PHYS 1110-02 Fall 2026 Quiz 3

Brief Solutions

1. Hanging ball

We can get away with not drawing a free body diagram for this situation, since the tensions all are directed along the cables. All the cables pull outward on the hub where they are connected. The ball does not accelerate, so the acceleration is zero in the vertical and horizontal directions. If we arbitrarily define the x axis as to the right ($\rightarrow$) and the y axis upward ($\uparrow$), we have

	x	y
T_1	$-T_1 \cos\theta_1$	$T_1 \sin\theta_1$
T_2	$T_2 \cos\theta_2$	$T_2 \sin\theta_2$
T_3	0	mg
$\sum F$	0	0

This gives us two equations in the two unknowns T_1 and T_2:

$$\begin{aligned} 0 &= -T_1 \cos\theta_1 + T_2 \cos\theta_2 \\ 0 &= T_1 \sin\theta_1 + T_2 \sin\theta_2 - mg \end{aligned}$$

Then it's a matter of algebra to solve for T_1 and T_2.

$$\begin{aligned} T_2 &= T_1 \frac{\cos\theta_1}{\cos\theta_2} \\ 0 &= T_1 \sin\theta_1 + T_1 \frac{\cos\theta_1}{\cos\theta_2} \sin\theta_2 - mg \\ T_1 \sin\theta_1 + T_1 \frac{\cos\theta_1}{\cos\theta_2} \sin\theta_2 &= mg \\ T_1 \left(\sin\theta_1 + \frac{\cos\theta_1}{\cos\theta_2} \sin\theta_2 \right) &= mg \\ T_1 &= \frac{mg}{\sin\theta_1 + \cos\theta_1 \tan\theta_2} \end{aligned}$$

Thus

$$\begin{aligned} T_1 &= \frac{(16.0\,\text{kg})(9.8\,\text{N/kg})}{\sin 50^\circ + \cos 50^\circ \tan 40^\circ} = 120.1\,\text{N} \\ T_2 &= T_1 \frac{\cos\theta_1}{\cos\theta_2} = 100.8\,\text{N} \\ T_3 &= 156.8\,\text{N} \end{aligned}$$

2. Block coasting uphill

In this scenario, the motion and acceleration are along an incline rather than vertical or horizontal, so we benefit from using coordinates oriented along the incline. I'll make $+x$ uphill parallel to the incline and $+y$

upward perpendicular to the incline.

	x	y
w	$-mg\sin\theta$	$-mg\cos\theta$
N	0	N
f	$-\mu N$	0
$\sum F$	ma	0

The y side tells us that $N = mg\cos\theta$ and thus $f = -\mu N = -\mu mg\cos\theta$. The x side then requires

$$\begin{aligned} ma &= -mg\sin\theta - \mu mg\cos\theta \\ a &= -g\left(\sin\theta + \mu\cos\theta\right) \\ &= -9.8\,\mathrm{m/s^2}\left(\sin 17^\circ + 0.24\cdot\cos 17^\circ\right) \\ &= -5.11\,\mathrm{m/s^2} \end{aligned}$$

3. Tethered blocks accelerating downhill

The question explicitly asks for the downhill acceleration. The acceleration may be downhill or uphill, depending on how the incline and friction interact. Since the question asks for downhill acceleration, it is prudent to define our $+x$ axis to point downhill. The tension in the cable connecting the two blocks pulls uphill (negative direction) on the downhill block and downhill (positive direction) on the uphill block.

For the downhill block, the forces have components along these axes of

	x	y
w_1	$+m_1 g\sin\theta$	$-m_1 g\cos\theta$
N_1	0	N_1
f_1	$-\mu_1 N_1$	0
T	$-T$	0
$\sum F$	$m_1 a$	0

T has no subscript because it is the same for both blocks. The same is true for a.

The y part gives us $N_1 = +m_1 g\cos\theta$ and consequently $f_1 = -\mu_1 m_1 g\cos\theta$.

The x part gives us

$$\begin{aligned} m_1 a &= m_1 g\sin\theta + 0 - \mu_1 m_1 g\cos\theta - T \\ T &= m_1 g\left(\sin\theta - \mu_1\cos\theta\right) - m_1 a \end{aligned}$$

For the uphill block, the forces have similar relations, except that the tension T is downhill.

	x	y
w_2	$+m_2 g\sin\theta$	$-m_2 g\cos\theta$
N_2	0	N_2
f_2	$-\mu_2 N_2$	0
T	$+T$	0
$\sum F$	$m_2 a$	0

As with block 1, $N_2 = +m_2 g \cos\theta$ and $f_2 = -\mu_2 m_2 g \cos\theta$. Further,

$$\begin{aligned} m_2 a &= m_2 g \sin\theta + 0 - \mu_2 m_2 g \cos\theta + T \\ T &= m_2 a - m_2 g (\sin\theta - \mu_2 \cos\theta) \end{aligned}$$

We can solve for a by setting the T expressions equal to each other:

$$\begin{aligned} m_1 g (\sin\theta - \mu_1 \cos\theta) - m_1 a &= m_2 a - m_2 g (\sin\theta - \mu_2 \cos\theta) \\ m_1 g (\sin\theta - \mu_1 \cos\theta) + m_2 g (\sin\theta - \mu_2 \cos\theta) &= m_2 a + m_1 a \\ (m_1 + m_2) g \sin\theta - (\mu_1 m_1 + \mu_2 m_2) g \cos\theta &= (m_1 + m_2) a \\ a &= g \left(\sin\theta - \frac{\mu_1 m_1 + \mu_2 m_2}{m_1 + m_2} \cos\theta \right) \end{aligned}$$

Plugging in the numbers yields

$$\begin{aligned} a &= 9.8\,\mathrm{m/s^2} \left(\sin 22^\circ - \frac{0.20 \cdot 2\,\mathrm{kg} + 0.45 \cdot 3\,\mathrm{kg}}{5.00\,\mathrm{kg}} \cos 22^\circ \right) \\ &= 0.491\,\mathrm{m/s^2} \end{aligned}$$

The blocks are accelerating downhill.

4. Circling pony

The radius of its path is 6.4 meters and its tangential speed is 4.0 meters per second.

A. Path length

The path length of one circuit is the circumference of the circle, $2\pi r = 40.2\,\mathrm{m}$.

B. Time of one circuit

This time is the period T. At speed $v = 2\pi r/T$, it will take time $T = 2\pi r/v = 2\pi(6.4\,\mathrm{m})/(4.0\,\mathrm{m/s}) = 10.1\,\mathrm{s}$.

C. Acceleration

The inward acceleration when moving with speed v in a circle of radius r is $v^2/r = (4.0\,\mathrm{m/s})^2/(6.4\,\mathrm{m}) = 2.5\,\mathrm{m/s}$.

D. The direction of the pony's acceleration is inward, directly toward the center of its path.

5. Sisyphus

The forces acting of the rock as Sisyphus pushes it up the hill are its weight $mg = 999.6\,\mathrm{N}$ vertically downward, friction 10.0 N downward parallel to the hill, a normal force upward perpendicular to the hill, and the push uphill from Sisyphus. As the rock rolls back downhill, its weight still acts directly downward and the normal force is still upward perpendicular to the hill, but the friction force is *uphill* and Sisyphus is no longer pushing.

A. Work done by gravity uphill

Gravity pushes down while the rock moves up, so the force does negative work of $W_g = -mgh = -(999.6\,\mathrm{N})(16\,\mathrm{m}) = -15993.6\,\mathrm{J}$.

B. Work done by friction uphill

Friction is also doing negative work, $W_f = -f\Delta x = -(10\,\mathrm{N})(200\,\mathrm{m}) = -2000\,\mathrm{J}$.

C. Work done by the normal force uphill

The normal force is perpendicular to the rock's displacement, so it does zero work.

D. Work done by Sisyphus uphill

We aren't told the force exerted by Sisyphus. However, we know that the kinetic energy of the rock was zero before he started pushing and when he finished pushing, so the total work done on the rock was zero.

$$\begin{aligned} 0 &= W_g + W_N + W_f + W_S \\ W_S &= -W_g - W_N - W_f \\ &= 15993.6\,\mathrm{J} - 0 + 2000\,\mathrm{J} \\ &= 17994\,\mathrm{J} \end{aligned}$$

To three significant figures, that is 18.0 kJ.

E. Kinetic energy at the bottom of the hill (end of the line downhill)

Here we use the work-energy theorem to find the change in kinetic energy. The rock's kinetic energy was zero when it slipped from Sisyphus's grasp. Its final kinetic energy is the work done on it during the descent. Gravity now does *positive* work on the rock, friction still does negative work, and the normal force and Sisyphus do zero work.

$$\begin{aligned} K_2 - K_1 &= W_g + W_f + W_N + W_S \\ K_2 &= K_1 + W_g + W_f + W_N + W_S \\ &= 0 + 15993.6\,\mathrm{J} + (-2000\,\mathrm{J}) + 0 + 0 \\ &= 13993.6\,\mathrm{J} \end{aligned}$$

To three significant figures, the rock's final kinetic energy is 14.0 kJ.