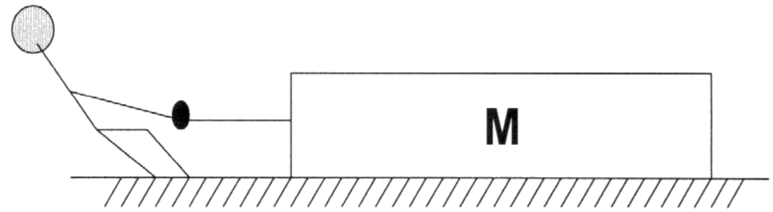
Name Solutions **Student ID** ____________ **Score** ________

last *first*

Part I. [25 points] The kid is trying to pull a block of mass $M = 35$ kg along a horizontal surface with a coefficient of static friction μ_s and kinetic friction $\mu_k = 0.05$.



1. [5 Points] The kid needs to pull with a force of at least 30 N to get the block to move. What is the value of μ_s?

   A. 0.083
   B. 0.087
   C. 0.091
   D. 0.31
   E. 3.4

$F = \mu_s N = 30N$

$= \mu_s Mg \quad$ so $\mu_s = \frac{30}{35 \cdot 9.8} = 0.087$

2. [5 Points] The kid continues to pull with a force of 30 N after the block starts moving. What is the magnitude of the acceleration of the block?

   A. 0.0 m/s^2
   B. 0.37 m/s^2
   C. 0.49 m/s^2
   D. 0.68 m/s^2
   E. 0.85 m/s^2

$\overset{30}{\longleftarrow} \bullet \overset{F_K}{\longrightarrow}$

$Ma = \Sigma F = 30N - \mu_K N$

$a = \frac{30N - 0.05 \cdot 9.8 \cdot 35}{35} = 0.367 \, m/s^2$

A small block of mass m=5 kg is now placed on top of the large block. The coefficients of static and kinetic friction between the bottom block and top block are $\mu_s' = 0.08$ and $\mu_k' = 0.04$, respectively.

3. [5 Points] With what magnitude force does the kid need to pull to cause the small block to just start to slip?

   A. 0.098 N
   B. 3.92 N
   C. 27.4 N
   D. 31.4 N
   E. 156 N

To get small block to slip, it must feel a force of $\mu_s N = \mu_s mg$

But, kid is pulling large block:

$F_{kid} = (M+m)a$

a from F on small block:

$ma = \mu_s mg \Rightarrow a = \mu_s g$

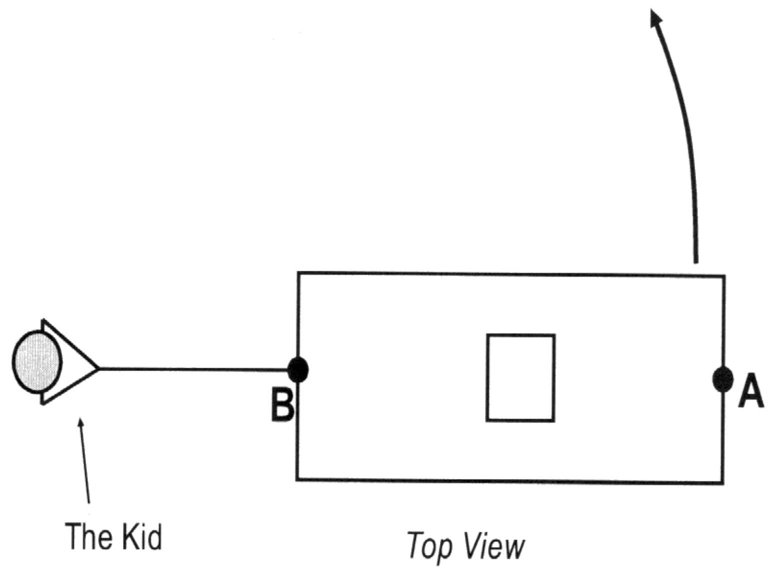
$F_{kid} = (M+m)\mu_s g$

$= (35+5)(0.08)(9.8) = 31.36 N$

Name Solutions Student ID ____________ Score________

last *first*

The kid is now using the same two blocks and string, but on a frictionless surface. She has gotten the block swinging around at an angular velocity ω = 2.0 rad/s, in a circle. The distance from the center of the kid to point B is R = 2.0 m. The kid finds the force on the string required to keep this motion going is 15 N. The coefficient of static friction between the two blocks remains as stated above. The large block is 1.0 meter long, and the small block is centered on the large block.



4. [5 Points] What is the linear velocity of point A?

A. 1.0 m/s
B. 2.0 m/s
C. 4.0 m/s
D. 6.0 m/s
E. 12 m/s

$v = R\omega$
$= 3 \cdot 2$
$= 6$

5. [5 Points] The upper block is slipping. What is the force due to friction on the small block by the large block?

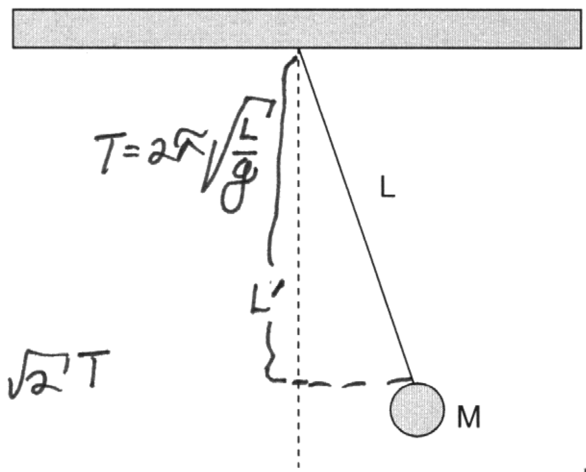
A. 2.0 N
B. 4.0 N
C. 14 N
D. 27 N
E. 49 N

slipping $F = \mu_k N = 0.04 \cdot 5 \cdot 9.8$
$= 1.96 N$

Name Solutions Student ID ____________ Score________

last *first*

Part II. [25 Points] A simple pendulum has a period of 1.8 s, and swings only at small angles.



$T = 2\pi\sqrt{\frac{L}{g}}$

6. [5 points] Its mass is doubled. What is its period now?

   A. 0.90 s
   B. 1.3 s
   C. 1.8 s
   D. 2.5 s
   E. 3.6 s

   Mass does not affect period

7. [5 points] Its length is doubled. What is its period now?

   A. 0.90 s
   B. 1.3 s
   C. 1.8 s
   D. 2.5 s
   E. 3.6 s

   $L \to 2L$ so $T \to \sqrt{2}\,T$

   $\frac{g}{L} = \frac{4\pi^2}{T}$

The original pendulum is released from rest at an angle $\theta = 13°$ from the vertical.

8. [5 points] What is its maximum angular acceleration?

   A. 0.40 rad/s^2
   B. 0.73 rad/s^2
   C. 1.4 rad/s^2
   D. 2.7 rad/s^2
   E. 5.5 rad/s^2

   $\tau = I\alpha$ $\vec{\tau} = \cancel{Mg}\ \vec{r} \times \vec{F}$; $\tau = LMg\sin\theta = I\alpha$

   $I = ML^2$

   $\alpha = \frac{\cancel{L}\cancel{M}g\sin\theta}{\cancel{M}L^{\cancel{2}}} = \frac{g}{L}\sin\theta = \frac{4\pi^2}{T^2}\sin\theta \cdot 7^4$

   $= 2.7\ \text{r/s}^2$

9. [5 Points] The kinetic energy when the pendulum is at the bottom of the arc is 10 J. What is the mass of the pendulum bob (M)?

   A. 1.6 kg
   B. 4.1 kg
   C. 9.7 kg
   D. 18 kg
   E. 50 kg

   $E = Mgh = 10\,J$

   $h = L - L' = L - L\cos\theta = L(1-\cos\theta)$

   so $E = MgL(1-\cos\theta)$ $\Rightarrow E = \frac{Mg^2T^2}{4\pi^2}(1-\cos\theta)$

   $L = \frac{T^2}{4\pi^2}g$

   Solve for M $= 49.5$ kg

The original pendulum is taken to a planet where g = 16 m/s^2.

10. [5 points] What is its period on that planet?

   A. 1.1 s
   B. 1.4 s
   C. 1.8 s
   D. 2.9 s
   E. 7.2 s

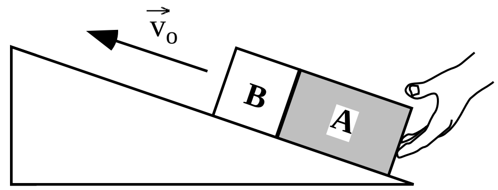
   $T = 2\pi\sqrt{\frac{L}{g}}$

   $g \to g'$ $T' = 2\pi\sqrt{\frac{L}{\frac{g'}{g}g}}$

   $= \sqrt{\frac{g}{g'}}\,T = \sqrt{\frac{9.8}{16}}\,T = 1.4\,s$

Name _______SOLUTION________________________**Student ID** _____________ **Score**______
last *first*

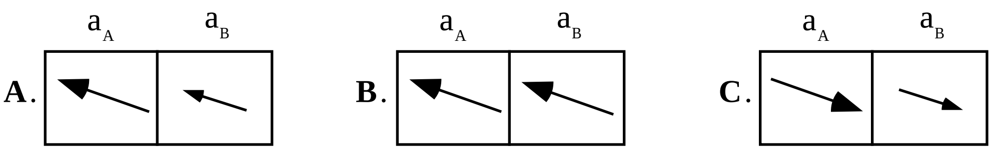
Speed of blocks is decreasing.



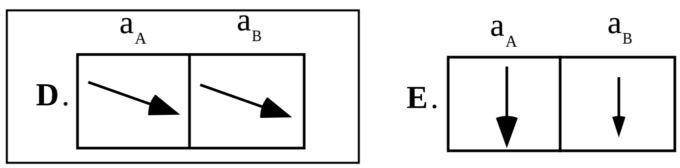
Incline is frictionless.

Part III. [25 points] Two blocks move on a frictionless incline with initial speed v_o, as shown, while a hand pushes with constant force parallel to the incline. The blocks are moving up the incline and slowing down. The mass of block A is greater than the mass of block B.

11. [5 pts] Choose the correct acceleration vectors for blocks A and B.



speed is decreasing, so **a** is opposite direction from $\mathbf{v_o}$; same rate for A & B, so a's are same.



Over a short time interval, the blocks have moved up the ramp a distance *d*.

12. [4 pts] Is the work done on block A by the hand *positive, negative,* or *zero?*

A. $\boxed{W_{\text{on A by hand}} > 0}$ Force on A by hand is same direction as displacement of A
B. $W_{\text{on A by hand}} < 0$
C. $W_{\text{on A by hand}} = 0$
D. This work does not exist
E. There is not enough information to answer.

13. [4 pts] Is the work done on the hand by block A *positive, negative,* or *zero?*

A. $W_{\text{on hand by A}} > 0$
B. $\boxed{W_{\text{on hand by A}} < 0}$ $F_{\text{on hand by A}}$ is opposite direction of displacement of hand (Newton's third law)
C. $W_{\text{on hand by A}} = 0$
D. This work does not exist
E. There is not enough information to answer.

14. [4 pts] Is the absolute value of the work done on block A by the hand *greater than, less than,* or *equal to* the absolute value of the work done on the hand by block A?

A. $W_{\text{on A by hand}} > W_{\text{on hand by A}}$
B. $W_{\text{on A by hand}} < W_{\text{on hand by A}}$
C. $\boxed{W_{\text{on A by hand}} = W_{\text{on hand by A}}}$ Newton's 3rd law: $F_{\text{on hand by A}}$ is same as $F_{\text{on A by hand}}$; and Δx is same.
D. There is not enough information to answer.

15. [4 pts] Is the net work done on block A (i.e., the sum of the works by all forces) *positive, negative,* or *zero?*

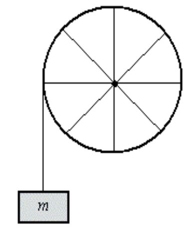
A. $W_{\text{net on A}} > 0$
B. $\boxed{W_{\text{net on A}} < 0}$ A is slowing down, so $\Delta KE<0$; by work-energy, $W_{net}=\Delta KE$
C. $W_{\text{net on A}} = 0$
D. There is not enough information to answer.

16. [4 pts] Is the absolute value of the net work done on block A *greater than, less than,* or *equal to* the absolute value of the net work done on block B?

A. $\boxed{\left|W_{\text{net on A}}\right| > \left|W_{\text{net on B}}\right|}$ $W_{net}=\Delta KE=1/2\ m(v_f^2-v_i^2)$; $(v_f^2-v_i^2)$ is same for A and B, $m_A>m_B$.
B. $\left|W_{\text{net on A}}\right| < \left|W_{\text{net on B}}\right|$
C. $\left|W_{\text{net on A}}\right| = \left|W_{\text{net on B}}\right|$
D. There is not enough information to answer.

Name:____ **Student ID:**_________ **Score:**________
last *first*

Part IV. Laboratory Question [25 points]



Experiment 8. [13 points] You analyze a video of the motion of a bicycle wheel from which is hanging a weight with a mass m=100 gm. The radius of the bicycle wheel in the groove at which the string is attached is measured to be 25.0 cm. The **VideoPoint** analysis program provides the following table of the wheel's angular position vs. time**.**

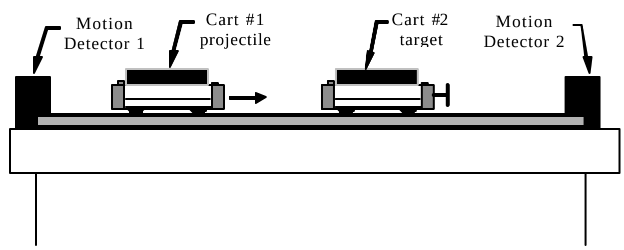
Elapsed Time (s)	0.00	0.20	0.40	0.60	0.80	1.00	1.20
Rotation Angle (^{o})	0.00	9.39	37.6	84.5	150.3	234.8	338.1

17. [4 points] What is the magnitude of the constant angular acceleration (in rad/s^2) of the wheel?
A. 0.273 **B.** 2.24 **C.** 8.20 **D.** 9.81 **E.** it is not a constant

18. [4 points] What is the angular velocity (in rad/s) of the wheel at t=0.60 s?
A. 0.156 **B.** 4.92 **C.** 23.6 **D.** 236 **E.** 440

19. [5 points] What is the value of the moment of inertia of the wheel (in kg m^2)?
A. 0.0122. **B.** 0.0299 **C.** 0.0496 **D.** 0.125 **E.** it is not a constant

---



Experiment 7. [12 points] Cart #1 has a mass $\mathbf{m_1}$ = 200 gm, and Cart #2 has a mass $\mathbf{m_2}$ = 300 gm. Two **SonicRanger** detectors record the position vs. time of the two carts. The **DataStudio** program analyzes their velocities along the track, and indicates that before the collision the velocity of Cart #1 is 40.0 cm/s and the velocity of Cart #2 is 0.00 cm/s. The carts collide and Velcro surfaces of the carts stick together, so that the pair of connected carts continues to move to the right on the track.

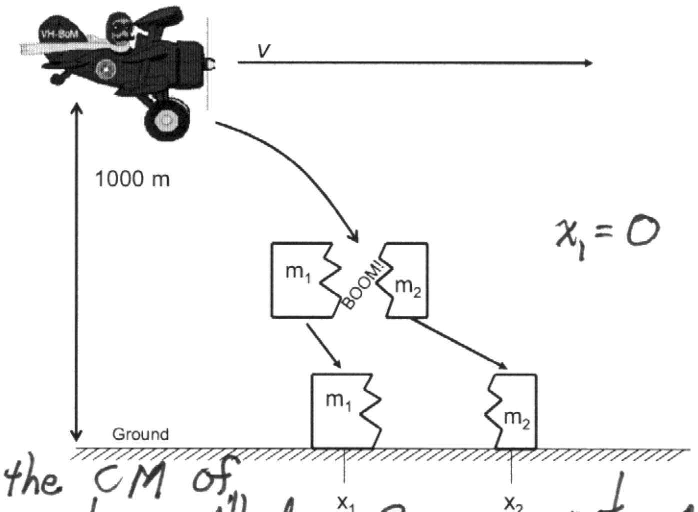
20. [4 points] Compared to the initial momentum, the net momentum of the system after the collision is:
A. zero **B.** decreased **C.** unchanged **D.** increased **E.** indeterminate

21. [4 points] Compared to the initial energy, the total energy present in the system after the collision is:
A. zero **B.** decreased **C.** unchanged **D.** increased **E.** indeterminate

22. [4 points] What is the final velocity in cm/s of the joined carts?
A. 0 **B.** 8 **C.** 16 **D.** .40 **E.** indeterminate

Name Solutions Student ID ____________ Score ________

last   first



$x_1 = 0$

Part V. [30 points] An airplane flying level overhead at a constant speed v and a height of h=1000 m drops a large care package of mass M. One second before it hits the ground a gas stove in the care package explodes, and the package splits into two pieces (no mass is lost). The total mass of the care package is 1500 kg, and the mass of the leftmost peice of the package is m_1=650 kg. The packages land at the same time, as shown, with 135 m between them (x_2-x_1 = 135m). Neglect air resistance.

23. [10 points] What is the x-coordinate of the plane at the moment the pieces package hit the ground?

It will be the same as the CM of the package – CM of the package will ~~drop~~ move @ same rate as plane!

$$x_c = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} = \frac{850 \cdot \cancel{80}\ 135}{1500} = \cancel{45.33m}\ 76.5m$$

24. [10 points] How high above the ground was the care package when the stove exploded?

Drops 1000 meters – $1000 = \frac{1}{2} 9.8 t^2$

$$t^2 = \frac{2000}{9.8} = 14.28 \text{ sec.}$$

How far in 13.28 sec?

$$1000 - \frac{1}{2} \cdot 9.8 \cdot (13.28)^2 = \boxed{135 m}$$

25. [10 points] What quantity of kinetic energy is provided by the explosion?

Pkgs are pushed apart → In 1 second pkg 1 went from

use CM frame

pkg 1 $x_1 = \cancel{45.33}\ 76.5m \rightarrow 0$

pkg 2 $x_2 = \cancel{45.33}\ 76.5m \rightarrow 135m$

so $V_1 = \frac{x_1}{1sec} = 76.5 m/s$

$$V_2 = \frac{135 - 76.5}{1s} = 58.5 m/s$$

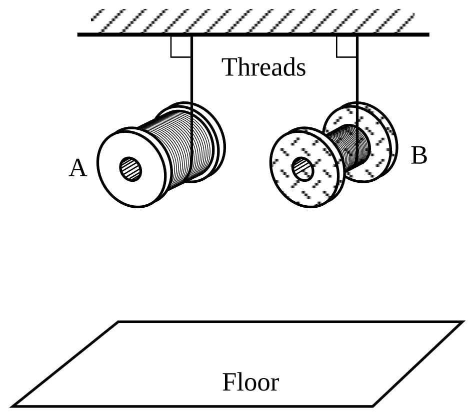
$$KE = \frac{1}{2}\left[m_1 V_1 + m_2 V_2\right] = \frac{1}{2}\left[650 \cdot 76.5 + 850 \cdot 58.5\right] = \boxed{49725}$$

Velocities should be squarted!

Should be 3.6 mega joules!

VI. [20 Total Pts.] Two spools, A and B, are constructed so that they have the *same* mass but *different* moments of inertia. They are wrapped with different lengths of *massless* thread. The end of each string is attached to a horizontal bar as shown. (Notice that the thread is wrapped out to a larger radius on spool A.)

Both spools are released from rest at the same time. It is observed that spool B hits the floor first.



$m_A = m_B$

$I_A \neq I_B$

26. [4 pts] Just before spool B strikes the floor is the (linear) velocity of spool A *greater than, less than*, or *equal to* that of spool B? If there is not enough information given to answer state so explicitly. Explain.

Spool B strikes the floor first. So, it must have a larger linear acceleration. Since they start from rest and fall for the same amount of time, spool B must also have the greater linear velocity.

27. [4 pts] Just before spool B strikes the floor is the angular velocity of spool A *greater than, less than*, or *equal to* that of spool B? If there is not enough information given to answer state so explicitly. Explain.

The linear acceleration is related to the angular acceleration by a factor of the radius out to which the thread is wrapped. (i.e. $a = \alpha r$) For B to have a larger linear acceleration with a smaller radius, it must have a larger angular acceleration.

28. [5 pts] Before spool B strikes the floor, is the tension in the thread attached to spool A *greater than, less than*, or *equal to* the tension in the thread attached to spool B? If there is not enough information given to answer state so explicitly. Explain.

Since spool B hits first, it has the larger linear acceleration. Thus, the difference between the tension and the weight is greater for spool B. Since both have the same weight, the spool attached to thread A has a tension which is greater than the tension in the thread attached to spool B.

29. [7 pts] Is the moment of inertia of spool A *greater than, less than*, or *equal to* the moment of inertia of spool B? If there is not enough information given to answer state so explicitly. Explain.

Torque is equal to the product of the moment of inertia and the angular acceleration ($\tau = I\alpha$). The torque on spool A is larger than that on spool B because the tension in the string and the radius of the spool are both larger for spool A. Spool A, however, has a smaller angular acceleration. To get a larger torque with a smaller angular acceleration, a larger moment of inertia is necessary. So, spool A has the larger moment of inertia.