

1. {1,5,9,10}

**Reminder:** Midterm 1 will take place on Thursday, 2/18, from 8:10 to 9:25 in our usual classroom. The exam will cover the first four chapters of Kleppner and Kolenkow. You will not need a calculator.

**1 - Center of mass of a non-uniform rod\* - KK 4.1** The mass per unit length of a non-uniform rod of length  $l$  is given by  $\lambda = A \cos(\pi x/2l)$ , where  $x$  is the position along the rod,  $0 \leq x \leq l$ .

- (a) What is the mass  $M$  of the rod?
- (b) What is the coordinate  $X$  of the center of mass?

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**2 - Acrobat and monkey - KK 4.5** A circus acrobat of mass  $M$  leaps straight up with initial velocity  $v_0$  from a trampoline. As he rises up, he takes a trained monkey of mass  $m$  off a perch at a height  $h$  above the trampoline. What is the maximum height attained by the pair?

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**3 - Rocket sled - KK 4.9** A rocket sled moves along a horizontal plane, and is retarded by a friction force  $f_{\text{friction}} = \mu W$ , where  $\mu$  is constant and  $W$  is the weight of the sled. The sled's initial mass is  $M$ , and its rocket engine expels mass at constant rate  $dM/dt \equiv \gamma$ ; the expelled mass has constant speed  $v_0$  relative to the rocket. The rocket starts from rest and the engine stops when half the sled's total mass is gone. Find an expression for the maximum speed.

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**4 - Rolling freight car with sand - KK 4.10** A freight car of mass  $M$  contains a mass of sand  $m$ . At  $t = 0$  a constant horizontal force  $R$  is applied in the direction of rolling and at the same time a port in the bottom is opened to let the sand flow out at constant rate  $dm/dt$ . Find the speed of the freight car when all the sand is gone. Assume the freight car is at rest at  $t = 0$ .

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