

## PHYS 2211 TRADITIONAL READING DAY STUDY SESSION WORKSHEET

## PROBLEMS

## KINEMATICS &amp; DYNAMICS

1. A major league baseball player hits a fly ball. The ball is hit when it is  $1.1\text{ m}$  above the ground, and it leaves the bat with a velocity of  $41\text{ m/s}$  at an angle of  $72^\circ$  above the horizontal.
  - (a) How far from home plate does the ball strike the ground?
  - (b) What is the maximum height attained by the ball?
  - (c) Assume now that the ball is caught at the same height as it was hit:
    - i. How far from home plate does the center fielder need to stand?
    - ii. How much time does he have to position himself?
2. A  $5\text{ kg}$  mass object moves under the influence of a force  $\mathbf{F} = (4t^2\hat{\mathbf{i}} - 3t\hat{\mathbf{j}})\text{ N}$ , where  $t$  is the time in seconds. It starts at rest at the origin at  $t = 0$ . Find its position and velocity at any later time  $t$ .
3. Mass  $M_A = 4\text{ kg}$  rests on top of mass  $M_B = 5\text{ kg}$  that rests on a frictionless table. The coefficient of friction between the two blocks is such that the blocks just start to slip when the horizontal force  $F$  applied to the lower block is  $27\text{ N}$ . Suppose that now a horizontal force is applied to the upper block. What is its maximum value of that force for the blocks to slide without slipping relative to each other?
4. A block with mass  $M_1$  rests on a frictionless table. It is connected by a massless string to a block with mass  $M_2$ , which hangs below the edge of the table. The system is released from rest at time  $t = 0$ . Find the distance block  $M_1$  moves in time  $t$ . You may assume that the string passes over a massless, frictionless pulley at the edge of the table to assist your calculations.

## ROTATIONAL MOTION

5. A jet engine, starting from rest, is accelerated at a rate of  $5\text{ rad/s}^2$ . After 15 seconds, what is the angular velocity of the engine? What is the total angular displacement over this period of time?
6. A particle starts from rest at the top of a fixed frictionless sphere of radius  $R$  and slides on the sphere under the force of gravity. How far below its starting point does it get before flying off the sphere?
7. A particle attached to a string of length  $2\text{ m}$  is given an initial velocity of  $6\text{ m/s}$ . The string is attached to a peg and, as the particle rotates about the peg, the string winds around the peg. What length of string has wound around the peg when the velocity of the particle is  $20\text{ m/s}$ ?
8. A uniform stick of mass  $M$  and length  $l$  is suspended horizontally with end  $B$  on the edge of a table. The other end  $A$  is held by hand. Point  $A$  is suddenly released. At the instant after release:
  - (a) What is the torque around  $B$ ?

- (b) What is the angular acceleration around  $B$ ?
- (c) What is the vertical acceleration of the center of mass?
- (d) What is the vertical force at  $B$ ?

MOMENTUM & IMPULSE

9. An object at rest explodes into three pieces. Two, each of the same mass, fly off in opposite directions with velocity  $50 \text{ m/s}$  and  $100 \text{ m/s}$  respectively. A third piece is also formed in the explosion, and has twice the mass of the first two pieces. What is the magnitude and direction of its velocity?
10. Water shoots out of a fire hydrant having nozzle diameter  $D$ , with nozzle speed  $V_0$ . What is the reaction force on the hydrant?
11. A car with mass  $m = 1200 \text{ kg}$  is traveling due south at  $36 \text{ m/s}$  when it is struck by a semi-truck with mass  $M = 16000 \text{ kg}$  moving towards the east at  $18 \text{ m/s}$ . Assuming the wreck stays in one piece, what is its final speed and direction?
12.  $N$  men, each with mass  $m$ , stand on a railway flatcar of mass  $M$ . They jump off one end of the flatcar with velocity  $u$  relative to the car. The car rolls in the opposite direction without friction. Assuming that  $m \ll M$ ,
  - (a) What is the final velocity of the flatcar if all the men jump off at once?
  - (b) What is the final velocity of the flatcar if the men jump off one by one? You may express your answer as a sum of terms.
  - (c) Which method results in a higher final velocity?

WORK & ENERGY

13. A block of mass  $m$  starts from rest and slides along a frictionless loop-the-loop. What should be its initial starting height such that it pushes against the top of the loop with a force equal to its weight?
14. A student is pulling on a rope to drag his backpack to school across the ice. He pulls with a force of  $22.9 \text{ N}$  at an angle of  $35^\circ$  to the horizontal to drag his backpack a horizontal distance of  $129 \text{ m}$ . Determine the work done on the backpack.
15. Find the escape speed of a rocket from the moon. Ignore the rotational motion of the moon. The mass of the moon is  $M = 7.36 \times 10^{22} \text{ kg}$ . The radius of the moon is  $R = 1.74 \times 10^6 \text{ m}$ . The universal gravitational constant is  $G = 6.7 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ .
16. A  $55 \text{ kg}$  athlete leaps into the air from a crouching position. Her center of mass rises  $60 \text{ cm}$  as her feet leave the ground and then it continues another  $80 \text{ cm}$  to the top of the leap. What is the average power she develops, assuming the force on the ground is constant?

ANSWERS

KINEMATICS & DYNAMICS

1. (a) 101 *m*. (b) 78.7 *m*. (c)i: 101 *m* ii: 8.0 seconds from the time the ball is hit.
2.  $\vec{x} = (\frac{1}{15}t^4\hat{i} - \frac{1}{10}t^3\hat{j})$ ;  $\vec{v} = (\frac{4}{15}t^3\hat{i} - \frac{3}{10}t^2\hat{j})$
3. 12.0 *N*
4.  $\frac{1}{2} \left( \frac{M_2}{M_1+M_2} \right) gt^2$

ROTATIONAL MOTION

5.  $W = 75 \text{ rad/sec}$ ;  $\theta = 563 \text{ rads}$ .
6.  $\cos^{-1}(2/3)$
7. 0.6 *m*
8. (a)  $\frac{lmg}{2}$  (b)  $\frac{3g}{2l}$  (c)  $\frac{3g}{4}$  (d)  $\frac{1}{4}mg$

MOMENTUM & IMPULSE

9. 25 *m/sec* in the direction of the slower piece.
10.  $\frac{\pi D^2 V^2}{4}$
11. magnitude = 16.9 *m/s*; angle = 8.5 degrees south of east
12. (a)  $\frac{Nmu}{M}$  (b)  $\frac{Nmu}{NM + m \sum_{i=1}^N (i-1)}$  (c) All men jump at once yields a higher velocity.

WORK & ENERGY

13. Drop from a height of *R* above the top of the loop or 3*R* from the bottom.
14. 2.42 *kJ*
15. 2.38*km/s*
16. 1.42 *kW*