Solutions to Homework Set #2

Phys2414 - Fall 2005

Please note: The numbers in the $\boxed{\text{boxes}}$ correspond to those that are generated by WebAssign. The numbers on your individual assignment will vary. Any calculated quantities that involve these variable numbers will be $\boxed{\text{boxed}}$ as well.

1. GRR1 2.P.023. (a) Find the altitude above the Earth's surface where Earth's gravitational field strength would be $\boxed{\text{two-thirds}}$ of its value at the surface. Assume $r_e = 6.371 \times 10^3$ km. (b) Find the altitude above the Earth's surface where Earth's gravitational field strength would be $\boxed{\text{one-third}}$ of its value at the surface. [Hint: First find the radius for each situation; then recall that the altitude is the distance from the surface to a point above the surface.]

We have $g = \frac{GM}{R^2}$, so let the new field strength be

$$g' = ng = \frac{GM}{r^2}$$

where $n = \boxed{2/3}$ for part (a) and $\boxed{1/3}$ for part (b). Determine r in terms of R:

$$\frac{g'}{g} = \frac{ng}{g} = n = \frac{\frac{GM}{r^2}}{\frac{GM}{R^2}} = \frac{R^2}{r^2}$$

so $r = \frac{R}{\sqrt{n}}$. Find an expression for the altitude h:

$$h = r - R = \frac{R}{\sqrt{n}} - R = R\left(\frac{1}{\sqrt{n}} - 1\right)$$

$$\text{(a) } h = \left(6.371 \times 10^3\, km\right)\left(\frac{1}{\sqrt{\boxed{2/3}}} - 1\right) = \boxed{1432\ km}$$

$$\text{(b) } h = \left(6.371 \times 10^3\, km\right)\left(\frac{1}{\sqrt{\boxed{1/3}}} - 1\right) = \boxed{4664\ km}$$

2. GRR1 2.P.025. A brick of mass $\boxed{2.00}$ kg is "weighed under water" by hanging it from a spring scale (similar to that shown in the figure below). (a) If the spring scale reads $\boxed{14.0}$ N, what is the upward force of water on the brick? (b) What is the reading of the pan scale on which the beaker sits? The weight of the water and the beaker together is $\boxed{12.0}$ N. [Hint: refer to Example 2.7.]

(a) Sum the forces on the brick. The brick is in static equilibrium, so we have $\overrightarrow{\mathbf{F}}_{net} = \overrightarrow{\mathbf{0}}$*:*

$$\begin{aligned}
\overrightarrow{\mathbf{F}}_{bs} + \overrightarrow{\mathbf{F}}_{bw} + \overrightarrow{\mathbf{W}}_{be} &= \overrightarrow{\mathbf{0}} \\
\overrightarrow{\mathbf{F}}_{bw} &= -\overrightarrow{\mathbf{F}}_{bs} - \overrightarrow{\mathbf{W}}_{be} \\
&= -(-\overrightarrow{\mathbf{F}}_{sb}) - m\overrightarrow{\mathbf{g}} \\
&= \boxed{14.0}\, N\ down - \left(\boxed{2.00}\, kg\right)\left(9.79\frac{N}{kg}\ down\right) \\
&= -\boxed{14.0}\, N\ up + \left(\boxed{2.00}\, kg\right)\left(9.79\frac{N}{kg}\ up\right) \\
&= \boxed{5.6\ \ N\ \ up}
\end{aligned}$$

(b) The reading of the pan scale is the sum of the weight of the water and the beaker together, $\boxed{12.0}$ *N, and the force of the water on the brick,* $\boxed{5.6}$ *N. Therefore the scale reads the sum of all these forces:*

$$\boxed{12.0}\, N + \boxed{5.6}\, N = \boxed{117.6}\, N$$

3. GRR1 2.P.044. The coefficient of static friction between block A and a horizontal floor is $\boxed{0.45}$ and the coefficient of static friction between block B and the floor is $\boxed{0.30}$. The mass of each block is $\boxed{2.0}$ kg and they are connected together by a cord. (a) If a horizontal force F pulling on block B is slowly increased until it is barely enough to make the two blocks start moving, what is the magnitude of F at the instant that they start to slide? (b) What is the tension in the cord connecting blocks A and B at that same instant?

(a) All forces are collinear. The magnitude of the force of the static friction on block A due to the floor must be equal to the magnitude of the tension in the cord:

$$T = f_{sA} = \mu_A N = \mu_A mg$$

The magnitude of the applied force must be equal to thye magnitude of the tension in the cord plus the magnitude of the force of static friction on block B due to the floor:

$$F = T + f_{sB} = \mu_A mg + \mu_B mg = mg(\mu_A + \mu_B) = (\boxed{2.0}\, kg)\left(9.8\frac{N}{kg}\right)(\boxed{0.45} + \boxed{0.30}) = \boxed{15\, N}$$

(b) Based on what we got above, tension is:

$$T = \mu_A mg = \boxed{0.45}(\boxed{2.0}\, kg)\left(9.8\frac{N}{kg}\right) = \boxed{8.8\, N}$$

4. GRR1 2.P.037. A box full of books rests on a wooden floor. The normal force the floor exerts on the box is $\boxed{250}$ N. (a) You push horizontally on the box with a force of $\boxed{120}$ N, but it refuses to budge. What can you say about the coefficient of static friction between the box and the floor? (b) If you must push horizontally on the box with a force of at least $\boxed{150}$ N to start it sliding, what is the coefficient of static friction? (c) Once the box is sliding, you only have to push with a force of $\boxed{120}$ N to keep it sliding. What is the coefficient of kinetic friction?

(a) The force of the static friction is greater than the applied force, so:

$$\begin{aligned} f_s &> F \\ \mu_s N &> F \\ \mu_s &> \frac{F}{N} \\ \mu_s &> \frac{\boxed{120}\,N}{\boxed{250}\,N} \\ \mu_s &> \boxed{0.48} \end{aligned}$$

(b) $\mu_s = \frac{F}{N} = \frac{\boxed{150}\,N}{\boxed{250}\,N} = \boxed{0.60}$

(c) $\mu_k = \frac{F}{N} = \frac{\boxed{120}\,N}{\boxed{250}\,N} = \boxed{0.48}$

5. GRR1 2.TB.010. A parked automobile slips out of gear, rolls unattended down a slight incline and then along a level road until it hits a stone wall. Draw a free-body diagram to show the forces acting on the car while it is in contact with the wall.

Let the subscripts be the following: c=car e=earth w=wall. The force on the car due to earth is downward $\left(\downarrow \vec{\mathbf{F}}_{ce}\right)$*, while the force due to the reaction of the wall is to the right* $\left(\rightarrow \vec{\mathbf{F}}_{cw}\right)$*.*

6. GRR1 2.TB.032. A toy freight train consists of an engine and three identical cars. The train is moving to the right at constant speed along a straight, level track. Three spring scales are used to connect the cars as follows: spring scale A is located between the engine and the first car; scale B is between the first and second cars; scale C is between the second and third cars. (a) If air resistance and friction are negligible, what are the relative readings on the three spring scales A, B, and C? (b) Repeat part (a), taking air resistance and friction into consideration this time. [Hint: draw a free-body diagram for the car in the middle.] (c) If air resistance and friction together cause a force of magnitude 5.5 N on each car, directed toward the left, find the readings of scales A, B, and C.

(a) Since the trian is moving at constant speed, and air resistance and friction friction are negligible, the readings on the three scales are all 0.

(b) Air resistance and friction are not considered negligible this time. The engine pulls the dars against these forces. Since the cars are identical, each car contributes one-third of the total frictional and drag forces. Each spring scale will measure the net force due to the cars behind it, so the relative readings on the three spring scales are A¿B¿C.

(c) Springs A, B, and C measure the forces on 3 cars, 2 cars, and 1 car, respectively. Therefore:
A=5.5 N+5.5 N+5.5 N=16.5 N
B=5.5 N+5.5 N=11.0 N
C=5.5 N

7. GRR1 2.TB.034. A crate full of artichokes rests on a ramp that is inclined 10.0 above the horizontal. Give the direction of the normal force and the friction force acting on the crate in each of these situations. (a) The crate is at rest. (b) The crate is being pushed and is sliding up the ramp. (c) The crate is being pushed and is sliding down the ramp.

(a)
$\vec{\mathbf{N}}$: *perpendicular to and away from*
$\vec{\mathbf{f}}$: *along the ramp upward*

(b)
$\vec{\mathbf{N}}$: *perpendicular to and away from*
$\vec{\mathbf{f}}$: *along the ramp downward*

(c)
$\overrightarrow{\mathbf{N}}$: *perpendicular to and away from*
$\overrightarrow{\mathbf{f}}$: *along the ramp upward*

8. GRR1 2.TB.043. Spring scale A is attached to the floor and a rope runs vertically upward, loops over the pulley, and runs down on the other side to a 120-N weight (the figure below (part b)). Scale B is attached to the ceiling and the pulley is hung below it. What are the readings of the two spring scales, A and B? Neglect the weights of the pulley and scales.

The tension in the lower rope is the same along its length. It is equal to the weight at the end of the rope, so scale A reads 120 N. There are two forces pulling downward on the pully due to the tension of 120 N in each part of the rope. Therefore:

$$T_B = 2 \times T_A = 240\,N$$

Scale B reads 240 N, since it supports the pully.

9. GRR1 2.TB.046. Four identical spring scales, A, B, C, and D are used to hang a 220.0-N sack of potatoes (the figure below). (a) Assume the scales have negligible weights and all four scales show the same reading. What is the reading of each scale? (b) Suppose that each scale has a weight of 5.0 N. If scales B and D show the same reading, what is the reading of each scale?

(a) The tension due to the weight of the potatoes is divided evenly between the two sets of scales:

$$\begin{aligned} 2T &= W \\ T &= \frac{W}{2} \\ &= \frac{220.0\,N}{2} \\ &= 110.0\,N \end{aligned}$$

(b) Scales B and D will read 75.0 N as before. Scales A and C will read an additional 5.0 N due to the weights of B and D, respectively.

$$T_A = T_C = 110.0\,N + 5.0\,N = 115.0\,N T_B = T_D = 110.0$$

10. GRR1 2.P.024. A spring hangs from a $\boxed{2.44}$-m-high ceiling. The relaxed length of the spring is $\boxed{0.305}$ m. A board, $\boxed{1.98}$ m in length, hangs from the spring so that its lower end just reaches, but does not touch, the floor. The board has a mass of $\boxed{10.4}$ kg and is perpendicular to the floor. Find the spring constant of the spring. Assume g = 9.807 N/kg.

Solve Hooke's law for the spring constant, and substitute the weight of the board (mg) for the force F:

$$k = \frac{F}{x} = \frac{mg}{x} = \frac{(\boxed{10.4})\left(9.807\frac{N}{kg}\right)}{\boxed{2.44}\,m - \boxed{0.305}\,m - \boxed{1.98}\,m} = \boxed{660}\,N/m$$