

Physics 2414, Spring 2008
Group Exercise 5, Feb 21, 2008

Name 1: _____ OUID 1: _____
Name 2: _____ OUID 2: _____
Name 3: *Solutions* OUID 3: _____
Name 4: _____ OUID 4: _____

Section Number: _____

Frictional Force

Notation

- \vec{F}_f - Frictional force (static or kinetic).
- \vec{F}_s - Static frictional force.
- \vec{F}_k - Kinetic frictional force.

Description

A tank (of mass 10 kg with water of mass 90 kg) open to the sunlight (so that the water evaporates) is attached to a mass $m_0 = 50$ kg using a massless frictionless pulley as shown in Figure 1. The surface on which the tank rests has coefficient of static friction $\mu_s = 0.8$, and coefficient of kinetic friction $\mu_k = 0.5$. Assume the string is long enough so it can accelerate for many hours.

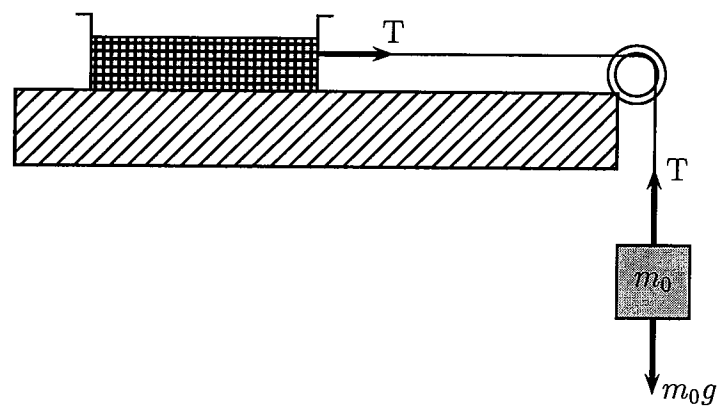
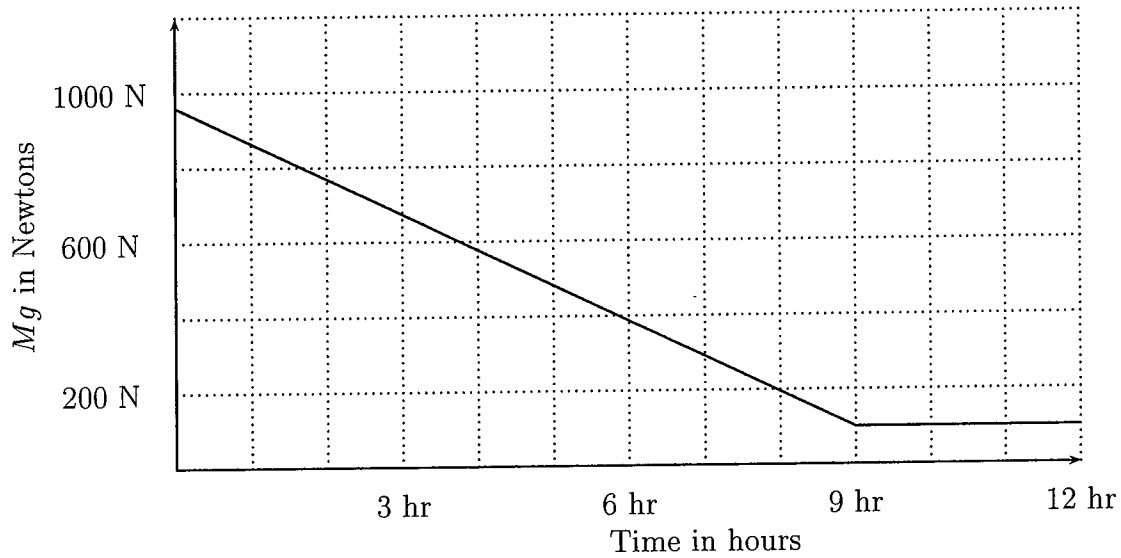


Figure 1: Diagram showing the water+tank being pulled by mass m_0 .

Due to evaporation, the weight ($= Mg$) of the tank+water varies as shown in the plot 1.

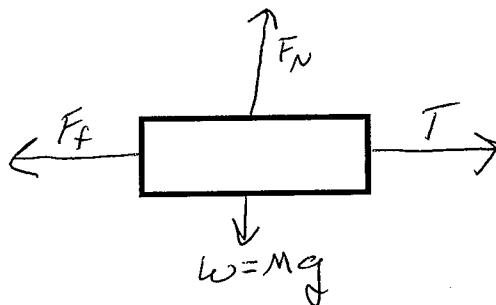


Plot 1: Mg verses time

Problems

1. Normal force:

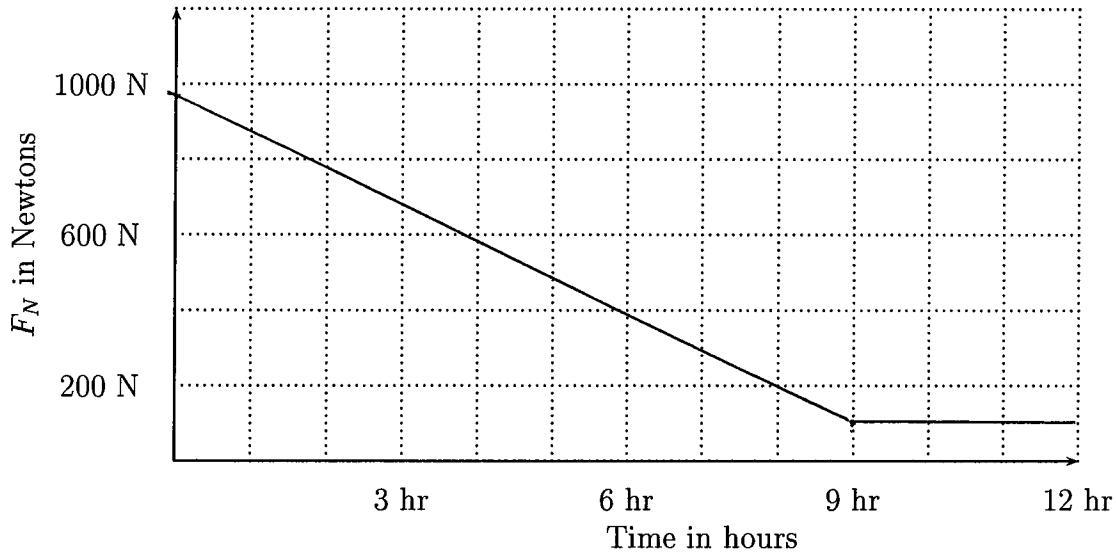
(a) Draw the free body diagram for the system consisting of the tank+water.



(b) Write the expression for the normal force on the tank+water system.

$$F_N = Mg$$

(c) Plot the normal force as a function of time in Plot 2.



Plot 2: Normal force verses time

2. Friction:

(a) Write the force equation for the tank+water in the horizontal direction.

$$+T - F_f = Ma$$

(b) At what time does the tank start to move?

(Hint: $T = m_0g = 490 \text{ N}$ before the tank starts moving; the acceleration of the tank is zero before it starts to move; and $F_f = \mu_s F_N$ instantly before the tank starts to move.)

Before moving use static friction

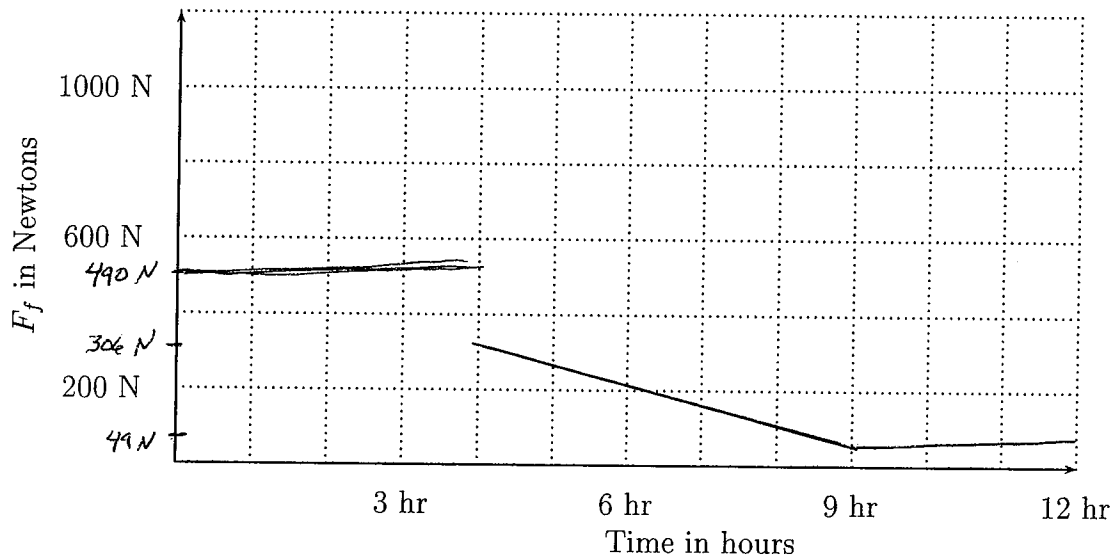
$$F_{f \max} = \mu_s F_N$$

$$\text{from 2a) } T = F_f = \mu_s F_N \quad F_N = \frac{T}{\mu_s} = \frac{490 \text{ N}}{0.8} = 612.5 \text{ N}$$

so once $F_N < 612.5 \text{ N}$ tank will accelerate

from plot 2, this occurs at ~4 hrs

- (c) Plot the frictional force as a function of time in Plot 3.
 (Hint: $F_s \leq \mu_s F_N$ and $F_k = \mu_k F_N$.)

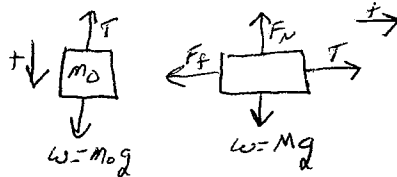


Plot 3: F_f versus time

- (d) What can you tell about the acceleration of the tank after it starts to move? Does the acceleration of the tank attain a constant value after all the water in the tank evaporates? What is the acceleration of the tank after all of the water has evaporated?

- time $t < 4$ hr
 $F_f = F_s = \mu_s F_N = T = \underline{490 N}$
- time $t = 4$ hr
 $F_f = F_k = \mu_k F_N = 0.5 \cdot 612 N = \underline{306 N}$
- time $t > 4$ hr & $t < 9$ hr
 $F_f = F_k = \mu_k F_N$
 Normal changing with time
- time $t > 9$ hr
 all water gone, $F_N = \text{constant}$
 $F_f = \mu_k F_N = 0.5 \cdot 98 N = \underline{49 N}$

- acceleration does reach a constant value after water evaporates



$$\begin{aligned}
 m_0 g - T &= m_0 a & T - F_f &= M a \\
 T &= m_0 g - m_0 a & T &= M a + F_f \\
 m_0 g - m_0 a &= M a + \mu_k M g \\
 m_0 g - \mu_k M g &= M a + m_0 a \\
 a &= g \frac{(m_0 - \mu_k M)}{M + m_0}
 \end{aligned}$$

$$a = 9.8 \text{ m/s}^2 \frac{(50 \text{ kg} - 0.5 \cdot 10 \text{ kg})}{10 \text{ kg} + 50 \text{ kg}} = \boxed{7.35 \text{ m/s}^2}$$