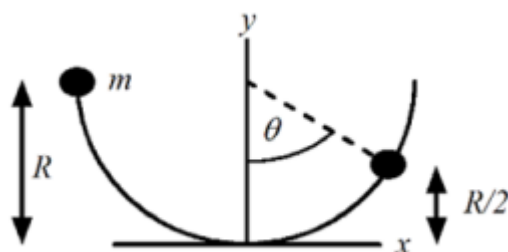


**Physics Exam - University of Houston 2021 Math Contest**  
**January 30, 2021**

---

Unless otherwise specified, please use  $g$  as the acceleration due to gravity at the surface of the earth. Vectors  $\hat{x}$ ,  $\hat{y}$ , and  $\hat{z}$  are unit vectors along  $x$ ,  $y$ , and  $z$ , respectively, in a normal Cartesian coordinate system. Let  $G$  be the universal gravitational constant. To simplify calculations, you may use  $g = 10 \text{ m/s}^2$ .

**Questions 1 - 3** pertain to a mass  $m$  that slides on a semicircular wire as shown. The coefficient of kinetic friction between the wire and mass  $m$  is  $\mu$ . Mass  $m$  is released from rest at a height  $R$  above the bottom of the hemisphere and stops at a height  $R/2$ .



1) The work done by friction during this process is given by

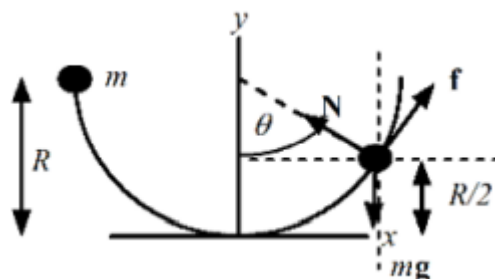
- a)  $mgR$     b)  $mgR/2$     c)  $-mgR/2$     d) 0    e)  $-mgR$     f) none of the other answers provided

2) The magnitude of the average force due to friction is given by

- a)  $\frac{mg}{\pi + 2 \cos^{-1}(\frac{1}{2})}$     b)  $\frac{mg}{\pi - 2 \cos^{-1}(\frac{1}{2})}$     c) 0    d)  $\frac{mg}{\pi - \cos^{-1}(\frac{1}{2})}$     e)  $\frac{mg}{\pi + \cos^{-1}(\frac{1}{2})}$

f) none of the other answers provided

3) In order for the object to remain at rest at the height  $R/2$ , the relationship between the force due to friction  $f$ , the normal force of contact  $N$  between mass  $m$  and the wire, the force due to gravity  $mg$ , and  $\theta$  is given by



- a)  $f \sin(\theta) + N \cos(\theta) - mg = 0$     b)  $f \cos(\theta) + N \sin(\theta) - mg = 0$     c)  $f \sin(\theta) + N \sin(\theta) - mg = 0$   
d)  $f \cos(\theta) + N \cos(\theta) - mg = 0$     e) none of the other answers provided













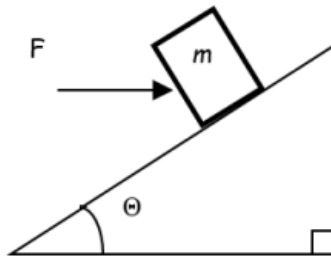




35) Two small charged objects repel each other with a force  $F$  when separated by a distance  $r$ . If the charge on both of the objects is doubled and the distance between them is increased to  $2r$ , the force becomes:

- a)  $\frac{F}{16}$       b)  $\frac{F}{4}$       c)  $\frac{F}{2}$       d)  $F$       e)  $\frac{F}{8}$       f) none of the other answers provided

36) A force of  $F = 5\text{N}$  acts horizontally on a mass of  $m = 1\text{ kg}$  being pushed on a frictionless incline that makes an angle  $\theta = 37^\circ$  with the horizontal. What is the magnitude of the acceleration of the mass?



- a)  $2\text{ m/s}^2$       b)  $1\text{ m/s}^2$       c)  $4\text{ m/s}^2$       d)  $3\text{ m/s}^2$       e) none of the other answers provided

37) A 5.0-kg bucket is lowered by a rope in which there is 35 N of tension. What is the magnitude of the acceleration of the bucket?

- a)  $5.0\text{ m/s}^2$       b)  $8.5\text{ m/s}^2$       c)  $1.5\text{ m/s}^2$       d)  $3.0\text{ m/s}^2$       e) none of the other answers provided

38) A man with a mass of 70 kg climbs at constant speed to the top of an 8 m vertical rope in 10 s. The average power expended by the man to overcome gravity is most nearly

- a) 560 W      b) 1.1 W      c) 700 W      d) 88 W      e) none of the other answers provided

39) Two cannons are launched at the same time with the same speed from the same location. Both cannons land at the same spot on the ground. Cannon  $A$  is launched at an angle greater than  $45^\circ$  and Cannon  $B$  is launched at an angle less than  $45^\circ$ . Which cannon arrives first?

- a) Both land at the same time      b) Cannon  $A$       c) Cannon  $B$   
d) More information is needed      e) none of the other answers provided

40) A student throws a baseball horizontally at a speed of 25 m/s from a cliff that is 45 m above the ground. How far from the base of the cliff does the ball hit the ground? Air resistance is negligible.

- a) 75 m      b) 230 m      c) 140 m      d) 45 m      e) none of the other answers provided