

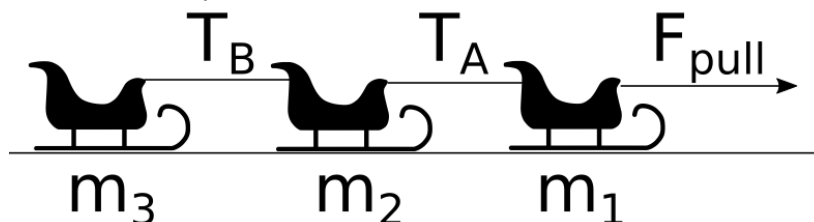
This open-book take-home exam is 10% of your course grade. (The in-class final exam will be 20% of your course grade. For the in-class exam, you can bring one sheet of handwritten notes and a calculator. The in-class exam will be much shorter than this practice exam.) You should complete this exam on your own, without working with other people. It is fine to discuss general topics from the course with your classmates, but it is not OK to share your solutions to these specific problems. Feel free to approximate $g = 10 \text{ m/s}^2 = 10 \text{ N/kg}$ if you wish. **In fact, I strongly prefer that you use $g = 10 \text{ m/s}^2 = 10 \text{ N/kg}$ here, as it simplifies many numerical results.**

Due by 6pm on Monday, December 11, 2017, in DRL 1W15.

No penalty if you turn it in by noon on Dec 14, but I will grade & return on-time exams by Dec 15.

Please show your work on these sheets. Use spare sheets at back of exam if needed.

1. (10%) Three sleds are pulled to the right across a horizontal sheet of ice using horizontal cables. Friction between the ice and the sleds is negligible. The three sleds (numbered from right to left) have masses $m_1 = 10.0 \text{ kg}$, $m_2 = 20.0 \text{ kg}$, and $m_3 = 30.0 \text{ kg}$ respectively. The pull exerted by the tow cable on sled 1 is $F_{\text{pull}} = 120 \text{ N}$ to the right. Sleds 1 and 2 are connected by a taut cable of tension T_A . Sleds 2 and 3 are connected by a taut cable of tension T_B .



(a) Find the acceleration a_x of the three-sled system, where the x axis points to the right.

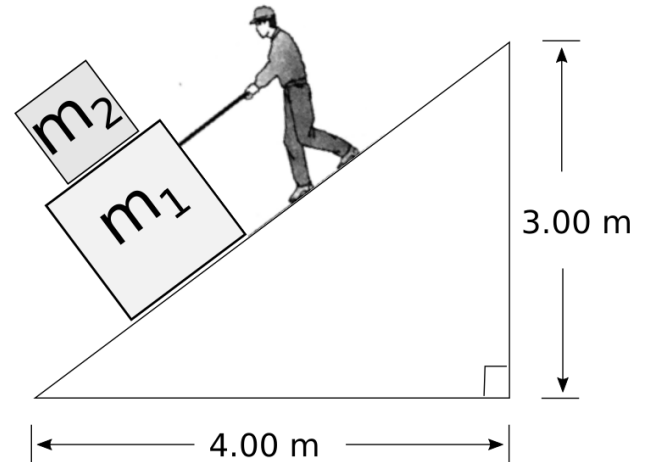
(b) Find the tensions T_A and T_B .

(Problem continues on next page.)

(c) Draw a free-body diagram for sled 3, then a free-body diagram for sled 2, then a free-body diagram for sled 1. Include both horizontal and vertical forces. Indicate the numerical magnitude of every force (including proper units).

2. (10%) You are lowering two boxes, one on top of the other, down a ramp as shown, by pulling on a taut cable that is parallel to the surface of the ramp. The lower box has mass $m_1 = 20.0$ kg, and the upper box has mass $m_2 = 10.0$ kg. The two boxes move together at constant speed 0.125 m/s: the upper box does not move with respect to the lower box. The coefficient of kinetic friction between the ramp and the lower box is $\mu_k = 0.250$, and the coefficient of static friction between the two boxes is $\mu_s = 0.900$.

(a) Find the magnitude of the force that the cable exerts on the lower box.



(b) Find the magnitude of the static frictional force that the lower box exerts on the upper box. Keep in mind that it is static friction that prevents the upper box from slipping off of the lower box. **Check** that your calculated value is smaller than the maximum possible value for static friction.

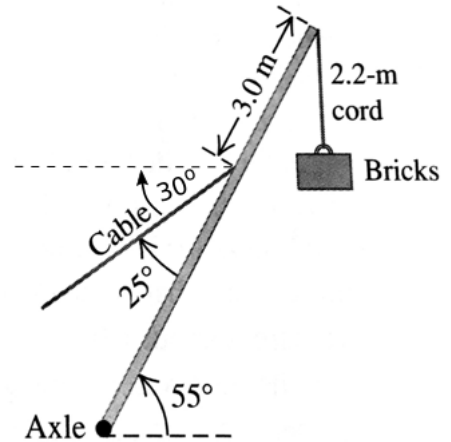
(Problem continues on next page.)

(c) Draw a free-body diagram for the upper box, showing the direction and numerical magnitude of each force. Decompose the gravitational force into components, as a check that your calculated force values add up as expected. Please label your forces G=gravity, S=static, N=normal, E=Earth, L=lower, U=upper.

(d) Draw a free-body diagram for the lower box, showing the direction and numerical magnitude of each force. Again decompose the gravitational force into components, as a check that your calculated force values add up as expected. Please label your forces G=gravity, S=static, K=kinetic, N=normal, E=Earth, L=lower, U=upper, R=ramp, T=tension (in Cable). [I count 6 forces acting on the lower crate; or 7 if you decompose gravity into two components.]

3. (10%) The boom of a crane pivots around a frictionless axle at its base and is supported by a cable that makes a 25° angle from the boom. (Equivalently, the cable makes a 30° angle below the horizontal, as indicated.) The boom is 16 m long and is uniform, so the boom's center of gravity is 8.0 m from the axle as measured along the boom; the weight of the boom is 15 kN. The cable is attached 3.0 m from the upper end of the boom (13 m from the axle). The boom is raised to 55° above the horizontal and holds, by a cord, a pallet of bricks whose weight is 11 kN. The cord itself has negligible weight and is 2.2 m long.

(a) Draw an extended free-body diagram of the crane boom, showing all forces acting on the boom and their lines of action.

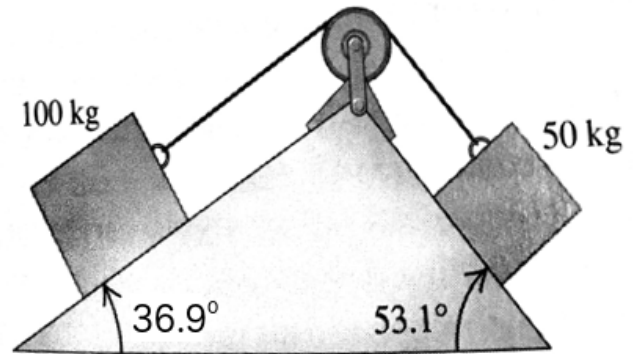


(b) What is the tension in the cable?

(c) What are the horizontal and vertical components of the “reaction” force that the axle exerts on the boom?

4. (10%) Two blocks are connected by a taut cable that passes over a small pulley (of negligible inertia). Friction in the pulley is negligible, and both blocks rest on planes of negligible friction.

(a) Which way will the system move when the blocks are released from rest? Indicate this direction on the diagram and define this to be the direction in which the x coordinate increases. (The same x coordinate will describe both the uphill motion of one block and the downhill motion of the other block, since the cable stays taut. You only need one coordinate for this problem.)



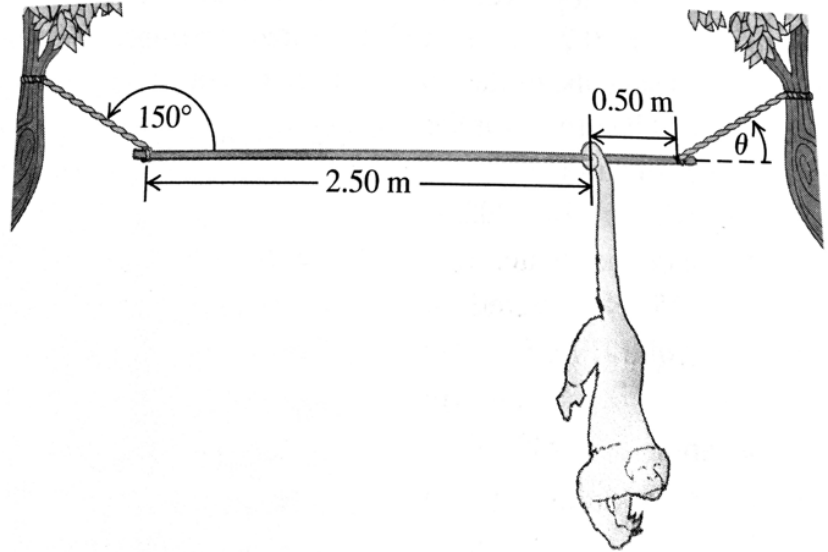
(b) Write Newton's second law, $ma_x = \sum F_x$, separately for each of the blocks. Since the cable stays taut, a_x is the same for both blocks.

(c) What is the acceleration, a_x of the blocks?

(d) What is the tension T in the cord?

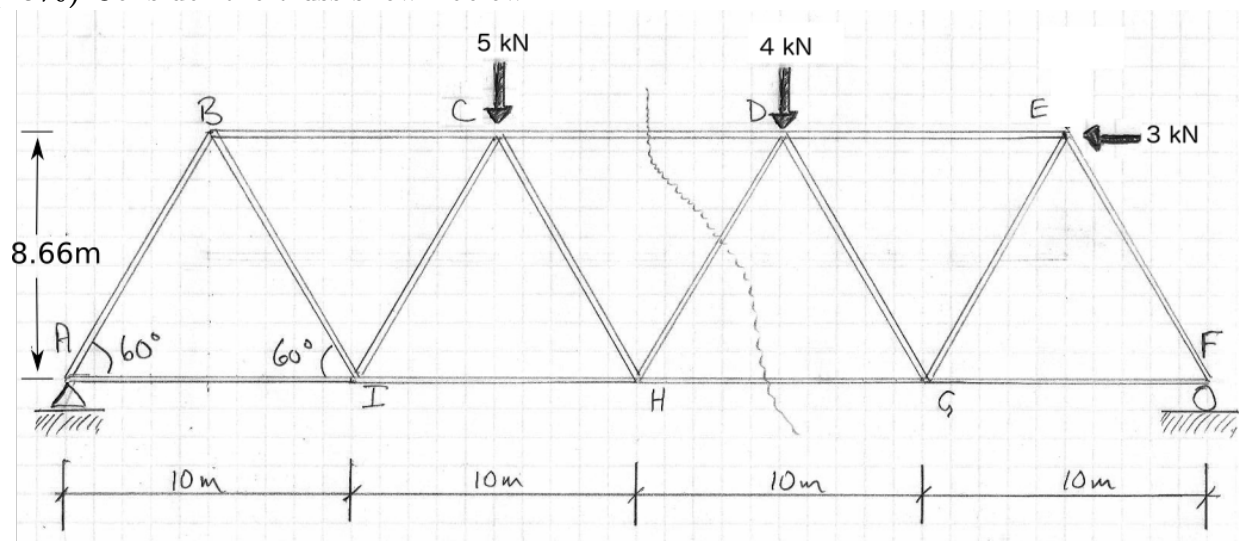
5. (10%) A 3.00 m long uniform rod, whose mass is 24.0 kg, is held in a horizontal position by two cables (of negligible mass) at its ends. The left cable makes a 150° angle with the rod, and the right cable makes an angle θ with the horizontal. A 9.0 kg monkey hangs motionless by his tail, a horizontal distance 0.50 m from the right end of the rod.

(a) Draw an extended free-body diagram for the rod.



(b) Find the tensions, T_L and T_R , in the left and right cables, and find the angle θ . (If you find $T_R \cos \theta$ and $T_R \sin \theta$, you can combine these to find T_R and θ .)

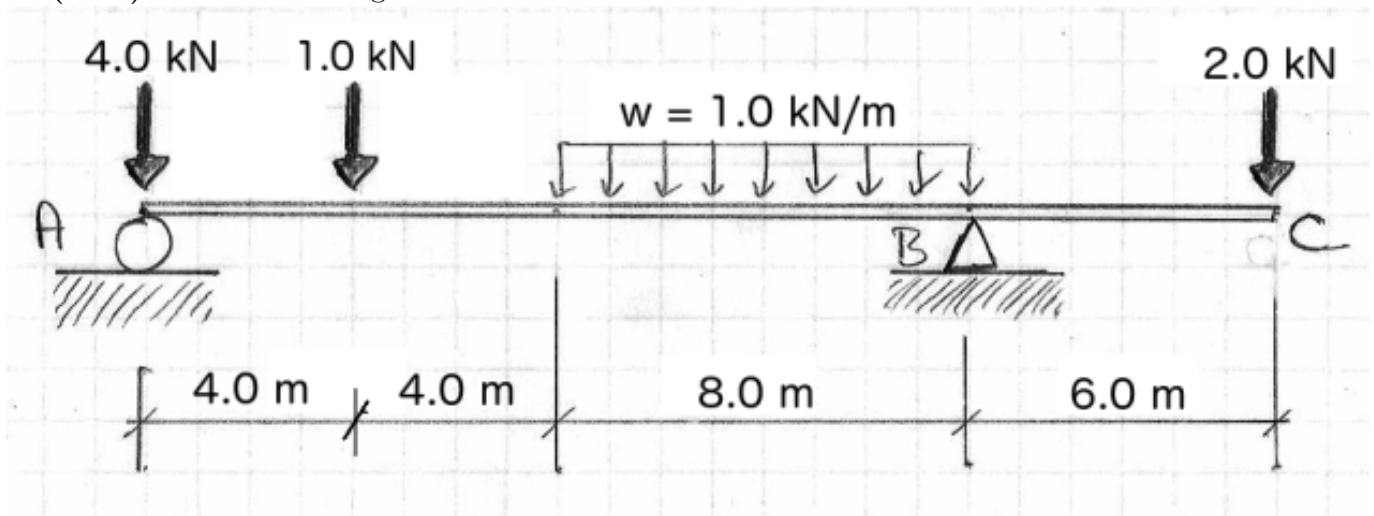
6. (15%) Consider the truss shown below.



(a) Find the force F_y exerted on the truss by the roller support at F .

(b) Using the Method of Sections, solve for the forces (tensions or compressions) in truss members CD , HD , and HG . Indicate whether each of these members is in tension or in compression.

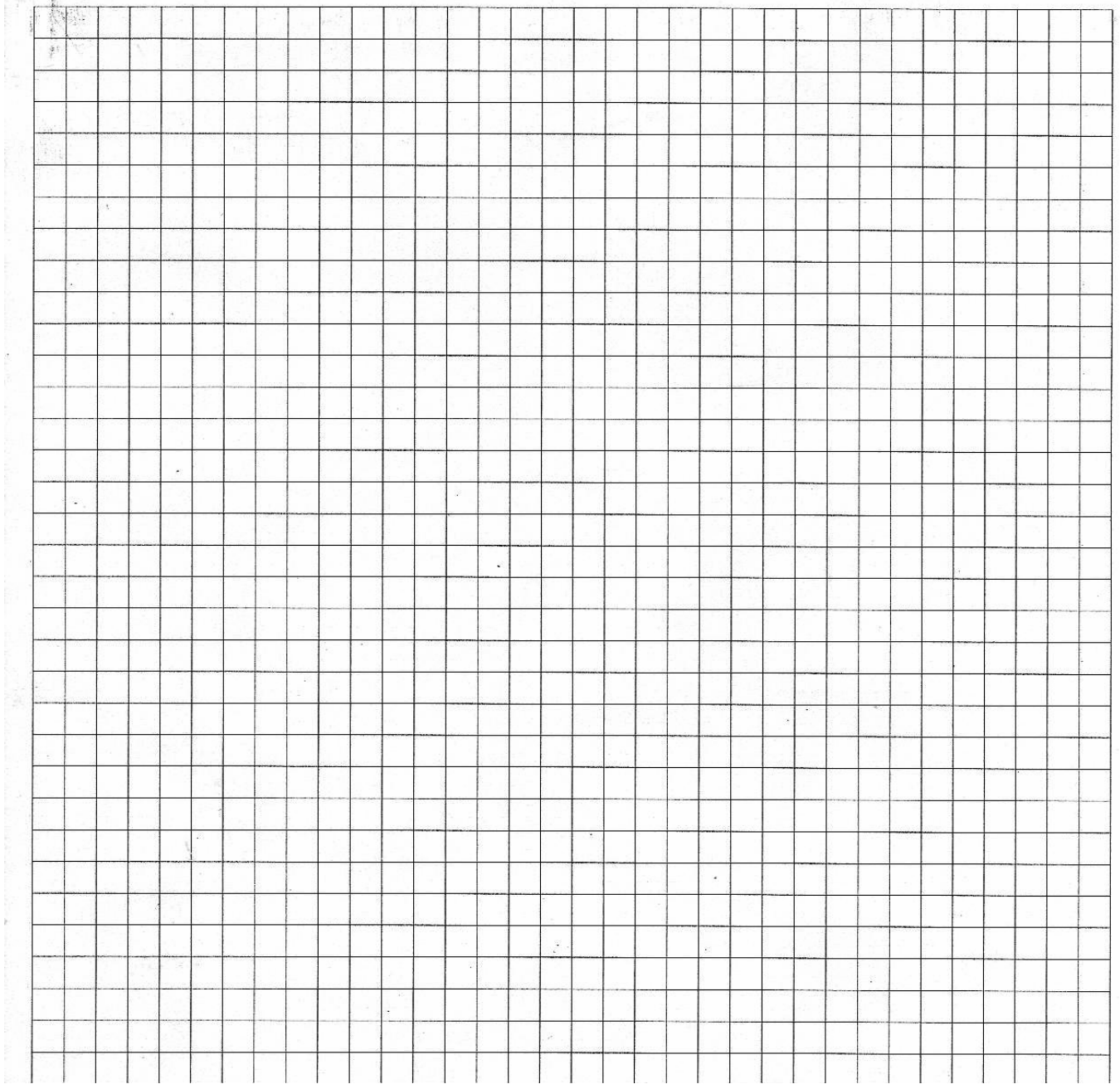
7. (15%) For the overhang beam shown below.



(a) Find the support forces A_y , B_x , and B_y exerted on the beam by supports A and B.

(Problem continues on next page.)

(b) Draw load (EFBD), shear (V), and bending moment (M) diagrams for the beam.



(c) What are the largest magnitude of the shear V (in kilonewtons) and the largest magnitude of the bending moment M (in kilonewton-meters)?

8. (10%) You and your friend are carrying a 200 kg box up a flight of stairs. The box is 1.00 m long and 0.500 m high, and its center of gravity is at its center. The stairs make a 45.0° angle to the floor. The crate is carried at a 45.0° angle, so that its bottom side is parallel to the stairs. Assume that each person applies, with his or her hands, a purely vertical force to the corresponding corner of the box.

(a) Draw an extended free-body diagram for the box, showing each force exerted on the box and its line of action. To simplify computing the moments (torques) in part (b) considerably, decompose the gravity vector into components parallel to the long and short axes of the box.

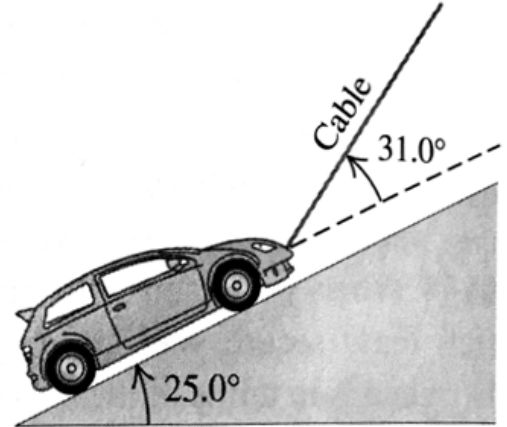


(b) What are the magnitudes, F_{below} and F_{above} of the vertical forces applied by the person below and the person above, respectively?

(c) Is it easier to be the person above or the person below on the stairs?

9. (10%) A car of mass 1230 kg is held in place by a light cable on a very smooth (negligible friction) ramp. The cable makes an angle 31.0° above the surface of the ramp. The ramp itself is inclined at 25.0° above the horizontal.

(a) Draw a free-body diagram for the car. (Just an ordinary FBD, not an extended one.)



(b) What is the tension T in the cable.

(c) What is the normal force F_N exerted by the ramp on the car.

(extra sheet)