

Fall 2008

RED

Barcode Here

Physics 105, sections 1 and 2

Exam 2

Colton 2-3669

Please write your CID \_\_\_\_\_

**3 hour time limit. One 3" × 5" handwritten note card permitted (both sides). Calculators permitted. No books.**

Constants:  $g = 9.80 \text{ m/s}^2$

Quadratic formula:  $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Keep four significant digits throughout your calculations; do not round up to less than four. When data is given, assume it has at least four significant digits. For example "15 meters" means 15.00 meters.

The problems are labeled with a question mark in brackets; [1?] means the answer goes in bubble sheet #1.

You are strongly encouraged to **write your work on the exam pages and write your answers into the answer blanks** (but of course also **record your final answers on the bubble sheet**).

Make sure your calculator is in DEGREES, not radians.

→Write your CID above upper right corner. Did you do this \_\_\_\_\_? You won't get your exam back without writing your CID.

**Treat all ropes as massless, and all pulleys as massless and frictionless.**

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When a bug collides with the windshield of a car, why does the bug get smashed whereas the windshield is practically unaffected? [1?] \_\_\_\_ (a) The bug experiences a greater force than the windshield. (b) The bug experiences a greater acceleration than the windshield (c) Both of the above

**1. Newton's third law says that the forces are equal, but since the masses obviously aren't the accelerations aren't either. Choice B.**

A woman with a parachute is falling at constant speed. The magnitude of the force of gravity is [2?] \_\_\_\_\_ (a) less than (b) greater than (c) the same as the magnitude of the force of the parachute on the woman.

**2. The woman is falling at a constant speed, so she is experiencing no acceleration. Therefore,  $F_{\text{net}}=0$  and  $F_{\text{parachute}}=F_{\text{gravity}}$ . Choice C.**

A physics problem refers to a "1300 N football player". The 1300 N most likely refers to [3?] \_\_\_\_ (a) his mass (b) his weight (c) his energy (d) his power (e) his spring constant

**3. The reference to the unit of "Newtons" indicates that this value is a force. Only choice B is a force.**

Newton's third law says that forces come in pairs. A book lying on a table feels a force of gravity and a normal force. The force that is the Newton's 3<sup>rd</sup> Law partner force with the force of gravity on the book is [4?]\_\_\_\_\_ (a) the gravitational force of the book pulling up on the earth (b) the normal force pushing up on the book (c) the pressure of the book pushing down on the table.

**4. The partner force of  $F_{\text{earth}}$  pulling down on book is  $F_{\text{book}}$  pulling up on the earth. Choice A.**

Mary (30 kg) and Fred (45 kg) have an argument on frictionless ice. Mary pushes Fred with a force of 70 N for 0.2 seconds. The numbers in the answer choices refer to magnitudes only. What is Fred's acceleration while she pushes him? [5?] \_\_\_\_\_ (a) 0 - 0.3 m/s<sup>2</sup> (b) 0.3 - 0.6 (c) 0.6 - 0.9 (d) 0.9 - 1.2 (e) 1.2 - 1.5 (f) 1.5 - 1.8 (g) 1.8 - 2.1 (h) 2.1 - 2.4 (i) more than 2.4 m/s<sup>2</sup>

What is Fred's speed when he is out of Mary's reach? [6?] \_\_\_\_\_ (a) 0 - 0.1 m/s (b) 0.1 - 0.2 (c) 0.2 - 0.3 (d) 0.3 - 0.4 (e) 0.4 - 0.5 (f) 0.5 - 0.6 (g) 0.6 - 0.7 (h) 0.7 - 0.8 (i) more than 0.8 m/s

What is Mary's acceleration while she pushes him? [7?] \_\_\_\_\_ (a) 0 - 0.3 m/s<sup>2</sup> (b) 0.3 - 0.6 (c) 0.6 - 0.9 (d) 0.9 - 1.2 (e) 1.2 - 1.5 (f) 1.5 - 1.8 (g) 1.8 - 2.1 (h) 2.1 - 2.4 (i) more than 2.4 m/s<sup>2</sup>

What is Mary's speed when she can no longer reach Fred? [8?] \_\_\_\_\_ (a) 0 - 0.1 m/s (b) 0.1 - 0.2 (c) 0.2 - 0.3 (d) 0.3 - 0.4 (e) 0.4 - 0.5 (f) 0.5 - 0.6 (g) 0.6 - 0.7 (h) 0.7 - 0.8 (i) more than 0.8 m/s

**5.  $\Sigma F_{\text{Fred}} = m_{\text{Fred}} a_{\text{Fred}} \rightarrow a_{\text{Fred}} = 70 \text{ N} / 45 \text{ kg} = 1.556 \text{ m/s}^2$  Choice F.**

**6.  $v_f = v_0 + at \rightarrow v_f = 0 + (1.556 \text{ m/s}^2)(.2 \text{ s}) = 0.3111 \text{ m/s}$  Choice D.**

**7.  $|F_{\text{Fred on Mary}}| = |F_{\text{Mary on Fred}}| \rightarrow a_{\text{Mary}} = 70 \text{ N} / 30 \text{ kg} = 2.333 \text{ m/s}^2$  Choice H.**

**8.  $v_f = 0 + (2.333 \text{ m/s}^2)(.2 \text{ s}) = 0.4667 \text{ m/s}$  Choice E.**

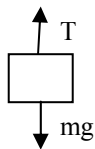
In the demo where a falling weight powered a light bulb, why did the weight fall faster when the light bulb was disconnected from the circuit? [9?] \_\_\_\_\_

- (a) The initial kinetic energy increased more than the electrical energy.
- (b) The initial potential energy was not converted into electrical energy.
- (c) There was increased gravitational force on the weight.
- (d) There was increased initial kinetic energy in the system.
- (e) There was increased initial potential energy in the system.

**9. Since no electrical energy had to be produced, more of the original potential energy could be converted into kinetic energy. Choice B.**

A 3 kg bucket is accelerated upwards by rope at a rate of 4.5 m/s<sup>2</sup>. What is the tension in the rope? [10?] \_\_\_\_\_  
 (a) less than 30.5 N (b) 30.5 - 32 (c) 32 - 33.5 (d) 33.5 - 35 (e) 35 - 36.5 (f) 36.5 - 38 (g) 38 - 39.5 (h) 39.5 - 41 (i) 41 - 42.5 (j) more than 42.5 N

10.



$$\begin{aligned} \Sigma F &= ma \\ T - mg &= ma \\ T &= mg + ma \end{aligned}$$

$$\begin{aligned} T &= (3)(9.8) + (3)(4.5) \\ T &= 42.9 \text{ N} \end{aligned}$$

**Choice J**

You throw balls from the top of a building towards a large flat parking lot: one straight up, one straight down and one horizontally, all with the same initial speed. Ignoring the force of air resistance, which ball will have the highest speed just before it hits the ground? [11?] \_\_\_\_\_ (a) the one thrown straight up (b) the one thrown straight down (c) the one thrown horizontally (d) they will all have the same speed

**11. All the balls start with the same potential energy and the same kinetic energy. Because no energy is lost to non-conservative forces and they all end up with the same potential energy (zero), all the balls must have the same final kinetic energy. Choice D.**

Two balls are thrown straight up into the air. The first ball is thrown twice as fast as the second ball. How do the heights reached by the balls compare? [12?] \_\_\_\_\_ (a) they both reach the same height (b) the first one goes about 1.41 times as high as the second one (c) the first goes two times as high as the second one (d) the first one goes four times as high as the second one.

12.  $KE_{\text{before}} = PE_{\text{after}}$   
 $\frac{1}{2}mv_0^2 = mgh$   
 $h = v_0^2 / 2g$   
 $h \sim v_0^2 \rightarrow$  twice the  $v_0$  gives 4 times the height. **Choice D.**

If I push on an object which is at rest (like a wall), then the force exerted by my hand on the object will be equal to the force exerted by the object on my hand. However, if I push on an object and cause it to accelerate, then the force exerted by my hand on the object will be [13?] \_\_\_\_\_ (a) greater than (b) less than (c) still equal to the force exerted by the object on my hand.

13. These are partner forces. Newton's 3<sup>rd</sup> Law doesn't depend on any accelerations. **Choice C.**

A 3 gram ping-pong ball starts at rest and is pushed 2.5 meters along an evacuated tube by a constant force of 40 N from air entering the tube behind it. What is the ball's exit velocity? [14?] \_\_\_\_\_ (a) less than 230 m/s (b) 230 - 240 (c) 240 - 250 (d) 250 - 260 (e) 260 - 270 (f) 270 - 280 (g) more than 280 m/s.

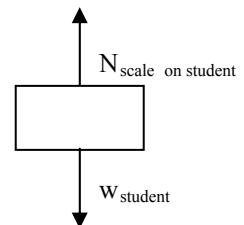
14.  $\sum F = ma \rightarrow a = 40 \text{ N} / .003 \text{ kg} = 13333 \text{ m/s}^2$   
 $v_f^2 = v_0^2 + 2a\Delta x \rightarrow v_f^2 = 0 + 2(13333)(2.5) \rightarrow v_f = 258.2 \text{ m/s}$  **Choice D.**

Two blocks slide with no friction down two slopes. Both blocks start and end at the same height. The first block slides down a 10° slope, the second one down a 20° slope (both angles are measured from the horizontal). Which statement is true? [15?] \_\_\_\_\_ (a) the first block reaches the bottom first (b) the second block reaches the bottom first (c) the first block is traveling fastest when it reaches the bottom (d) the second block is traveling fastest when it reaches the bottom.

15.  $PE_i = KE_f \rightarrow$  both end up at the same speed. C and D cannot be true. However, the second block has a larger acceleration (albeit for a shorter time), so it reaches the bottom first. **Choice B.**

A student stands on a conventional scale while riding in an elevator from the first floor to the fourth floor. The elevator speeds up from the first to the second floor, goes at a constant speed from the second to the third floor, then slows down from the third to the fourth floor. The reading on the scale [16?] \_\_\_\_\_

- (a) decreases the whole time
- (b) decreases, then increases, then stays constant
- (c) decreases, then stays constant, then increases
- (d) increases the whole time
- (e) increases, then decreases, then stays constant
- (f) increases, then stays constant, then decreases
- (g) stays constant the whole time



16.  $\sum F = ma$   
 $N - w = ma$   
 $N = w + ma$   
**When a is positive,  $N > w$ . When  $a = 0$ ,  $N = w$ . When a is negative,  $N < w$ . Choice F**

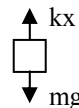
How many joules of energy does a 60 W light bulb consume if it is accidentally left on for 24 hours? [17?] \_\_\_\_\_ (a) less than 5200 kJ (b) 5200 - 5300 (c) 5300 - 5400 (d) 5400 - 5500 (e) 5500 - 5600 (f) 5600 - 5700 (g) 5800 - 5900 (h) more than 5900 kJ.

17.  $P = E/\Delta t \rightarrow E = P\Delta t$   
 $E = (60 \text{ W})(24\text{hrs} * 3600\text{s}/\text{hr}) = 5,184,000 \text{ J} = 5184 \text{ kJ}$  **Choice A**

You want to measure the spring constant of a hanging spring. You add a 0.5 kg mass to the spring and let the spring slowly stretch out so that the mass eventually hangs without moving at a distance of 19 cm below where it started. What is the spring constant  $k$ ? [18?] \_\_\_\_\_ (a) 0 - 7 N/m (b) 7 - 14 (c) 14 - 21 (d) 21 - 28 (e) 28 - 35 (f) 35 - 42 (g) 42 - 49 (h) 49 - 56 (i) 56 - 63 (j) more than 63 N/m.

18. "hangs without moving"  $\rightarrow$  forces are balanced

$$kx = mg \rightarrow k = mg/x = (.5\text{kg})(9.8 \text{ m/s}^2)/.19\text{m} = 25.79 \text{ N/m} \quad \text{Choice D}$$



You want to measure the spring constant of a second hanging spring a different way. You add a 0.5 kg mass to the spring and quickly release the mass so that it starts oscillating up and down with no additional forces on it. At the lowest point of the first oscillation, the mass has stretched the spring out to a distance of 31 cm below where it started. What is the spring constant  $k$ ? [19?] \_\_\_\_\_ (a) 0 - 7 N/m (b) 7 - 14 (c) 14 - 21 (d) 21 - 28 (e) 28 - 35 (f) 35 - 42 (g) 42 - 49 (h) 49 - 56 (i) 56 - 63 (j) more than 63 N/m.

19. "No addition forces" means the forces are balanced

$$PE_{g,i} = PE_{\text{spring},f}$$

$$mgy - \frac{1}{2}kx^2$$

but  $x =$  spring displacement from equilibrium, which in this case is the same as what  $y$  represents:

$$mgy = \frac{1}{2}ky^2 \rightarrow k = 2mg/y$$

$$k = (2)(.5\text{kg})(9.8\text{m/s}^2)/0.31\text{m} = 31.61 \text{ N/m} \quad \text{Choice E}$$

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A 1.2 kg block on a 0.8 m long ramp doesn't slide until the ramp's angle is  $37^\circ$  from horizontal. What is  $\mu_s$ ? [20?] \_\_\_\_\_ (a) less than 0.73 (b) 0.73 - 0.76 (c) 0.76 - 0.79 (d) 0.79 - 0.82 (e) 0.82 - 0.85 (f) 0.85 - 0.88 (g) 0.88 - 0.91 (h) more than 0.91

20.  $\sum F_y = 0 \rightarrow N = mg \cos \theta$

$$\sum F_x = 0 \text{ (right before it starts to move)}$$

$$mg \sin \theta = F_{\text{friction}} = \mu_s N = \mu_s mg \cos \theta$$

$$\sin \theta = \mu_s \cos \theta \rightarrow \mu_s = \tan \theta = \tan 37^\circ = 0.7536 \quad \text{Choice B}$$

Once the block starts to slide at  $37^\circ$ , it takes 2.1 s to slide down the ramp. What is  $\mu_k$ ? [21?] \_\_\_\_\_ (a) less than 0.73 (b) 0.73 - 0.76 (c) 0.76 - 0.79 (d) 0.79 - 0.82 (e) 0.82 - 0.85 (f) 0.85 - 0.88 (g) 0.88 - 0.91 (h) more than 0.91

$$21. x = \frac{1}{2} at^2$$

$$(.8 \text{ m}) = \frac{1}{2} (a) (2.1 \text{ s})^2$$

$$a = 0.3628 \text{ m/s}^2$$

$$\sum F_x = ma_x$$

$$mg \sin \theta - \mu_k N = ma$$

$$mg \sin \theta - \mu_k mg \cos \theta = ma$$

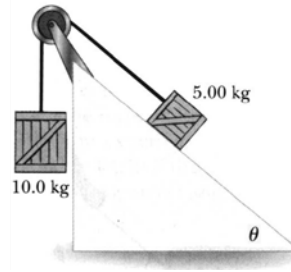
$$\mu_k = (g \sin \theta - a) / (g \cos \theta) = 0.7072 \quad \text{Choice A}$$

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A 700 kg, 300 hp (223,710 W) sports car can travel at a maximum speed of 130 mph (58.12 m/s) when it uses all available power. Assume that at that high speed practically all of the work done by the engine goes into fighting air resistance. How strong is the air resistance force at 130 mph? [22?] \_\_\_\_\_ (a) less than 3600 N (b) 3600 - 3700 (c) 3700 - 3800 (d) 3800 - 3900 (e) 3900 - 4000 (f) 4000 - 4100 (g) more than 4100 N

22.  $P = Fv \rightarrow F = P/v = 223710 \text{ W} / 58.12 \text{ m/s} = 3849 \text{ N} \quad \text{Choice D}$

Two crates, 10 kg and 5 kg, are connected by a light string that passes over a pulley as shown in the figure. The 5 kg crate lies on an incline of angle  $\theta = 40^\circ$ . The coefficients of friction on the incline are  $\mu_s = 0.3$  and  $\mu_k = 0.2$ .



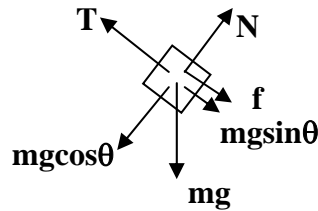
The frictional force on the 5 kg block is [23?] \_\_\_\_\_ (a)  $\mu_k mg$   
 (b)  $\mu_k mg \sin \theta$  (c)  $\mu_k mg \cos \theta$  (d)  $\mu_k mg \tan \theta$  (e)  $mg$  (f)  $mg \sin \theta$   
 (g)  $mg \cos \theta$  (h)  $mg \tan \theta$

The frictional force is directed [24?] \_\_\_\_\_ (a) up the incline (b) down the incline (c) normal to the incline.

The acceleration of the crates is [25?] \_\_\_\_\_ (a) less than  $3.5 \text{ m/s}^2$  (b)  $3.5 - 3.8$  (c)  $3.8 - 4.1$  (d)  $4.1 - 4.4$  (e)  $4.4 - 4.7$   
 (f)  $4.7 - 5.0$  (g) more than  $5.0 \text{ m/s}^2$

If the 5 and 10 kg blocks were to switch places ( $\mu$  on the incline staying the same), the hanging block, now 5 kg, would [26?] \_\_\_\_\_ (a) move up, (b) move down, (c) not move.

free body diagram:



23.  $\sum F_y = 0 \rightarrow N = mg \cos \theta$   
 $f = \mu N = \mu mg \cos \theta$  Choice C

24. Friction opposes motion. The block gets pulled up (see next problem), so friction = down Choice B

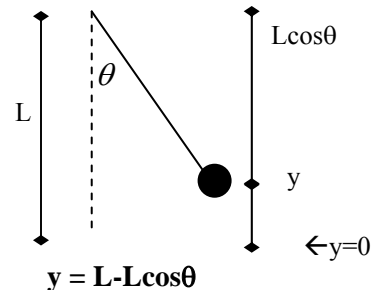
25.  $\sum F_{\text{group}} = m_{\text{group}} a_{\text{group}}$   
 $m_1 g - m_2 g \sin \theta - f = (m_1 + m_2) a$  ( $f = \mu m_2 g \cos \theta$ )  
 $a = (m_1 g - m_2 g \sin \theta - \mu m_2 g \cos \theta) / (m_1 + m_2) = 3.933 \text{ m/s}^2$  Choice C

26. This problem was tough, hardest on the exam. Here's how I thought about it--  
 At the point where they almost move:  $\sum F_{5\text{kg}} = 0 \rightarrow T = (5\text{kg})(9.8\text{m/s}^2) = 49 \text{ N}$   
 Look at the forces on the 10 kg block:  $T = 49 \text{ N}$  up the slope  $mg \sin \theta = 62.99 \text{ N}$  down the slope  
 With no friction, it would go down! (hanging block would go up)  
 However, max static friction =  $\mu_s N = (.3)(10)(9.8) \cos 37^\circ = 23.48 \text{ N}$   
 Therefore, T and max static friction together are enough to prevent movement. Choice C.

A pendulum consisting of a string (length  $L$ ) with a metal ball (mass  $m$ ) on the end is released from an angle  $\theta$ , measured from the vertical. How fast is the ball going at the lowest point of the swing? [27?] \_\_\_\_\_

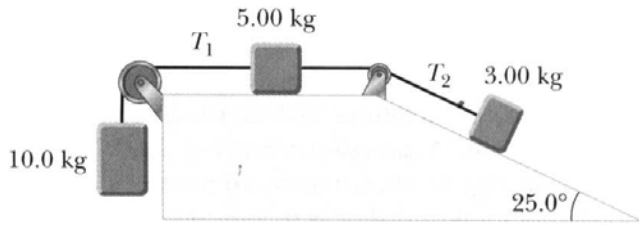
- (a)  $\sqrt{2gL}$  (b)  $\sqrt{2gL(1-\cos \theta)}$  (c)  $\sqrt{\frac{2gL}{\cos \theta}}$  (d)  $\sqrt{2gL \sin \theta}$  (e)  $\sqrt{\frac{gL}{\sin \theta}}$  (f)  $\sqrt{\frac{2mgL}{\tan \theta}}$  (g)  $\sqrt{\frac{2mL \tan \theta}{g}}$   
 (h)  $\sqrt{mg(1-\cos \theta)}$  (i)  $\sqrt{mgL(1-\sin \theta)}$  (j)  $\sqrt{mL(g-\cos \theta)}$

27.  $PE_i = KE_f$   
 $mg y = \frac{1}{2} m v^2$   
 $v = \sqrt{2gy}$   
 $v = \sqrt{2g(L-L \cos \theta)}$   
 $v = \sqrt{2gL(1-\cos \theta)}$  Choice B



The three blocks of masses 10 kg, 5 kg, and 3 kg are connected as shown in the figure. The acceleration of the 5 kg block is  $2.2 \text{ m/s}^2$  to the left and there is friction (coefficient  $\mu$ ) between the blocks and the surfaces. What is  $\mu$ ? [28?]

\_\_\_\_\_ (a) less than 0.48 (b) 0.48 - 0.5 (c) 0.5 - 0.52 (d) 0.52 - 0.54 (e) 0.54 - 0.56 (f) 0.56 - 0.58 (g) 0.58 - 0.6 (h) 0.6 - 0.62 (i) more than 0.62. *Hint:* this is likely most easily done by considering the blocks together as a group.

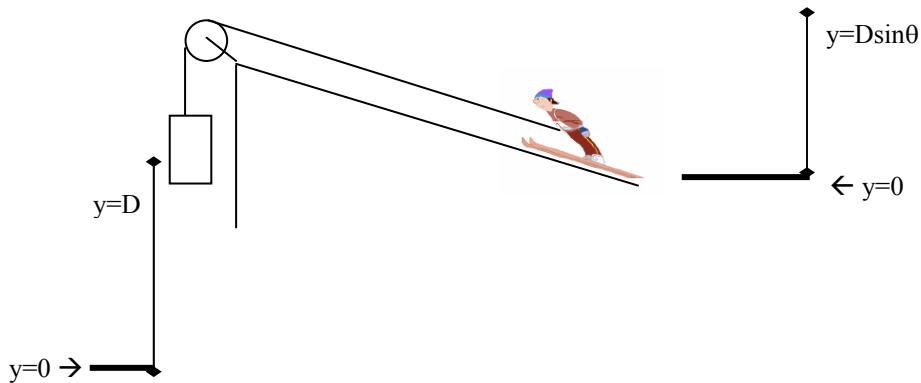


28.  $\Sigma F_{\text{group}} = m_{\text{group}} a_{\text{group}}$   
 $m_1 g - f_2 - f_3 - m_3 g \sin \theta = m_{\text{total}} a$   
 $m_1 g - \mu N_2 - \mu N_3 - m_3 g \sin \theta = m_{\text{total}} a$   
 $m_1 g - \mu m_2 g - \mu m_3 g \cos \theta - m_3 g \sin \theta = m_{\text{total}} a$

solving for  $\mu$ ...

$m_1 g - m_3 g \sin \theta - m_{\text{tot}} a = \mu (m_2 g + m_3 g \cos \theta)$   
 $\mu = (m_1 g - m_3 g \sin \theta - m_{\text{tot}} a) / (m_2 g + m_3 g \cos \theta)$   
 $\mu = 0.6078$  Choice H

Vern, the famous “pulley ski-jumper” is 70 kg, and is pulled via a pulley by a giant 500 kg hanging block up a 30 m incline (that’s the distance along the incline, not the vertical distance). The incline is at a  $35^\circ$  angle from the horizontal, and the friction coefficient between skier and incline is 0.1. How fast is Vern going when he takes off from the incline (he misses the giant pulley)? [29?] \_\_\_\_\_ (a) less than 21 m/s (b) 21 - 22 (c) 22 - 23 (d) 23 - 24 (e) 24 - 25 (f) 25 - 26 (g) more than 26 m/s

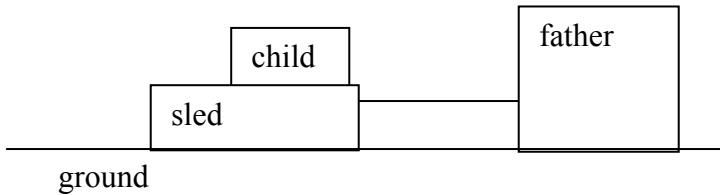


29.  $E_{\text{bef}} + W_{\text{net}} = E_{\text{aft}}$   
 $PE_{\text{block}_i} - f \cdot D = PE_{\text{Vern}_f} + KE_{\text{Vern}_f} + KE_{\text{block}_f}$   
 $PE_{\text{block}_i} - \mu (m_v g \cos \theta) \cdot D = PE_{\text{Vern}_f} + KE_{\text{Vern}_f} + KE_{\text{block}_f}$   
 $m_B g D - \mu m_v g \cos \theta D = m_v g D \sin \theta + \frac{1}{2} m_v v_f^2 + \frac{1}{2} m_B v_f^2$   
 $v_f = \sqrt{(m_B g D - \mu m_v g \cos \theta D - m_v g D \sin \theta) / (\frac{1}{2} m_v + \frac{1}{2} m_B)} = 21.64 \text{ m/s}$  Choice B

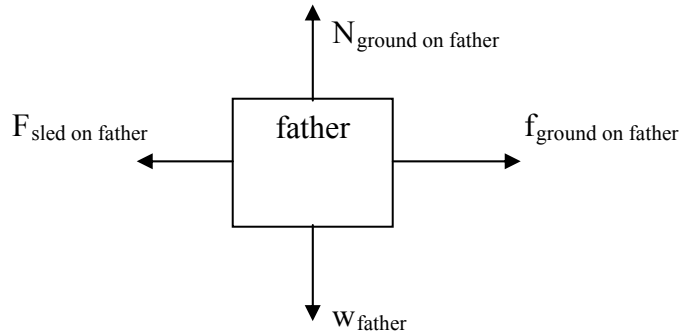
Write your CID separately on this sheet to guarantee your free body diagram doesn't get lost:

CID: \_\_\_\_\_

**Problem 30.** This is worth 3 points; the rest of the exam is worth 97 points. A father pulls too hard to the right on a sled and his child slides off. See the figure; apologies for the box-like people.



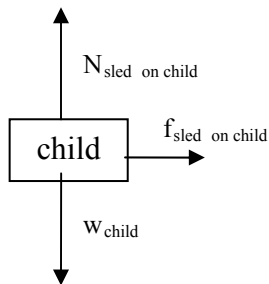
Draw the free body diagrams of the child and the sled during the time the child is sliding off. Include friction on all surfaces. In your diagrams, label the gravitational forces as “ $w_{\text{object}}$ ” (for “weight of object”). For all other forces, label what is producing the force and on what it is acting. Do so like this: use “ $F_{1\text{on}2}$ ” to mean “Force produced by object 1 acting on object 2”, or e.g. “ $N_{1\text{on}2}$ ” for “normal force of object 1 on object 2” or “ $f_{1\text{on}2}$ ” for “friction force of object 1 on object 2”. I have done this here for the father, so you can see exactly what I mean.



Now, your turn:

**The answers:**

**Free body diagram of child**



**Free body diagram of sled**

