Physics 2414, Spring 2005
Group Exercise 2, Feb 3, 2005

Name 1: ______________ OUID 1: ______________

Name 2: ______________ OUID 2: ______________

Name 3: Solutions ______________ OUID 3: Solutions ______________

Name 4: ______________ OUID 4: ______________

Section Number: ____

Frictional Force

Notation

$\vec{\mathbf{F}}_f$ - Frictional force (static or kinetic).
$\vec{\mathbf{F}}_s$ - Static frictional force.
$\vec{\mathbf{F}}_k$ - 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 $\mu_k = 0.5$.

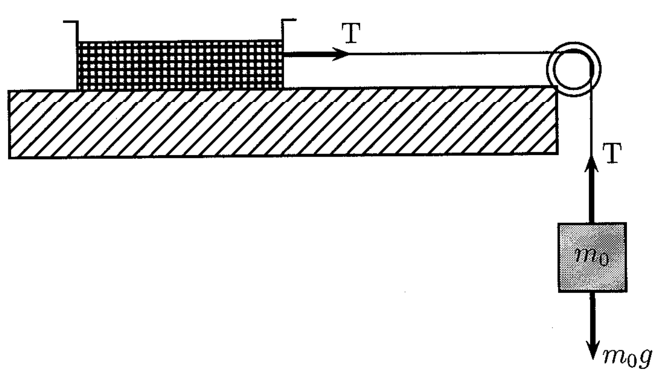
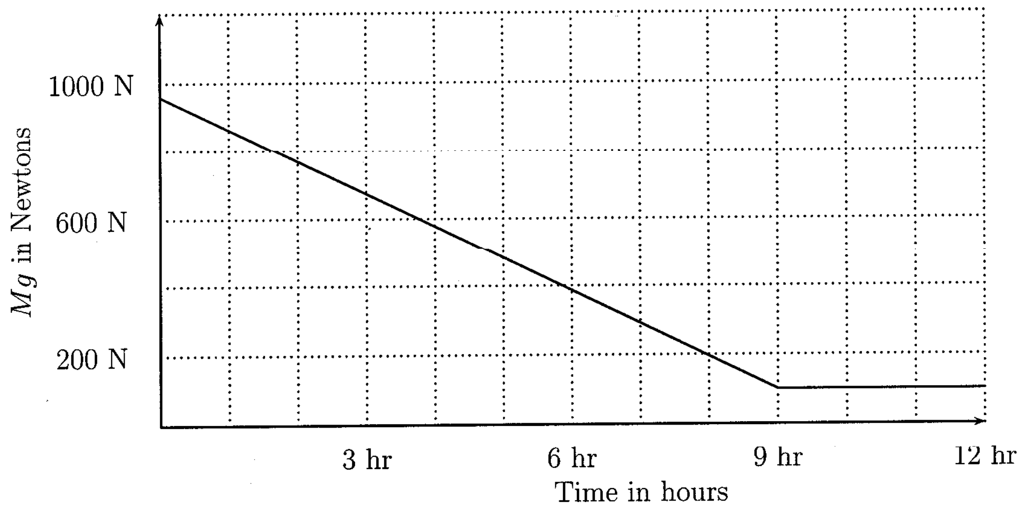


Figure 1: Diagram showing the water+tank being pulled by mass m_0.

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

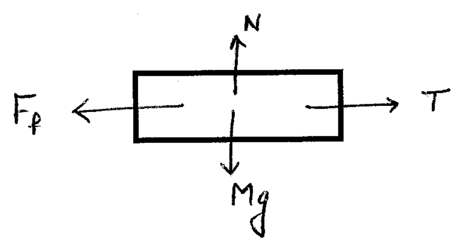


Plot 1: Mg verses time

Problems

1. *Normal force:*

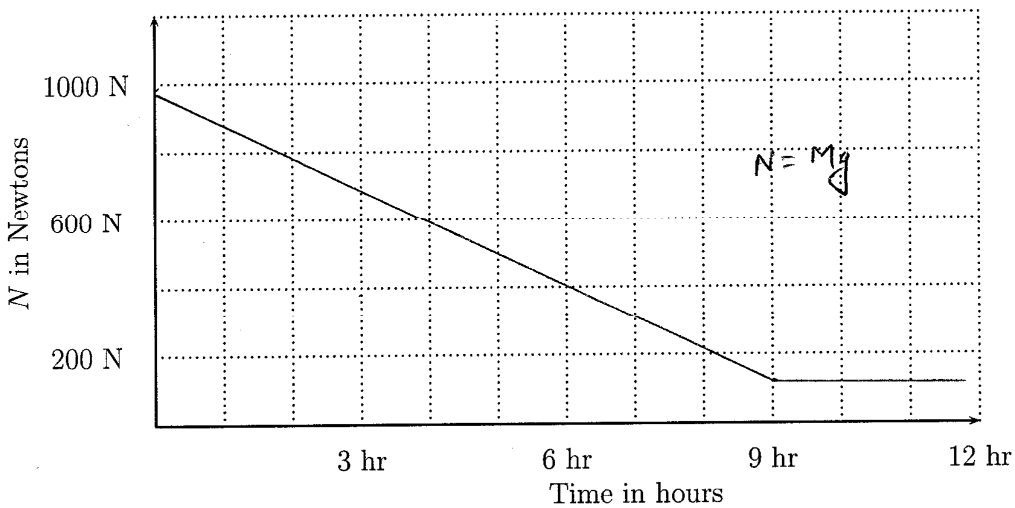
(a) Draw the free body diagram for the system consisting of the tank+water.



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

$$N = Mg$$

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



Plot 2: N verses time

2. *Friction:*

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

$$+T - F_f = M a_{tank}$$

(b) At what time does the tank start to move?
(Hint: T $= m_0 g - 490$ N before the tank starts moving; the acceleration of the tank is zero before it starts to move; and $F_f = \mu_s N$ instantly before the tank starts to move.)

Using ①(a), $a_{tank} = 0$, $F_f = \mu_s N$ we have

$$T - \mu_s N = 0$$

$$N = \frac{T}{\mu_s} = \frac{490}{0.8} = 612.5 \text{ N}$$

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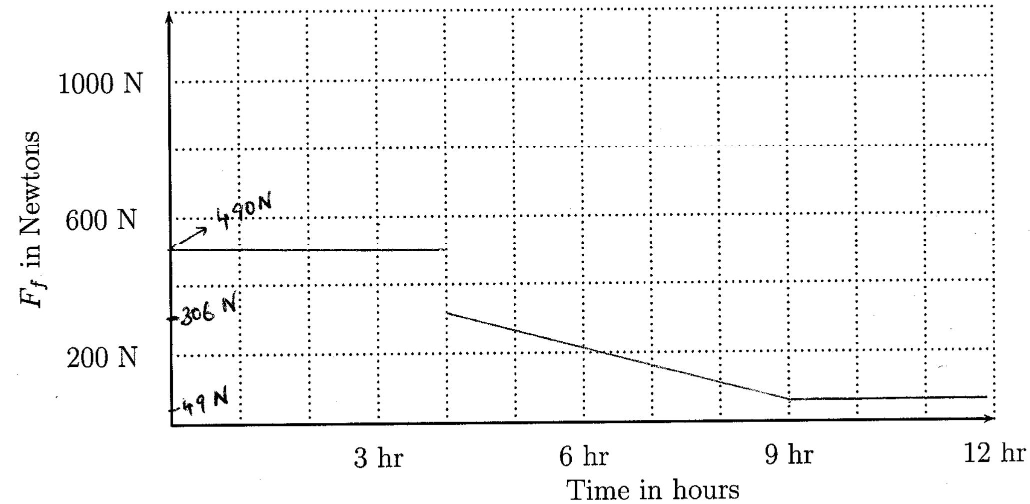
Using plot 2, we conclude that time $\sim$ 4 hrs.

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



Plot 3: F_f verses 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? Give a qualitative answer.

② (c)

time < 4 hr

$F_f = F_s = \mu_s N = T$

$= 490\,N$

time > 4 hr

$F_f = \mu_k N$

at time = 4 hr

$F_f = \mu_k N$

$= 0.5 \times 612.5$

$= 306.25\,N$

at time = 9 hr

$F_f = \mu_k N$

$= 0.5 \times 98$

$= 49\,N$

②(d) Yes.