Fall 2007 RED Barcode Here

Physics 105, sections 1 and 2

Exam 3 Please write your CID_____

Colton 2-3669

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

Constants: $g = 9.80$ m/s^2 Mass of Earth = 5.98×10^{24} kg

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 Radius of Earth = 6.38×10^6 m

Mass of Sun = 1.991×10^{30} kg Radius of Earth's orbit = 1.496×10^{11} m

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.

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**).

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

Problem 1. An astronaut floating in orbit shakes a mass rapidly back and forth. She reports correctly back to Earth that [1?] _______

a. the shaking requires no effort because the mass is weightless in space.
b. the shaking requires less back and forth force than shaking it on Earth.
c. the mass resists acceleration the same as it would on Earth.

1. The mass doesn't change, and Newton's 2nd Law still applies as usual. Choice c

Problem 2. If the astronaut and mass are in orbit 3000 km (3×10^6 m) *above the earth's surface*, they must be moving a speed of [2?]________ m/s.

a. Less than 6744 m/s
b. 6744 – 7069
c. 7069 – 7394
d. 7394 – 7719
e. 7719 – 8044
f. More than 8044 m/s

2. $F = ma = m\frac{v^2}{r} = \frac{GMm}{r^2}$

$v = \sqrt{\frac{GM}{r}}$ **= sqrt(6.67 × 10^{-11} N·m^2/kg^2 * 5.98 × 10^{24} kg /(6.38e6 + 3.00e6)m) = 6520 m/s.**

Problem 3. A car is on a ferry boat and both are at rest. The car accelerates forward by pushing backward on the ferry. In doing so the magnitude of the car's momentum changes by a certain amount, and that of the ferry changes by [3?] ______ a. a larger amount b. the same amount c. a smaller amount (neglect any other forces on the ferry)

Problem 4. While the car is moving forward, the center of mass of the car-ferry system [4?] _____ a. moves forward b. moves backward c. is at rest.

Problem 5. When the car reaches the end of the ferry, it puts on its brakes and stops (still on the ferry). The ferry is now moving [5?] _______ a. forward b. backwards c. not at all.

3. There are no external forces so total momentum is conserved. Thus any change in the car's momentum must be balanced by an opposite change in the boat's momentum. Choice b

4. There are no net forces on the system, so the center of mass cannot accelerate in any direction. Choice c

5. Total momentum is conserved. It was initially zero, so it must end up as zero: if the car has zero momentum, the ferry must have zero momentum. Choice c.

Problem 6. A 10.0 kg block moving east at 2.60 m/s on a frictionless horizontal surface collides with an 8.5-kg block moving north at 3.40 m/s. After the collision, you measure the first block moving north at 1.50 m/s. In what general direction will the second block be going after the collision? [6?] _______ a. N b. S c. W d. E e. N and W f. N and E g. S and W h. S and E.

Problem 7. How fast will the second block be going after the collision? [7?] ______

a. Less than 2.8 m/s
b. 2.8 – 3
c. 3 – 3.2
d. 3.2 – 3.4
e. 3.4 -3.6
f. Faster than 3.6 m/s

Problem 8. Kinetic energy was conserved in the collision [8?] ______ a. True b. False.

Problem 9. Momentum was conserved [9?] ______ a. True b. False

6. The initial momentum of the system is 26 kg m/s east and 28.9 kg m/s north. Momentum is conserved, so the final momentum is the same. The final momentum is partly taken up by the 10.0 kg block's momentum: 15 kg m/s north. But the rest (all of the east momentum and the rest of the north momentum) must be taken up by the 8.5 kg block. So it travels northeast. Choice F.

7. Momentum of 8.5 kg block then equals 26 kg m/s east and 28.9 – 15 = 13.9 kg m/s north. The magnitude of the momentum is sqrt(26^2 + 13.9^2) = 29.48 kg m/s, and its velocity is momentum divided by mass, 29.48/8.5 = 3.47 m/s.

8. Initial KE = ½ 10 (2.6)^2 + ½ 8.5 (3.4)^2 = 82.93 J. Final KE = ½ 10 (1.5)^2 + ½ 8.5 (3.47^2) = 62.39 J. Kinetic energy was lost! Choice b.

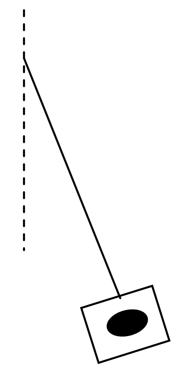
9. There were no outside forces, so momentum was conserved. Choice a.

Problem 10. A skater of mass M is going 5 m/s and grabs another skater at rest of twice the mass, 2M.   Assuming no friction from the ice, they now move together with a speed of [10?]____________

a. Less than 0.9 m/s
b. 0.9 – 1
c. 1 - 1.1
d. 1.1 – 1.2
e. 1.2 – 1.3
f. 1.3 – 1.4
g. 1.4 – 1.5
h. Faster than 1.5 m/s

10. M*5 = 3M * v   v=5/3m/s = 1.667 m/s

Problem 11. A high-speed bullet (0.005 kg) imbeds itself into a small block of wood (0.175 kg) hanging from a string. The wood (with bullet inside) swings up to a height of 0.0937 m above its original position. How fast was the bullet going initially? [11?] ______



a. Less than 42 m/s
b. 42 – 44
c. 44 – 46
d. 46 – 48
e. 48 – 50
f. 50 – 52
g. Faster than 52 m/s

11. Step 1: momentum is conserved in the collision.

$(0.005)(v_{bullet}) = (0.180)v_{combined}$

$v_{bullet} = 36\ v_{combined}$

Step 2: energy is conserved after the collision.

$½\ (0.180)\ v_{combined}$^2 = (0.180)(9.8)(0.0937)

$v_{combined} = 1.3551$ m/s

Plug back into $v_{bullet} = 36\ v_{combined}$,   then vbullet = 48.78 m/s

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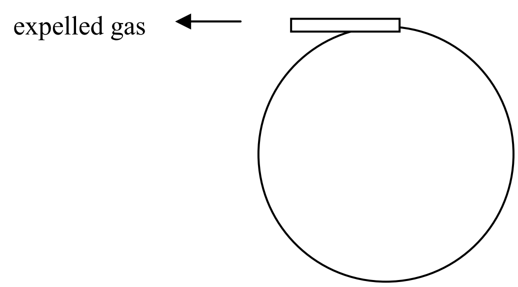
Problem 12. A satellite in the shape of a solid cylinder of mass 25 kg and radius 1.3 m has a very small jet at the edge that provides a force of 30 N on the gasses it expels.   The torque about the center due to the jet is [12?] _______



a. Less than 37.2 N·m
b. 37.2 – 38.3
c. 38.3 – 39.4
d. 39.4 – 40.5
e. 40.5 – 41.5
f. More than 41.5 N·m

Problem 13. The angular acceleration of the satellite will be [13?] ___________

a. Less than 1.73 rad/s^2
b. 1.73 – 1.83
c. 1.83 – 1.93
d. 1.93 – 2.03
e. 2.03 - 2.13
f. More than 2.13 rad/s^2

12. τ= RF = 1.3 *30 = 39 Nm

13. α = T/I = T/(1/2 MR^2) = 39/0.5/25/1.3^2 = 1.846 rad/s^2

Problem 14. A figure skater stands on one spot on the ice and spins around with her arms extended. When she pulls in her arms, she reduces her rotational inertia and her angular speed increases so that her angular momentum is conserved. Neglect possible energy losses due to friction. Compared to her initial rotational kinetic energy, her rotational kinetic energy after she has pulled in her arms must be: [14?] _________

a. the same
b. larger after she's rotating faster
c. smaller after her rotational inertia is smaller.

14. She did work to pull in her arms; that work went into increasing her angular kinetic energy. Choice b

Problem 15. A girl on a merry-go-round throws a large rock off tangentially in the same direction she is rotating. Does her angular velocity change? [15?] _________

a. Yes, she speeds up.
b. Yes, she slows down.
c. No, her angular velocity does not change.

15. She exerted a forward force on the rock, so the rock exerted a backward force on her. Since this was tangential, this force supplied a torque, which slowed her down. Choice b

Problem 16. A student sits on a rotating stool holding two 6.5 kg weights at arms' length, each 1.00 m from the axis of rotation. The moment of inertia of the student & stool (without weights) is a constant 3.00 $kg \cdot m^2$. Consider the weights to be point masses; neglect the mass of his arms. He is initially rotating at 6.0 radians per second. He then brings in his arms so that the weights are a mere 0.25 m from the axis of rotation. What is his new angular velocity? [16?] ________

a. Less than 19.7 rad/s
b. 19.7 – 20.7
c. 20.7 – 21.7
d. 21.7 – 22.7
e. 22.7 – 23.7
f. 23.7 – 24.7
g. More than 24.7 rad/s

16. $I_{initial}$ = 3 + 2×6.5×1^2 = 16 kg m^2. I_{final} = 3 + 2×6.5×0.25^2 = 3.8125 kg m^2.
Cons. of ang. mom.: $I_{initial}\omega_{initial} = I_{final}\omega_{final} \rightarrow \omega_{final}$ = (16)(6.0)/3.8125 = 25.18 rad/s

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Problem 17. A car goes around a turn of radius 7 m. The coefficient of static friction between the road and tires is 0.8. The maximum speed the car can have on this curve is [17?]____________ m/s without slipping off the road.

a. Less than 7.1 m/s
b. 7.1 – 7.2
c. 7.2 – 7.3
d. 7.3 – 7.4
e. 7.4 – 7.5
f. More than 7.5 m/s

Problem 18. If it moves at constant speed, the acceleration of the car is [18?] ___________ a.forward b. backward c. toward the center d. outward from the center e. zero.

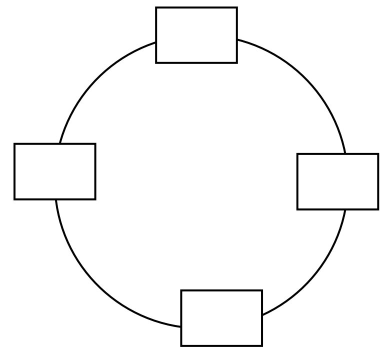
17. $F_{\max} = ma = m\frac{v_{\max}^2}{r} = \mu_k N = \mu_k mg$ $\quad v_{\max} = \sqrt{\mu_k r g}$ **= sqrt(0.8*7*g) = 7.408 m/s**

18. acceleration is in direction of the net force (friction), toward the center. Choice c

Problem 19. Two nonuniform cylinders of the same size and mass roll down an incline. Cylinder A has most of its weight concentrated at the rim, while cylinder B has most of its weight concentrated at the center. Which reaches the bottom of the incline first? [19?] ________ a. A b. B c. Both reach the bottom at the same time.

19. Cyl A will turn a larger fraction of its initial PE into rotational KE, and so will have a lesser fraction available for translation KE, and will travel slower. So B wins the race.

Problem 20. Joe (mass 50 kg) is on a Ferris Wheel of radius 6 m. If he is going at a constant speed of 4 m/s, his acceleration at the bottom of the circle is [20?] ______



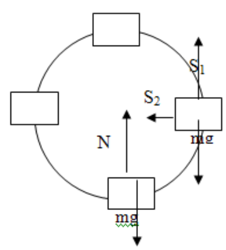
a. Less than 2.5 m/s
b. 2.5 – 2.6
c. 2.6 – 2.7
d. 2.7 – 2.8
e. 2.8 – 2.9
f. More than 2.9 m/s

Problem 21. The normal (seat) force on Joe at that point will be [21?] ____________

a. Less than 520 N
b. 520 – 550
c. 550 – 580
d. 580 – 610
e. 610 – 640
f. More than 640 N

Problem 22. If Joe is on the right side of the circle moving at constant speed, the direction of the total seat force on Joe is [22?]_________ a. up b. down c. right d. left e. up and right f. up and left g. down and right h. down and left i. zero

20. $a = \frac{v^2}{r} =$ **4^2/6 = 2.667 m/s^2**

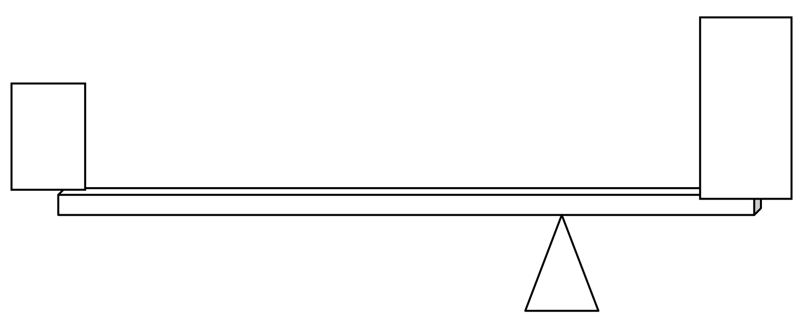


21. $N - mg = ma$

$N = m(g+a) =$ **50*(g+a) =623 N**

22. When at the position on the right side of the circle, The seat must push up to overcome the weight, because there is no acceleration in the vertical direction and push left to turn him in a circle. Choice f.

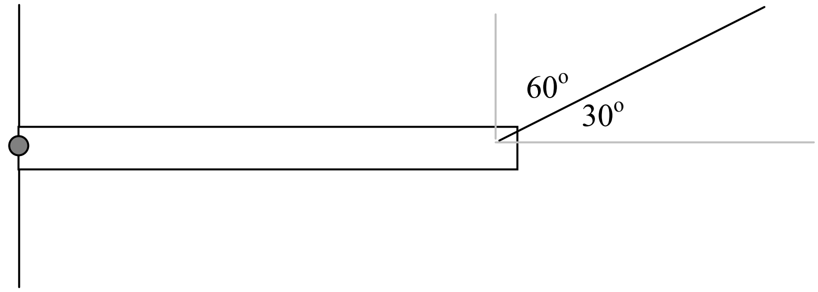
Problem 23. A 4-meter-long uniform plank weighing 200 N and two masses are balanced on a fulcrum that is 1 meter from the right end. The two masses are essentially at the ends of the plank. If the weight of mass on the *right* is 400 N, the weight of the mass on the left must be [23?] ________



a. Less than 56.5 N
b. 56.5 – 60
c. 60 – 63.5
d. 63.5 – 67
e. 67 – 70.5
f. More than 70.5 N

23. $\sum \tau = 0 \rightarrow w_1 \cdot 1m - w_b \cdot 1m - w_2 \cdot 3m = 0$; $w2 = \left(w_1 \cdot 1m - w_b \cdot 1m\right)/3m$

w2= (400*1 – 200*1)/3 = 66.67 N



Problem 24. A 3 meter long uniform beam of unknown weight is attached to a wall and supported by a cable that provides a force upward and to the right. It attaches at the right end of the beam. The force the cable supplies is 5500 N. This causes a torque of [24?]_________ Nm about the left end of the beam.

a. Less than 8330 N
b. 8330 – 8430
c. 8430 – 8530
d. 8530 – 8630
e. 8630 – 8730
f. More than 8730 N

Problem 25. The vertical force of the wall on the beam is [25?] ____ a. up b. down c. zero

Problem 26. The horizontal force of the wall is [26?] ______ a. left b. right c. zero

Problem 27. If we calculate torques about the right end, the magnitude of the torque due to the wall's force is [27?] ____________ a. greater than b. less than c. the same as the magnitude of the torque due to the weight of the beam.

24. $\tau = rF_{\perp}$ = 3m*5500 N sin(30) = 8250 Nm

25. Take the torque about the right end for example. Since the weight of the beam causes a CCW torque, the wall must provide a CW torque, or vertical force : up. Choice a

26. The tension has a right horizontal component, so for the forces to sum to zero, the wall pulls the board to the left. Choice a

27. Since the torques must sum to zero about any point (if in equilibrium), the two must be equal and opposite. Choice c

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Problem 28. A large cylinder is initially spinning at 30 rad/s. After it rotates 20 full *revolutions* while slowing down steadily, it is at rest. The angular acceleration magnitude was [28?] __________

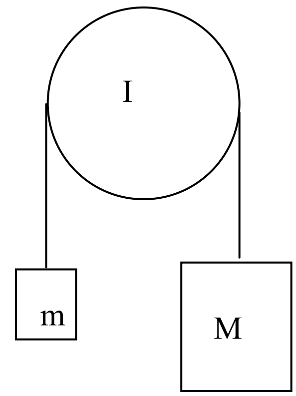
a. Less than 3.35 rad/s^2
b. 3.35 – 3.45
c. 3.45 – 3.55
d. 3.55 – 3.65
e. 3.65 – 3.75
f. 3.75 – 3.85
g. More than 3.85 rad/s^2

28. $\omega^2 = \omega_o^2 + 2\alpha\Delta\theta$

$\alpha = \dfrac{\omega^2 - \omega_o^2}{2\Delta\theta}$ **= – 30^2/2/(20*2*pi) = - 3.58**

Problem 29. Two masses (m = 1 kg and M = 5 kg) on a string go over a large pulley with moment of inertia I = 2 kg·m^2 and radius R = 0.25 m. The string does not slip on the pulley as the large mass falls, so the pulley & masses accelerate together. The tension [29?] _______

a. is the same for both
b. is greatest above M
c. is greatest above m



Problem 30. The acceleration of the masses is [30?] __________
(Hint: you need an equation for each object)

a. Less than 0.87 m/s^2
b. 0.87 – 0.97
c. 0.97 – 1.07
d. 1.07 – 1.17
e. 1.17 – 1.27
f. 1.27 – 1.37
g. More than 1.37 m/s^2

29. Looking at the forces on the pulley: if the tension from M (T_M) were not larger than the tension from m (T_m), the pulley would not start rotating clockwise (as it obviously must.) So there must be a net torque. Choice b

30. Equation 1, forces on m: $\Sigma F=ma \rightarrow T_m - mg = ma \rightarrow T_m = m(g+a)$
Equation 2, forces on M: $\Sigma F=Ma \rightarrow Mg - T_M = Ma \rightarrow T_M = M(g-a)$
Equation 3, torques on pulley: $\Sigma\tau=I\alpha \rightarrow T_M R - T_m R = I\alpha \rightarrow T_M R - T_m R = I\,(a/R)$

Plug in T_m and T_M, solve for a: $a = \dfrac{(M-m)g}{m+M+I/R^2}$ **= 1.032 m/s^2**