Show ALL work. All work must be done on these test sheets. There is no way for you to receive credit for work that is not explicitly written down. I also recommend showing work for the multiple choice questions as partial credit may be possible on a few of them.

Credit for problems will be awarded based upon "our standard problem solving approach" which emphasizes starting from fundamentals and following standard problem solving procedures. Problem solving style is important here. You do not receive credit for any pictures I have supplied – draw your own.

Moments of Inertia of Rolling Objects about their center-of-mass and symmetry axis:

$I_{solid\ ball} = 2/5\ MR^2$ $\quad I_{disk} = 1/2\ MR^2$ $\quad I_{hoop} = MR^2$

Moments of Inertia of Objects spun about an edge

$I_{rod\ about\ an\ end} = 1/3\ ML^2$ $\quad I_{rectangle\ about\ an\ axis\ along\ edge} = 1/3\ ML^2$

100 mph = 44.7 m/s, 1 inch = 2.54 cm, $\sin 30^o = 0.5$, $\sin 45^o = 0.707$, $\sin 60^o = 0.866$
G=6.67e-11 Nm^2/kg^2, M_{Earth}=5.96e+24 kg, M_{moon}=7.35e+22 kg, M_{Sun}=2.0e+30 kg
Radius of Moon=1740 km, Radius of Sun=6.96e+5 km, Radius of Earth=6370 km
1 eV = 1.602e-19 J, 1 hp = 746 W, c=3.00e+8 m/s

4430

True/False

T 1. A force which is always perpendicular to the velocity of a particle does no work on the particle.

F 2. A kiloWatt-hour is a unit of power

T 3. Internal forces do not affect the motion of the center-of-mass of the system.

T 4. The momentum of a system can be conserved even if the mechanical energy is not.

F 5. In a perfectly inelastic collision all of the kinetic energy of the particles is lost.

T 6. All parts of a rotating wheel have the same angular velocity

T 7. All parts of a rotating wheel have the same angular acceleration.

T 8. The moment of inertia of an object depends upon the location of the rotation axis.

F 9. The moment of inertia of a body depends on the angular velocity of the body.

9×1 = 9
17×3 = 51
10×4 = 40
100

Multiple Choice

1. A bomb hanging from a string explodes into pieces of different shapes and sizes. After the explosion:
   a) the vector momentum of each piece is identical
   b) the total momentum is increased
   c) the momentum of all the pieces, exhaust, and smoke adds up to zero
   d) not enough information to comment
   e) none of these

2. If an *inelastic* collision takes place between two objects and there are no external forces, then:
   A) momentum and kinetic energy are conserved
   B) momentum is conserved, but kinetic energy is not.
   C) kinetic energy is conserved, but momentum is not.
   D) neither momentum nor kinetic energy is conserved.
   E) it is not possible to determine if either momentum or kinetic energy are conserved without knowing more of the details of the collision

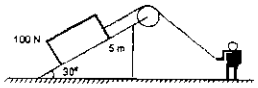
3. For the potential energy function $U(x,y) = 3xy + 5x^2 + 6y^3$, the corresponding force is
   A) $5x^2\,\mathbf{i} + 6y^3\,\mathbf{j}$
   B) $3xy\,\mathbf{i} + 3xy\,\mathbf{j}$
   C) $(-3y-10x)\,\mathbf{i} + (-3x-18y^2)\,\mathbf{j}$
   D) $(3y+10x)\,\mathbf{i} + (-3x-18y^2)\,\mathbf{j}$

$F_x = -\frac{dU}{dx} = -3y - 10x$

$F_y = -\frac{dU}{dx} = -3x - 18y^2$

4. An object moves in a circle at constant speed. The work done by the centripetal force is zero because
   A) the displacement for each revolution is zero
   B) the average force for each revolution is zero
   C) there is no friction
   D) the magnitude of the acceleration is zero
   E) the centripetal force is perpendicular to the velocity

5. A man pulls a 100-N crate up a frictionless 30° slope 5 m high as shown. Assuming that the crate moves at constant speed, the work done by the man is:



mgh
100(5)

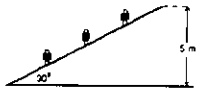
   A) −500 J
   B) −250 J
   C) 0
   D) 250 J
   E) 500 J

6. When a certain rubber band is stretched a distance x, it exerts a restoring force $F = ax + bx^2$, where a and b are constants. The work done in stretching this rubber band from $x = 0$ to $x = L$ is:
   A) $aL^2 + bLx^2$
   B) $aL + 2bL^2$
   C) $a + 2bL$
   D) bL
   E) $aL^2/2 + bL^3/3$

$\int_0^L F\,dx = \int_0^L (ax + bx^2)\,dx$

$\frac{1}{2}aL^2 + \frac{1}{3}bL^3$

7. An escalator is used to move 20 people (60 kg each) per minute from the first floor of a department store to the second floor, 5 m above. The power required is approximately.

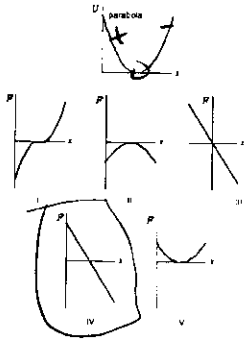


   A) 100 W
   B) 200 W
   C) 1000 W
   D) 2000 W
   E) 60,000 W

$\frac{\text{Energy}}{\text{time}} = \frac{Mgh}{\text{time}} = \frac{20(60)(9.8)5}{60}$

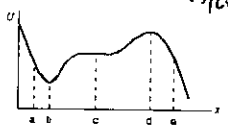
980

8. The first graph shows the potential energy $U(x)$ for a particle moving on the x axis. Which of the following five graphs correctly gives the force F exerted on the particle?



   A) I
   B) II
   C) III
   D) IV
   E) V

9. The diagram shows a plot of the potential energy as a function of x for a particle moving along the x axis. The points of stable equilibrium are: is/a-e



   A) only a
   B) only b
   C) only c
   D) only d
   E) b and d

55

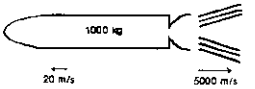
10. Which one of the following statements is true?
A) the center of mass of an object must lie within the object
B) all the mass of an object is actually concentrated at its center of mass
C) the center of mass of an object cannot move if there is zero net force on the object
D) the center of mass of a cylinder must lie on its axis
E) none of the above

No acceleration does not imply v=0

11. The center of mass of a system of particles has a constant velocity if
A) the forces exerted by the particles on each other sum to zero
B) the external forces acting on particles of the system sum to zero
C) the velocity of the center of mass is initially zero
D) the particles are distributed symmetrically around the center of mass
E) the center of mass is at the geometric center of the system

12. A man sits in the back of a canoe in still water. He then moves to the front of the canoe and sits there. Afterwards the canoe
A) is forward of its original position and moving forward
B) is forward of its original position and moving backward
C) is rearward of its original position and moving forward
D) is rearward of its original position and moving backward
E) is rearward of its original position and not moving

13. A 1000-kg space probe is motionless in space. To start moving, its main engine is fired for 5 s during which time it ejects exhaust gases at 5000 m/s. At the end of this process it is moving at 20 m/s. The approximate mass of the ejected gas is



A) 0.8 kg
B) 4 kg
C) 5 kg
D) 20 kg
E) 25 kg

$0 = MV + mv$

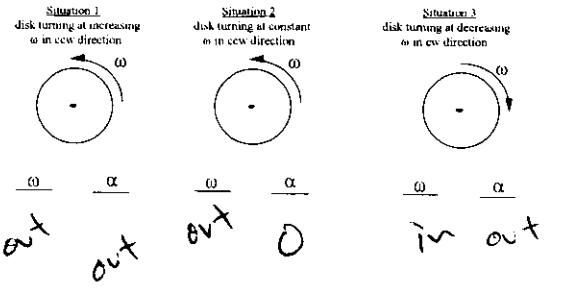
$0 = 1000(-20) + m(5000)$

$m = 4$ kg

51

14. One revolution is the same as
A) 1 rad
B) 57 rad
C) π/2 rad
D) π rad
E) 2π rad

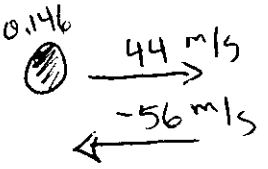
15. The figures below show a disk spinning about an axis through its center. For each of the three situations described, indicate the direction of the angular velocity ω and the angular acceleration α [Note: in=into-the-paper, out=out-of-the-paper, 0=zero].



16. A ball is dropped from a height h and hits the ground with speed v. To have the ball hit the ground at a speed of 2v it should be dropped from a height
A) h/2
B) h
C) 2h
D) 3h
E) 4h

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

17. A pitcher throws a 44 m/s fastball. The bat reverses the ball's velocity and it leaves the bat at 56 m/s. What was the average force on the 0.145 kg baseball during the contact time of 15 ms?
A) 0.43 kN
B) 0.54 kN
C) 0.97 kN
D) 1.45 kN

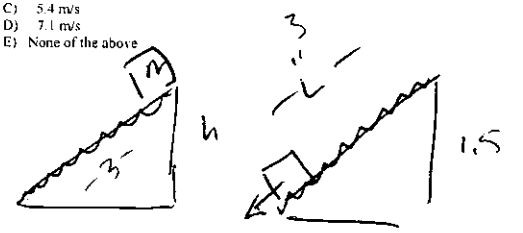


$\frac{\Delta p}{\Delta t} = \frac{0.146(-56-44)}{0.015}$

$= 973$ Newtons

53

Problem 1. A block of mass 5 kg slides down an inclined plane of length 3 m that makes an angle of 30° with the horizontal. The coefficient of friction between the block and the plane is 0.2. The block is released from rest at the top of the incline, and at the bottom has a speed
A) 2.5 m/s
B) 3.3 m/s
C) 5.4 m/s
D) 7.1 m/s
E) None of the above



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

$mgh - \mu mg\cos\theta\, L = \frac{1}{2}mv^2$

$9.8(1.5) - 0.2\, 9.8 \cos 30^\circ\, 3 = \frac{1}{2}v^2$

$14.7 - 5.09$

$v = 4.4$ m/s

55^{30}

SP211.1126
3 Nov 2009
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Problem 2. A proton hits a stationary alpha particle causing the alpha particle to recoil at 2.4E6 m/s at 20° with respect to the initial proton velocity. Assuming the mass of the alpha to be 4 times the proton mass, the deflected proton moves 8E6 m/s at what angle with respect to its initial velocity?

x-comp of momentum

$$mv_0 = mv\cos\theta + MV\cos 20^\circ$$

y-comp of momentum

$$0 = MV\sin 20^\circ - mv\sin\theta$$

$$0 = 4(2.4+6)\sin 20^\circ - 1(8+6)\sin\theta$$

$$\theta = 24^\circ$$

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Problem 3. Tarzan/Jane Problem

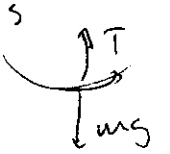
Tarzan, who weighs 688 N, swings from a cliff at the end of a convenient vine that is 18 m long. From the top of the cliff to the bottom of the swing, he descends by 3.2 m. The vine will break if the force on it exceeds 950 N.

Find the tension in the vine – does it break?

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

$$9.8(3.2) = \frac{1}{2}v^2$$

$$v = 7.92 \text{ m/s}$$



$$m\frac{v^2}{r} = T - mg$$

$$\frac{688}{9.8}\frac{(7.92)^2}{18} = T - 688$$

$$T = 932 \text{ Newtons}$$

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3 Nov 2009
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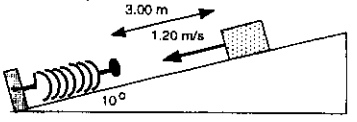
Problem 4. A large block of ice, 13 kg, slides down a ramp towards a spring at the bottom as shown below. The ramp is frictionless and the spring has a spring constant of k = 490 N/m. At the instant that the block is 3 m up the ramp from the top of the spring, the block of ice has a speed of 1.2 m/s.

Find the distance that the spring is compressed before the ice first comes to rest.



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

$$13(9.8)\ 3\sin 10^\circ + \frac{1}{2}13(1.2)^2 = \frac{1}{2}490x^2$$

$$x = 0.56 \text{ m}$$

Actually we should have set $h = (L+x)\sin\theta$ which would have resulted in

$$x = 0.60 \text{ m}$$

$$11^{00}$$

$$\frac{15^{30}}{3} = 15.5$$

46.5 min