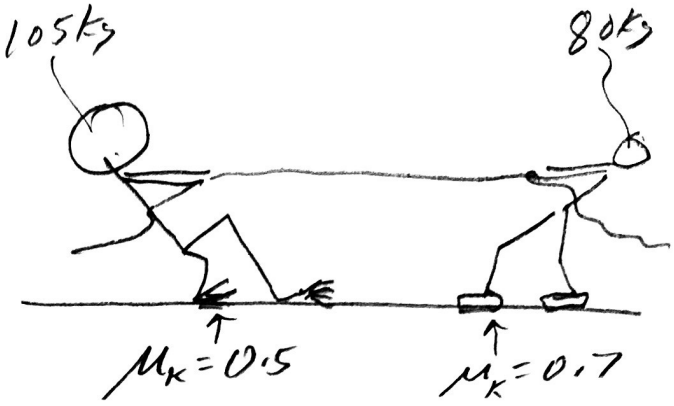
$F_{Fr} = \mu_k F_N = 0.6(68.6N) = 41.2N$

$\Sigma F = 41.2N + F_N - 90N$

$4.12N = 41.2N + F_N - 90N$

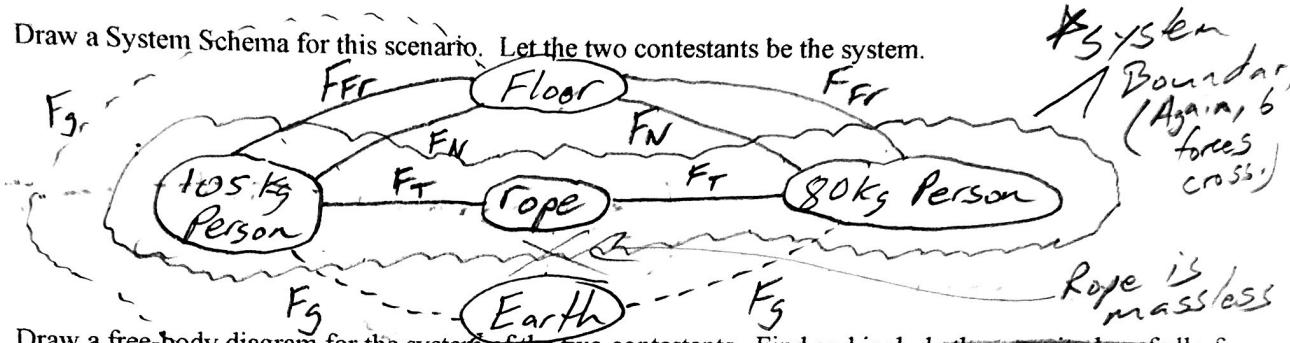
$F_N = 52.9N$

2. Two people are playing tug-of-war on a level surface. The person on our right has a mass of 80kg, and their gym shoes have a coefficient of kinetic friction of 0.7 with the floor. The person on our left has a mass of 105kg, but they are barefoot, with a current $\mu_k = 0.5$. All of their feet are slipping.

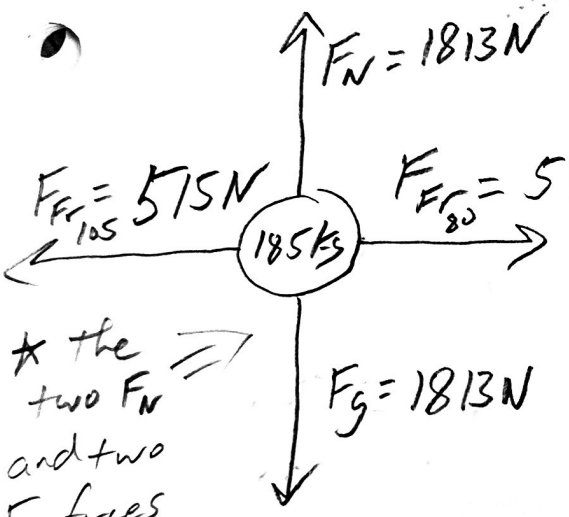


a. Draw a cartoon showing the context of this problem in the space to the upper right.

b. Draw a System Schema for this scenario. Let the two contestants be the system.



b. Draw a free-body diagram for the system of the two contestants. Find and include the magnitudes of all of the individual external forces by writing two equations for net force and setting them equal.



$$F_{Fr_{80}} = \mu F_N = \mu mg = 0.7(80kg)(9.8 m/s^2) = 549N$$

$$F_{Fr_{105}} = 0.5(105kg)(9.8 m/s^2) = 515N$$

★ the two F_N and two F_g forces are lumped together

d. ~~Draw a free body diagram for the system of the contestant on our right~~ Find their acceleration

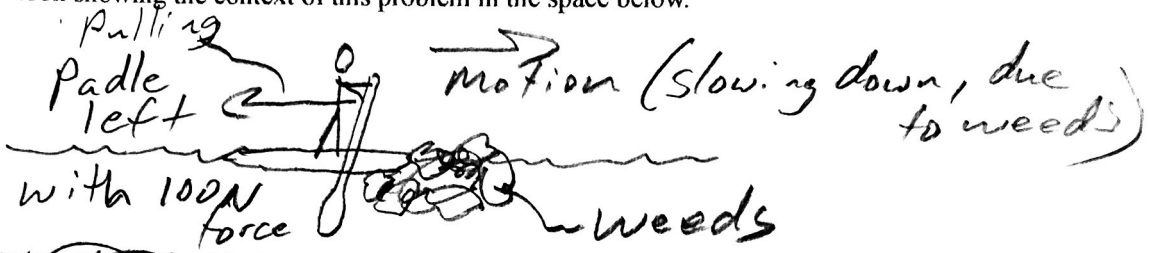
$$\Sigma F = 549N - 515N = 34N$$

$$\Sigma F = ma = 185kg\,(a)$$

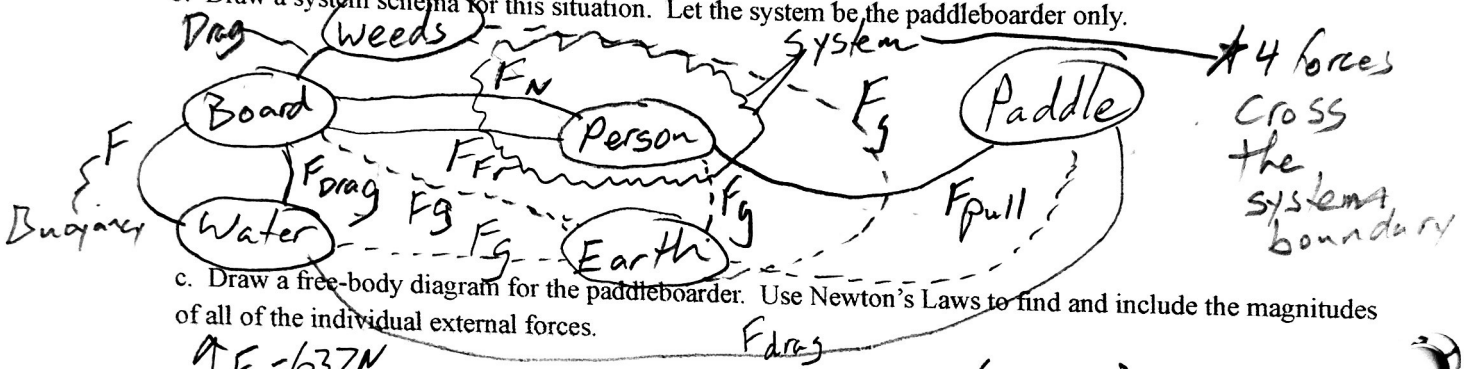
$$185kg\,(a) = 34N \Rightarrow a = 0.184 m/s^2$$

3. A standup paddleboarder is traveling rightward across a lake. The paddleboard has just run into a large mat of aquatic vegetation (weeds) which is causing both the paddleboard and the paddleboarder to slow down (current acceleration = 0.8m/s^2 **to the left**). In an effort to power through the weeds, the paddleboarder is ~~pushing~~ pulling their paddle leftward with a force of 100N. Their feet are not slipping on the paddleboard. The mass of the paddleboarder is 65kg, and the mass of the paddleboard is 35kg. The mass of the paddle is unknown.

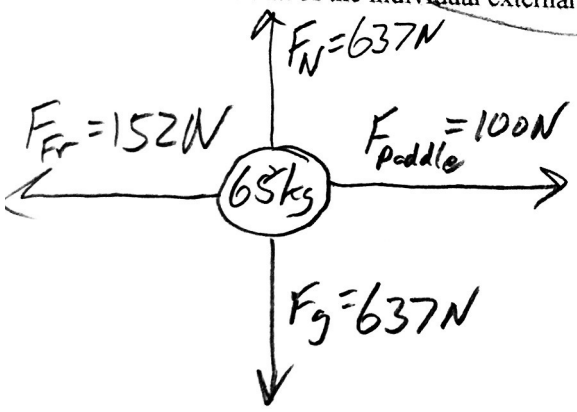
a. Draw a cartoon showing the context of this problem in the space below.



b. Draw a system schema for this situation. Let the system be the paddleboarder only.



c. Draw a free-body diagram for the paddleboarder. Use Newton's Laws to find and include the magnitudes of all of the individual external forces.



F_{drag}

$\Sigma F = 65kg(-0.8m/s^2) = -52N$

$\Sigma F = 100N + F_{Fr}$

$100N + F_{Fr} = -52N$

$F_{Fr} = -152N$

d. ~~Draw a free-body diagram for the system of the paddleboarder~~ paddleboard.

d. What can we say about the value of μ_s between the paddleboarder and the paddleboard?

$F_{Frs} \leq \mu_s F_N \Rightarrow 152 \leq \mu_s (637N) \Rightarrow \mu_s \geq 0.239$