

Solutions

Fall 2014
Physics 105, sections 1 and 3
Exam 2
Colton

RED

barcode here

Please write your CID _____
so that you can get your exam back

No time limit. A handwritten 3" x 5" note card is allowed. No books. Student calculators allowed. All problems equal weight.

Constants/Materials parameters:

$g = 9.8 \text{ m/s}^2$
 $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$
 $k_B = 1.381 \times 10^{-23} \text{ J/K}$
 $N_A = 6.022 \times 10^{23}$
 $R = k_B \cdot N_A = 8.314 \text{ J/mol}\cdot\text{K}$
 $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\cdot\text{K}^4$
Mass of Sun = $1.991 \times 10^{30} \text{ kg}$
Mass of Earth = $5.98 \times 10^{24} \text{ kg}$

Radius of Earth = $6.38 \times 10^6 \text{ m}$
Radius of Earth's orbit = 1 A.U. = $1.496 \times 10^{11} \text{ m}$
Density of water: 1000 kg/m^3
Density of air: 1.29 kg/m^3
Linear exp. coeff. of copper: $17 \times 10^{-6} /^\circ\text{C}$
Linear exp. coeff. of steel: $11 \times 10^{-6} /^\circ\text{C}$
Specific heat of water: $4186 \text{ J/kg}\cdot^\circ\text{C}$

Specific heat of ice: $2090 \text{ J/kg}\cdot^\circ\text{C}$
Specific heat of steam: $2010 \text{ J/kg}\cdot^\circ\text{C}$
Specific heat of alum.: $900 \text{ J/kg}\cdot^\circ\text{C}$
Latent heat of melting (water): $3.33 \times 10^5 \text{ J/kg}$
Latent heat of boiling (water): $2.26 \times 10^6 \text{ J/kg}$
Thermal conduct. of alum.: $238 \text{ J/s}\cdot\text{m}\cdot^\circ\text{C}$
 $v_{\text{sound}} = 343 \text{ m/s at } 20^\circ\text{C}$

Conversion factors

1 inch = 2.54 cm
1 foot = 0.3048 m
1 mile = 1.609 km
1 mi/hr = 1 mph = 0.44704 m/s

1 lb = 4.448 N
1 m³ = 1000 L
1 gallon = 3.785 L = 3785 cm³
1 atm = $1.013 \times 10^5 \text{ Pa} = 14.7 \text{ psi}$

$$T_F = \frac{9}{5}T_C + 32$$
$$T_K = T_C + 273.15$$

Instructions:

- Write your CID at the top of the page, otherwise you may not get this exam booklet back.
- Circle your answers in this booklet if you wish to record them, but be sure to **mark your answers on the bubble sheet.** (You will not get the bubble sheet back.)
- Unless otherwise specified, **ignore air resistance** in all problems.
- Use $g = 9.8 \text{ m/s}^2$.

Some notes on the answer ranges:

If a set of answers is given like this

- Less than 30 N
- 30 – 40
- 40 – 50
- 50 – 60
- More than 60 N

you can generally consider choice (a) to mean "20 – 30 N", and choice (e) to mean "60 – 70 N". I often write them like that so that if I've made a mistake when making up the answer ranges, and the answer is really less than 20 N, or larger than 70 N, then there is still an answer that is correct.

I randomize the answer choices, so the first and last choices should receive their statistical fair share of answers.

Any units and/or exponents given in the first and last answer choices also apply to the middle choices.

1. A toy car is allowed to roll down a ramp. As the car is moving down the ramp and speeding up, the net force on it is:
- Up the ramp, and increasing in magnitude
 - Up the ramp, and decreasing in magnitude
 - Up the ramp, and constant in magnitude
 - Zero
 - Down the ramp, and increasing in magnitude
 - Down the ramp, and decreasing in magnitude
 - Down the ramp, and constant in magnitude**



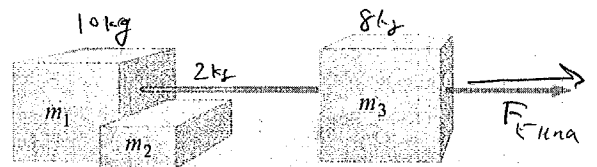
Both N and mg are constant, so net force is constant.

Also, it's accelerating down the ramp, so net force must be down the ramp.

2. A toy car is given a push up a ramp. After it's released, it moves up the ramp but begins to slow down. As the car is moving up the ramp and slowing down, the net force on it is:
- Up the ramp, and increasing in magnitude
 - Up the ramp, and decreasing in magnitude
 - Up the ramp, and constant in magnitude
 - Zero
 - Down the ramp, and increasing in magnitude
 - Down the ramp, and decreasing in magnitude
 - Down the ramp, and constant in magnitude**

The situation is identical to the previous problem

3. Three blocks are assembled as shown in the figure on a frictionless surface. The three masses m_1 , m_2 , and m_3 are 10 kg, 2 kg, and 8 kg, respectively. Elena pulls to the right on m_3 with a force of 20 N. How much force is exerted by m_1 on m_2 ? (Choose the closest answer.)



- 1.5 N
- 2.0**
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0 N

First: $\sum F_{group} = m_{group} a_{group}$

$$F_{Elena} = (m_1 + m_2 + m_3) a$$

$$a = \frac{F_{Elena}}{m_1 + m_2 + m_3} = \frac{20 \text{ N}}{20 \text{ kg}} = 1 \text{ m/s}^2$$

Second: $\sum F_{m_2} = m_2 a$

$$F_{12} = (2 \text{ kg})(1 \text{ m/s}^2)$$

$$F_{12} = 2 \text{ N}$$

4. A spring is slowly stretched out, and the force required to stretch the spring is recorded at each instant. The result is shown in the graph to the right. What was the spring constant of the spring?

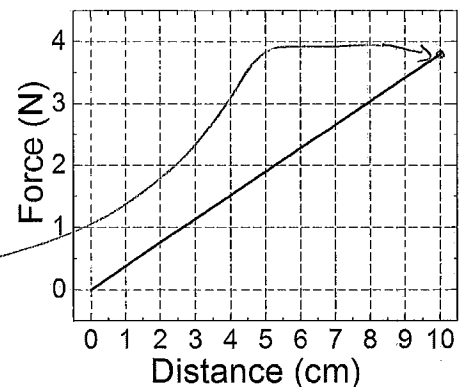
- Less than 25 N/m
- 25 - 27
- 27 - 29
- 29 - 31
- 31 - 33
- 33 - 35
- 35 - 37
- More than 37 N/m**

$$F_{spring} = kx$$

Just pick a point on the graph, for example

$$F_{spring} = 3.8 \text{ N and } \Delta x = 10 \text{ cm}$$

$$k = \frac{F_{spring}}{\Delta x} = \frac{3.8 \text{ N}}{0.10 \text{ m}} = 38 \text{ N/m}$$



5. Same situation. How much work was done in stretching out the spring?

- Less than 0.16 J
- 0.16 - 0.18
- 0.18 - 0.20**
- 0.20 - 0.22
- 0.22 - 0.24
- 0.24 - 0.26
- 0.26 - 0.28
- More than 0.28 J

Two methods:

$$1) W = F_{ave} \cdot \Delta x = 1.9 \text{ N} \cdot 0.1 \text{ m}$$

$$W = (1.9 \text{ N})(0.1 \text{ m}) = 0.19 \text{ J}$$

$$2) E_{int} + W = E_{aft}$$

$$W = \frac{1}{2} k x^2$$

$$W = \frac{1}{2} (38 \text{ N/m})(0.1 \text{ m})^2$$

$$W = 0.19 \text{ J} \quad \text{They match!}$$

6. A 400 g bead slides on a curved wire, starting from rest at point A in the figure. The wire is frictionless. In the figure, $y_1 = 0.5$ m and $y_2 = 0.2$ m. How fast is the bead going at point C?

- Less than 2.2 m/s
- 2.2 - 2.3
- 2.3 - 2.4
- 2.4 - 2.5
- 2.5 - 2.6
- 2.6 - 2.7
- 2.7 - 2.8
- More than 2.8 m/s

Handwritten solution for Q6:

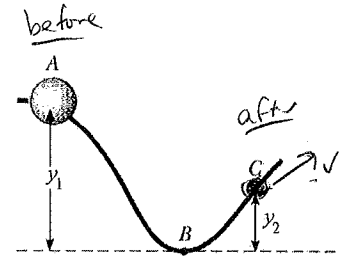
$$E_{\text{bef}} + W = E_{\text{aft}}$$

$$mgh = \frac{1}{2}mv^2$$

measured from C

$$v = \sqrt{2gh} = \sqrt{2 \cdot 9.8 \text{ m/s}^2 \cdot (0.5 \text{ m} - 0.2 \text{ m})}$$

$$= \boxed{2.42 \text{ m/s}}$$



7. Nancy pushes a 3 kg box horizontally along the floor. The box is initially at rest. She does 150 J of work on the box. At the same time friction provides an opposing force of 20 N. If the box moves 5 m, at the end how fast is it going?

- Less than 5.4 m/s
- 5.4 - 5.5
- 5.5 - 5.6
- 5.6 - 5.7
- 5.7 - 5.8
- 5.8 - 5.9
- 5.9 - 6.0
- More than 6.0 m/s

Handwritten solution for Q7:

$$W_{\text{Nancy}} - f \cdot d = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2}{m}(W_{\text{Nancy}} - fd)}$$

$$= \sqrt{\frac{2}{3 \text{ kg}}(150 \text{ J} - 20 \text{ N} \cdot 5 \text{ m})}$$

$$= \boxed{5.77 \text{ m/s}}$$

8. Vern, the famous "pulley ski-jumper" is 80 kg, and is pulled via a pulley by a 400 kg hanging block up a 30 m incline that has a vertical height change of 12 m; see the figure. Friction and air resistance provide a constant backwards force on Vern of 70 N. How fast will Vern be going when he takes off from the incline? (Hint: this is most easily done with work and energy.)

- Less than 24 m/s
- 24 - 26
- 26 - 28
- 28 - 30
- 30 - 32
- 32 - 34
- 34 - 36
- More than 36 m/s

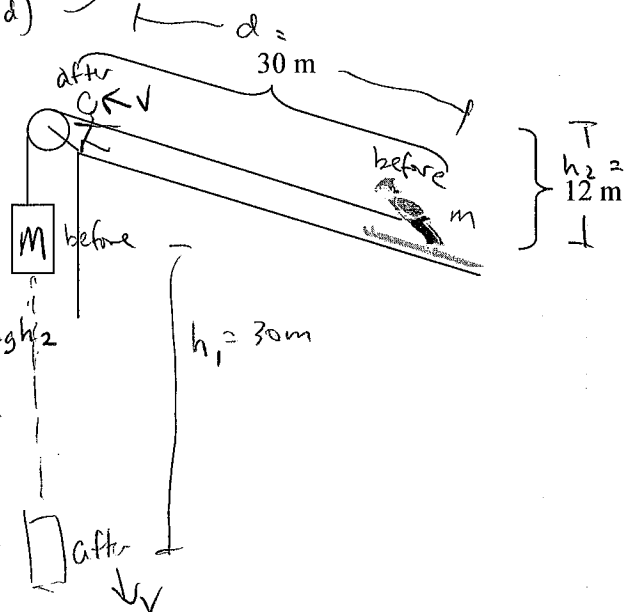
Handwritten solution for Q8:

$$Mgh_1 - f \cdot d = \frac{1}{2}mv^2 + \frac{1}{2}Mv^2 + mgh_2$$

$$Mgh_1 - mgh_2 - f \cdot d = \frac{1}{2}(m+M)v^2$$

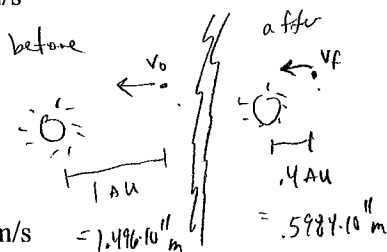
$$v = \sqrt{\frac{400 \cdot 9.8 \cdot 30 - 80 \cdot 9.8 \cdot 12 - 70 \cdot 30}{\frac{1}{2}(80 + 400)}}$$

$$= \boxed{21.02 \text{ m/s}}$$



9. A particular comet passes the Earth, a distance from the sun of 1 "A.U." (astronomical unit), traveling at a speed of 38 km/s. One month later it is much closer to the sun, 0.4 A.U. How fast will it be traveling then? (Hint: this is a conservation of energy problem. Consider its potential energy relative to the sun.)

- Less than 65 km/s
- 65 - 67
- 67 - 69
- 69 - 71
- 71 - 73
- 73 - 75
- 75 - 77
- More than 77 km/s



Handwritten solution for Q9:

$$E_{\text{bef}} + W = E_{\text{aft}}$$

$$KE_i + PE_i = KE_f + PE_f$$

$$\frac{1}{2}mv_i^2 - \frac{GMm}{r_0} = \frac{1}{2}mv_f^2 - \frac{GMm}{r_f}$$

$$v_f = \sqrt{v_0^2 + 2GM \left(\frac{1}{r_f} - \frac{1}{r_0} \right)}$$

$$= \sqrt{38000^2 + 2 \cdot 6.67 \cdot 10^{-11} \cdot 1.99 \cdot 10^{30} \left(\frac{1}{.5984 \cdot 10^{11}} - \frac{1}{1.496 \cdot 10^{11}} \right)}$$

$$= \boxed{64087 \text{ m/s}}$$

$$= \boxed{64.1 \text{ km/s}}$$

10. A 80 kg student climbs a 5 m long rope and stops at the top. What must her average speed be in order to match the power output of a 100 W light bulb?

- a. Less than 0.11 m/s
- b. 0.11 - 0.12
- c. 0.12 - 0.13**
- d. 0.13 - 0.14
- e. 0.14 - 0.15
- f. 0.15 - 0.16
- g. 0.16 - 0.17
- h. More than 0.17 m/s

$$P = \frac{\text{Work}}{\text{time}} = \frac{\Delta \text{energy}}{\text{time}}$$

$$P = \frac{mgy}{\text{time}}$$

$$v = \frac{y}{t} = \frac{P}{mg} = \frac{100 \text{ W}}{(80 \text{ kg})(9.8 \text{ m/s}^2)} = \boxed{.1276 \frac{\text{m}}{\text{s}}}$$

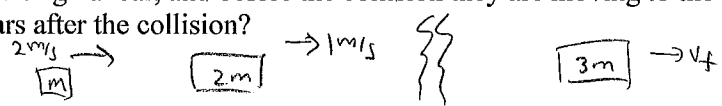
11. Suppose Katie is floating in outer space with no forces acting on her. She is at rest, so her momentum is zero. Suddenly, she takes a ball out of her pocket and throws it. The ball goes one way, and she goes the other way. Was the momentum of the "Katie & the ball" system conserved?

- a. yes**
- b. no

Ball has + momentum
Katie has - momentum
total momentum after = 0

12. A railroad car of mass 3000 kg moving to the right at 2 m/s collides and couples with two coupled railroad cars. The two each have the same mass as the original car, and before the collision they are moving to the right at 1 m/s. What is the speed of the three coupled cars after the collision?

- a. Less than 1.1 m/s
- b. 1.1 - 1.2
- c. 1.2 - 1.3
- d. 1.3 - 1.4**
- e. 1.4 - 1.5
- f. 1.5 - 1.6
- g. 1.6 - 1.7
- h. More than 1.7 m/s



$$\sum \vec{p}_{\text{bef}} = \sum \vec{p}_{\text{aft}}$$

$$m \cdot 2 \text{ m/s} + 2m \cdot 1 \text{ m/s} = 3m \cdot v_f$$

$$v_f = \frac{2 + 2}{3} \frac{\text{m}}{\text{s}} = \boxed{1.33 \frac{\text{m}}{\text{s}}}$$

13. The preceding collision was

- a. elastic
- b. inelastic**
- c. cannot tell from information given

perfectly inelastic, even, because they stick together.

14. I happened to be visiting Dr. Hess's class once when he did an amazing demonstration. (He's one of the other BYU physics professors.) He wanted to show how force in a collision can be reduced by extending the time of the collision. He had a student throw a raw egg with substantial velocity towards a sheet that Dr. Hess and a second student were holding. The sheet was supposed to slow down the egg gradually so that it wouldn't be broken. However, the student throwing the egg (again, with substantial velocity) threw it towards the wrong side of Dr. Hess, completely missing the sheet! Without batting an eye, Dr. Hess caught the egg barehanded with his free hand. The egg didn't break! It was amazing! Suppose the egg (mass 60 g) was thrown at 9 m/s, and the collision with Dr. Hess's hand happened over 0.38 m (=15 inches) as Dr. Hess was moving his hand backwards while catching the egg. Assuming uniform deceleration, the collision would have taken 0.0844 seconds (you can check that with kinematics formulas if you like but you don't have to). What was the average force on the egg during that time? Note: I've deliberately written the answer choices in pounds so that you can get a better sense for the force that the egg actually withstood; you do need to convert your answer to pounds.

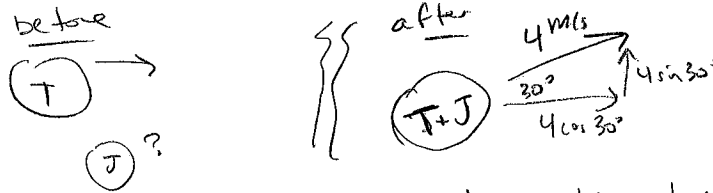
- a. Less than 1.3 lbs
- b. 1.3 - 1.5**
- c. 1.5 - 1.7
- d. 1.7 - 1.9
- e. 1.9 - 2.1
- f. 2.1 - 2.3
- g. 2.3 - 2.5
- h. More than 2.5 lbs

$$F \Delta t = \Delta p$$

$$\rightarrow F = \frac{\Delta p}{\Delta t} = \frac{(.060 \text{ kg})(9 \text{ m/s})}{.0844 \text{ s}} = \underline{6.378 \text{ N}} \times \frac{1 \text{ lb}}{4.448 \text{ N}} = \boxed{1.438 \text{ lbs}}$$

15. Two ice skaters on frictionless ice collide. Tom (mass 60 kg) runs into Jerry (mass 80 kg). Tom is initially traveling east at 3 m/s, but Jerry's velocity (magnitude and direction) is unknown. They grab onto each other as they collide, and together they go off at an angle of 30° north of east at a speed of 4 m/s. In what general direction was Jerry's initial velocity?

- a. north
b. northeast
 c. east
 d. southeast
 e. south
 f. southwest
 g. west
 h. northwest



J must provide some N momentum, because there is N mom. after
 some E momentum, because there is more E mom. after than there is before

16. Same situation. What was the magnitude of Jerry's initial velocity?

- a. Less than 4.4 m/s
 b. 4.4 - 4.6
 c. 4.6 - 4.8
 d. 4.8 - 5.0
e. 5.0 - 5.2
 f. 5.2 - 5.4
 g. 5.4 - 5.6
 h. More than 5.6 m/s

$$\sum p_{x \text{ bef}} = \sum p_{x \text{ aft}}$$

$$(60 \text{ kg})(3 \frac{\text{m}}{\text{s}}) + (80 \text{ kg}) v_x = (140 \text{ kg})(4 \frac{\text{m}}{\text{s}} \cos 30^\circ)$$

$$v_x = 3.812 \text{ m/s}$$

$$\sum p_{y \text{ bef}} = \sum p_{y \text{ aft}}$$

$$(80 \text{ kg}) v_y = (140 \text{ kg})(4 \frac{\text{m}}{\text{s}} \sin 30^\circ)$$

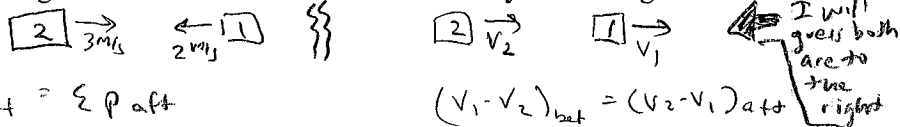
$$v_y = 3.5 \text{ m/s}$$

$$v = \sqrt{3.812^2 + 3.5^2} \frac{\text{m}}{\text{s}}$$

$$= 5.175 \text{ m/s}$$

17. On a frictionless air track, a 2 kg cart and a 1 kg cart have an elastic collision. The 2 kg cart is initially traveling to the right at 3 m/s; the 1 kg cart is initially traveling to the left at 2 m/s. What is the velocity of the 2 kg cart after the collision? (Choose the closest answer.)

- a. Faster than 2.0 m/s to the left
 b. 1.5 - 2.0 to the left
 c. 1.0 - 1.5 to the left
 d. 0.5 - 1.0 to the left
e. 0 - 0.5 to the left
 f. 0 - 0.5 to the right
 g. 0.5 - 1.0 to the right
 h. 1.0 - 1.5 to the right
 i. 1.5 - 2.0 to the right
 j. Faster than 2.0 m/s to the right



$$\sum p_{\text{bef}} = \sum p_{\text{aft}}$$

$$2 \cdot 3 - 1 \cdot 2 = 2v_2 + 1v_1$$

$$4 = 2v_2 + v_1$$

Must solve simultaneous eqns

$$4 = 2v_2 + (v_2 + 5)$$

$$-1 = 3v_2$$

$$v_2 = -\frac{1}{3} \frac{\text{m}}{\text{s}} = -0.333 \text{ m/s}$$

= 0.333 m/s to the left

$$(v_1 - v_2)_{\text{bef}} = (v_2 - v_1)_{\text{aft}}$$

$$-2 - 3 = v_2 - v_1$$

$$-5 = v_2 - v_1$$

$$v_1 = v_2 + 5$$

I will guess both are to the right

18. Friction slows down a top that has a 11 cm radius, with an angular deceleration of 0.5 rad/s^2 . The top was initially spinning at a rate of 2 rpm (rev/min). How long does it take the top to stop?

- a. Less than 0.41 s
b. 0.41 - 0.43
 c. 0.43 - 0.45
 d. 0.45 - 0.47
 e. 0.47 - 0.49
 f. 0.49 - 0.51
 g. 0.51 - 0.53
 h. More than 0.53 s

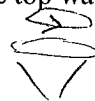
$$2 \frac{\text{rev}}{\text{min}} \times \frac{2\pi \text{ rad}}{1 \text{ rev}} \times \frac{1 \text{ min}}{60 \text{ s}} = 0.2094 \text{ rad/s}$$

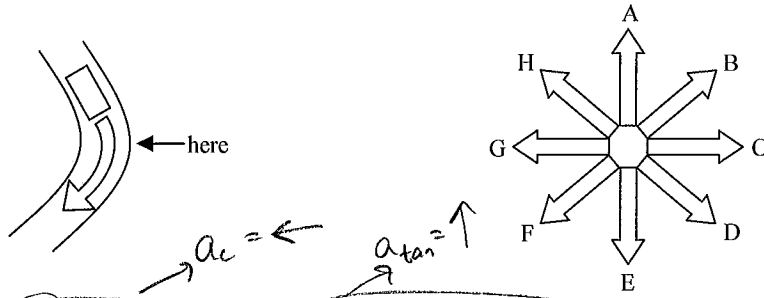
kinematics:

$$\omega_f = \omega_0 + \alpha t$$

$$0 = 0.2094 \frac{\text{rad}}{\text{s}} - 0.5 \frac{\text{rad}}{\text{s}^2} \cdot t$$

$$t = \frac{0.2094}{0.5} \text{ s} = 0.4189 \text{ s}$$





19. A car goes around a corner as shown, while slowing down. At the point labeled "here", in what general direction is the car's acceleration, as indicated by the arrows on the right?

- a. A
- b. B
- c. C
- d. D
- e. E

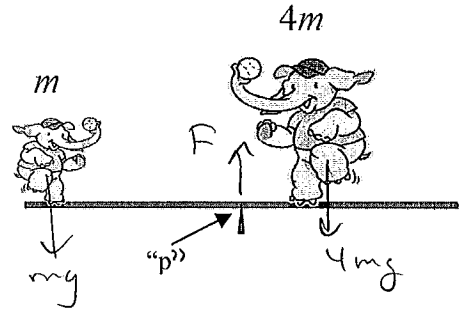
- f. F
- g. G
- h. H
- i. None; the car is not accelerating.

combined = ↖

20. A big elephant and a small elephant are balanced on a beam as shown. What is true about the magnitudes of the torques supplied by the two elephants about the central pivot point, "p"?

- a. $|\tau_{\text{big elephant}}| > |\tau_{\text{small elephant}}|$
- b. $|\tau_{\text{big elephant}}| < |\tau_{\text{small elephant}}|$
- c. $|\tau_{\text{big elephant}}| = |\tau_{\text{small elephant}}|$

$\sum \tau_p = 0$
torques must balance



21. Same situation. How large is the upward force from the pivot point?

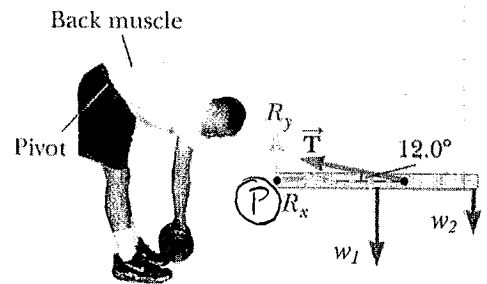
- a. mg
- b. $2mg$
- c. $3mg$
- d. $4mg$
- e. $5mg$
- f. $6mg$
- g. $7mg$
- h. $8mg$

$$\sum F = 0$$

$$-mg + F - 4mg = 0$$

$$F = 5mg$$

22. The back of a person bending over to pick up an object is modeled as a uniform horizontal bar as shown, where the forces acting on the back are w_1 = the weight of the spine and upper body, w_2 = the weight of the object being picked up, T = the tension in the back muscle, R_x = the compressional force in the spine, and R_y = the vertical support of the spine from the pelvis and surrounding muscles. For a certain person, suppose the back has a length of 0.8 m, $w_1 = 400$ N, $w_2 = 200$ N, and the back muscle is attached 0.6 m from the left end. What is T ?



- a. Less than 2400 N
- b. 2400 - 2600
- c. 2600 - 2800
- d. 2800 - 3000
- e. 3000 - 3200
- f. 3200 - 3400
- g. 3400 - 3600
- h. More than 3600 N

$$\sum \tau_p = 0$$

$$(T \sin 12^\circ)(0.6 \text{ m}) - (w_1)(0.4 \text{ m}) - (w_2)(0.8 \text{ m}) = 0$$

$$T = \frac{.4 w_1 + .8 w_2}{.6 \sin 12^\circ} = \frac{(.4)(400 \text{ N}) + (.8)(200 \text{ N})}{.6 \sin 12^\circ}$$

$$= 2565 \text{ N}$$

23. A cylinder and a sphere race down a hill, having started from the same height. Both roll without slipping. No energy is lost to friction or air resistance. Which one will arrive at the bottom first?
- Cylinder
 - Sphere
 - They tie
 - It depends on the mass of the objects
 - It depends on the diameters of the objects
- As done in class. Reason: less PE will be transformed into rotational KE, so more will be translational KE and it will go faster.

24. Same situation. After reaching the bottom, the two objects continue up a different hill on the far side. Which one will roll farther up the second hill?
- Cylinder
 - Sphere
 - They tie
 - It depends on the mass of the objects
 - It depends on the diameters of the objects
- Both must attain the same height as where they started

25. A 12 kg box is attached to a cord that is wrapped around a pulley of radius $r = 5$ cm which hangs from the ceiling as shown. The pulley is frictionless, but it does have mass... however its mass is not distributed like a simple cylindrical object; i.e. its moment of inertia does not equal $\frac{1}{2}mr^2$. The acceleration of the box is measured to be 2 m/s^2 (downward). What is the moment of inertia of the pulley?

- Less than $0.12 \text{ kg}\cdot\text{m}^2$
- $0.12 - 0.13$
- $0.13 - 0.14$
- $0.14 - 0.15$
- $0.15 - 0.16$
- $0.16 - 0.17$
- $0.17 - 0.18$
- More than $0.18 \text{ kg}\cdot\text{m}^2$

$$\sum F_{\text{box}} = ma$$

$$mg - T = ma$$

$$T = mg - ma$$

$$\sum \tau_{\text{pulley}} = I\alpha$$

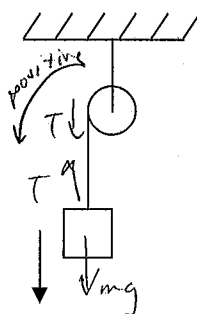
$$T \cdot r = I \left(\frac{a}{r} \right)$$

$$(mg - ma)r = I \frac{a}{r}$$

$$I = mr^2 \cdot \frac{g-a}{a}$$

$$= (12 \text{ kg})(0.05 \text{ m})^2 \frac{9.8 - 2}{2}$$

$$= \boxed{.117 \text{ kg}\cdot\text{m}^2}$$



26. A large airplane wheel has a radius of 1.25 m and a moment of inertia of $110 \text{ kg}\cdot\text{m}^2$. How much work is needed to accelerate the wheel from rest to the point where its tangential speed is 45 m/s ?

- Less than 70000 J
- $70000 - 71000$
- $71000 - 72000$
- $72000 - 73000$
- $73000 - 74000$
- $74000 - 75000$
- $75000 - 76000$
- More than 76000 J

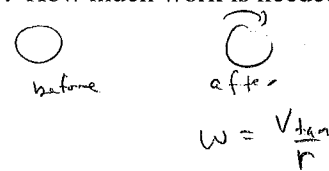
$$E_{\text{before}} + W = E_{\text{after}}$$

↑
only KE_{rot}

$$W = \frac{1}{2} I \omega^2$$

$$= \frac{1}{2} (110 \text{ kg}\cdot\text{m}^2) \left(\frac{45 \text{ m/s}}{1.25 \text{ m}} \right)^2$$

$$= \boxed{71280 \text{ J}}$$



27. Hugh holds a spinning bicycle wheel while standing on a rotating platform. In trial A he first holds the wheel vertically, then slowly turns it to the side so that it is spinning horizontally in the clockwise direction as viewed from above. In trial B he first holds the wheel horizontally spinning counter-clockwise, then slowly turns it over so that it is spinning clockwise. In both trials he is not rotating prior to moving the wheel, but begins to rotate as a result of moving the wheel. What is true about Hugh's final angular velocity in trial A compared to trial B?

- $\omega_A > \omega_B$
- $\omega_A < \omega_B$
- $\omega_A = \omega_B$

$$L_{\text{before}} = L_{\text{after}}$$

$$A: 0 = -L_{\text{wheel}} + L_{\text{Hugh}}$$

$$L_{\text{Hugh}} = |L_{\text{wheel}}|$$

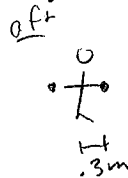
$$B: |L_{\text{wheel}}| = -|L_{\text{wheel}}| + L_{\text{Hugh}}$$

$$L_{\text{Hugh}} = 2|L_{\text{wheel}}|$$

B is bigger!

28. A student sits on a rotating stool holding two 3 kg weights. When his arms are extended horizontally, the masses are 1.1 m from the axis of rotation, and he rotates with an angular speed of 6 rad/s. The moment of inertia of the student plus stool is $3.5 \text{ kg}\cdot\text{m}^2$ and is assumed to be constant. (Note that this moment of inertia does not include the two 3 kg masses.) The student then pulls the weights in horizontally so that they are 0.3 m from the rotation axis. What is the new angular speed of the student?

- a. Less than 11 rad/s
- b. 11 - 13
- c. 13 - 15
- d. 15 - 17
- e. 17 - 19
- f. 19 - 21
- g. 21 - 23
- h. More than 23 rad/s



$$L_{\text{before}} = L_{\text{after}}$$

$$I_o \omega_o = I_f \omega_f$$

$$(I_{\text{student}} + 2mr_o^2) \omega_o = (I_{\text{student}} + 2mr_f^2) \omega_f$$

$$\omega_f = \left(\frac{I_{\text{student}} + 2mr_o^2}{I_{\text{student}} + 2mr_f^2} \right) \omega_o$$

$$= \left(\frac{3.5 + 2 \cdot 3 \cdot 1.1^2}{3.5 + 2 \cdot 3 \cdot 0.3^2} \right) \cdot 6 \frac{\text{rad}}{\text{s}}$$

$$= \boxed{15.98 \frac{\text{rad}}{\text{s}}}$$