Let $g_{\text{Earth}} = 10 \text{ m/s}^2$ throughout the exam

I. You pull a sled with two children on it up a hill that makes a $20^\circ$ angle with the horizontal. The combined mass of the sled and children is 60 kg. The coefficient of kinetic friction is 0.2, and the coefficient of static friction is 0.30.

a) How hard should you pull parallel to the hill’s surface if you want the sled to move at a constant speed?

b) How hard should you pull parallel to the hill’s surface if you want the sled to accelerate up the hill at a rate of $1 \text{ m/s}^2$?

c) If you let the sled sit on the hill without pulling it, will it slide down or stay in place? (show all work, starting with fundamental principles)
II. Tetherball is a schoolyard game played by spinning a ball around a pole. In the diagram at the right, a 1.3-kg tetherball is attached to a L=1.2 m rope that makes an angle of $\theta=40^\circ$ with the vertical as it moves with a uniform speed along a circular path in a horizontal plane around a pole.

a) Make a force diagram for the ball while it is in motion, and in the position shown in the diagram. Be sure to label all forces.

b) Find the tension in the rope.

c) Determine the speed at which the ball moves.
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3. Which of the following will remain in the air the LEAST amount of time (neglecting air resistance)?
   a) A marble launched straight up from the ground at 10 m/s
   b) A marble launched from the ground with a speed of 20 m/s at an angle of 30° from the horizontal
   c) A marble that stays in the air for 1.2 s
   d) A marble that is dropped from 10 m above the ground
   e) A marble that is launched horizontally from a 10 m high

4. In each of the six figures below, a tugboat is pushing two barges to the right. The systems of tugboats and barges are accelerating at different rates. As shown in the figures, the barges have different loads so they have different masses, and the tugboats have different masses also. The accelerations of the systems are given for each case. Ignore the effects of friction.

Rank these six cases on the basis of the magnitude of the force that barge 2 exerts on barge 1 from GREATEST to LEAST.

   a) Barge 2 doesn’t exert a force on barge because barge 1 is pushing it forward.
   b) D, A, B, E, F, C
   c) E, C, F, B, D, A
   d) E, D, A, C, B, F
   e) D=E, A=B=C, F

5. A 1.2 kg block is pulled with a force $F=3 \text{ N}$ that makes a 20° angle with the horizontal as it moves at a steady speed as shown below. Which of the following is closest to the coefficient of friction between the block and the surface?
   a) 0.15
   b) 0.17
   c) 0.20
   d) 0.23
   e) 0.26
Let $g_{\text{Earth}} = 10 \text{ m/s}^2$ throughout the exam

6. A hanging block is attached by a string to another block that is placed on a horizontal surface, as shown. The string passes over a massless, frictionless pulley. The coefficient of friction between the surface and the block is 0.2. Which of the following is closest to the rate at which the blocks accelerate when they are released?
   a) $1.0 \text{ m/s}^2$
   b) $1.2 \text{ m/s}^2$
   c) $1.4 \text{ m/s}^2$
   d) $2.0 \text{ m/s}^2$
   e) $2.5 \text{ m/s}^2$

7. A satellite is in a circular orbit around a very small planet. The orbital radius of the satellite is 29 km and the gravitational acceleration at that height is $2.1 \text{ m/s}^2$. What is the satellite’s orbital speed?
   a) $420 \text{ m/s}$
   b) $220 \text{ m/s}$
   c) $350 \text{ m/s}$
   d) $250 \text{ m/s}$
   e) $330 \text{ m/s}$

8. A projectile is launched horizontally with a speed of $1.8 \text{ m/s}$ at the surface of Mars (mass= $6.4 \times 10^{23} \text{ kg}$, radius= $3.4 \times 10^6 \text{ m}$) from a height of $1.3 \text{ m}$. Determine how far away the projectile lands from where it was launched.
   a) $1.8 \text{ m}$
   b) $1.5 \text{ m}$
   c) $1.3 \text{ m}$
   d) $1.1 \text{ m}$
   e) $0.92 \text{ m}$