Physics 221

Practice Exercises and Problems, Form: A

Name: ______________________

Date: ______________________

Section 1. Calculate the magnitude of a vector.

1. At some instant, you are traveling in your car and your velocity is $< 30, 0, 20 >$ m/s. s What is your speed and what is your direction (unit vector)?

Section 2. Determine vector components

2. While traveling around the loop on the Super-Duper-Looper at an amusement park ride, the magnitude of the net force on you when you are at an angle of 125 ° (with respect to the +x axis) is 600 N. Write the net force on you as a vector.

Section 3. Add vectors

3. The initial position of a mouse in a maze is $< 0.2, 0, 0.6 >$ m. Its displacement after 1 minute is $< -0.5, 0, 0.3 >$. What is its new position?

Section 4. Subtract vectors

4. A 57-gram tennis ball with a velocity of $< 40, -10, 0 >$ m/s rebounds from a wall with a velocity of $< -35, -9, 0 >$ m/s. What is the change in the momentum of the ball?

Section 5. Apply the definition of velocity

5. An object hanging from a spring travels from its lowest point 0.1 m below its equilibrium position to its highest point 0.1m above its equilibrium position in half a period. If its period is 2.4 s, what is it average velocity during this interval? Remember to express this as a vector.
6. For a small enough time interval, you can approximate the velocity of an object as being constant (even if there is a net force on the object). Suppose you are analyzing video of a school of fish and find a certain fish to be at the position $< 0.160, -0.080, 0 >$ m moving with a velocity $< -0.500, 0.200, 0 >$ m/s at some instant t.. Where will the fish be 0.0200 s later?

Section 6. Apply the momentum principle to calculate final momentum.

7. At some instant t, the net force on you as you ride the Ferris Thrill Ride is $< -1352, -439, 0 >$ N and your momentum is $< -349, 1076, 0 >$ kg m/s. What will be your momentum 0.05 s later?

Section 7. Apply the momentum principle to calculate an unknown force

8. To investigate the effect of air on the motion of a 0.01-kg styrofoam ball, you analyze the motion of the ball in the laboratory. Using position data collected with video analysis, you determine that at $t = 0.50$ s, the momentum of the ball is $< 0.00536, -0.01705, 0 >$ kg m/s. At $t = 0.51$ s, the momentum of the ball is $< 0.00517, -0.0174, 0 >$ kg m/s. What is the force of air on the ball during this time interval?

Section 8. Calculate gravitational force

9. A binary star system consists of two stars named $\alpha-$Warde and $\beta-$Warde. $\alpha-$Warde has a mass of 2×10^{30} kg and $\beta-$Warde has a mass of 10×10^{30} kg. At some instant, $\alpha-$Warde is at $< -1.23594e + 11, -3.46579e + 11, 0 >$ and $\beta-$Warde is at $< -9.52812e + 10, 6.93159e + 10, 0 >$. What is the gravitational force on each star? (Note: two answers expected for this answer because the gravitational forces are not equal.)

Section 9. Apply the momentum principle if $\vec{p}(t)$ is known

10. In the lab, you measure the position as a function of time of a 0.2-kg object oscillating on a spring, fit a curve to the data, and find that it satisfies the equation:

$$x(t) = 0.05cos(3t) \text{ m}$$

What is the momentum of the object as a function of time and what is the net force on the object as a function of time?

Section 10. Momentum principle applied to circular motion

11. A test tube containing a certain fluid sample is placed into a centrifuge and spun in a horizontal circle at a rate of 30 revolutions per second in a radius of 0.10 m. If the density of the fluid is 1.2 grams/ml and the test tube contains 5 ml of fluid. What is the magnitude of the net force on the sample and what is the direction of the net force at any instant of time?

12. Consider the plane of the centrifuge to be the x-z plane. The y-axis is vertical and points toward upward, away from Earth. If at some instant, the sample is at a position given by the unit vector $< -0.906, 0, -0.423 >$, what is the force of the test tube on the sample?

Section 11. Circular orbit

13. If you want a satellite to orbit Earth in a circle with a period of 24 hours, what must be the radius of its orbit? What would be its altitude? This orbit is called a geosynchronous orbit.

Section 12. Force of a spring on an object

14. If you hang a 0.1-kg object in equilibrium from a spring with stiffness 15 N/m, how much will the spring stretch from its unstretched length?

15. Suppose that a 500-kg car has 4 springs, each connected to an axle near a wheel. If the car is in equilibrium and each spring is compressed 0.05 m, what is the stiffness of each spring?

16. While playing around in lab, you place a 0.5-kg object on the end of a 10-N/m spring and swing it above your head in a nearly horizontal circle of radius 0.5 m and a period 2.0 s. Approximately how much will the spring stretch?

Section 13. Calculate work done by a force

17. For exercise, you stretch a stiff spring of stiffness 100 N/m by pulling on the spring. One side of the spring is attached to the wall. Presently, you are barely able to stretch it 0.4 m. By the end of the year, you hope to stretch it 0.8 m. How much additional work must you do on the spring to stretch it from s=0.4 m to s=0.8 m?

18. In computer game, Dennis the Menace attaches small boosters to a poor frog. As the frog moves from $< -1, 0, 2 >$ m to $< 4, -5, 3 >$ m. There are two thrusters simultaneously firing with forces $< -10, 0, 0 >$ N and $< 0, 10, 0 >$ N respectively. What is the total work done on the frog?

19. Did the frog in the previous question speed up or slow down?

20. Box 1 slides down a ramp of length 5 m and height 4 m. Box 2 is dropped from a height of 4 m and falls straight down. What is the work done by gravity on each box if each box has a mass of 10 kg.

Section 14. Energy principle

21. A satellite's circular orbit above the earth is increased from an altitude of 400 km to an altitude of 600 km. How much total work must be done on the satellite-Earth system during this process? Assume that the only changes in the energy of the system is kinetic and gravitational potential energy. Assume that the mass of the satellite remains constant and is 250 kg.

22. How much total work must be done on an electron traveling at a speed of $0.95c$ to accelerate it to $0.99c$? The mass of an electron is 9e-31 kg.

23. Suppose that a certain kayak of mass 120 kg (including the kayaker) on a smooth lake slows down from a speed of 20 m/s to 10 m/s during a displacement of magnitude 20.0 m. What is the work done by water on the kayak?

24. Assuming the net force on the kayak is constant, what is the force of the water on the kayak in the previous question?

25. The escape speed from a planet depends on its mass and radius. This speed is the minimum speed so that a spaceship with this kinetic energy will be able to travel infinitely far away (without firing its thrusters at all). If the escape speed for a body is equal to the speed of light, then even light cannot escape it and we call the body a black hole. The radius, in this case, is called the Schwartzchild radius. What is the Schwartzchild radius for a star with 10 times the mass of Sun (2e30 kg)?

26. In one type of fusion reaction, 6 hydrogen atoms (each one with 1 proton and no neutrons) eventually form 1 atom of helium (2 neutrons and 2 protons) and two atoms of hydrogen. This is called the proton-proton cycle. The mass of hydrogen is 1.007825 MeV/c^2. The mass of helium is 4.002603 MeV/c^2. What is the change in rest energy, in units of MeV, during this reaction?

27. If a roller coaster at the top of a hill is just barely moving and drops 25 m to the bottom of a hill, how fast will it be moving if the only changes in the energy of the roller coaster–Earth system are its kinetic energy and gravitational potential energy?

Answer Key for Exam A

Section 1. Calculate the magnitude of a vector.

1. At some instant, you are traveling in your car and your velocity is $<30, 0, 20>$ m/s. s What is your speed and what is your direction (unit vector)?

   $|\vec{v}| = 36$ m/s
   $\hat{v} =< 0.833, 0, 0.556 >$

Section 2. Determine vector components

2. While traveling around the loop on the Super-Duper-Looper at an amusement park ride, the magnitude of the net force on you when you are at an angle of 125 ° (with respect to the +x axis) is 600 N. Write the net force on you as a vector.

   $\vec{F}_{net} =< 344, -492, 0 >$ N

Section 3. Add vectors

3. The initial position of a mouse in a maze is $< 0.2, 0, 0.6 >$ m. Its displacement after 1 minute is $< -0.5, 0, 0.3 >$. What is its new position?

   $\vec{r}_f =< -0.3, 0, 0.9 >$ m

Section 4. Subtract vectors

4. A 57-gram tennis ball with a velocity of $< 40, -10, 0 >$ m/s rebounds from a wall with a velocity of $< -35, -9, 0 >$ m/s. What is the change in the momentum of the ball?

   $\Delta\vec{p} = m(\Delta\vec{v}) =< -4.3, 0.057, 0 >$ kg m/s

Section 5. Apply the definition of velocity

5. An object hanging from a spring travels from its lowest point 0.1 m below its equilibrium position to its highest point 0.1m above its equilibrium position in half a period. If its period is 2.4 s, what is it average velocity during this interval? Remember to express this as a vector.

   $\vec{v}_{ave} =< 0, 0.167, 0 >$ m/s

6. For a small enough time interval, you can approximate the velocity of an object as being constant (even if there is a net force on the object). Suppose you are analyzing video of a school of fish and find a certain fish to be at the position $< 0.160, -0.080, 0 >$ m moving with a velocity $< -0.500, 0.200, 0 >$ m/s at some instant t.. Where will the fish be 0.0200 s later?

   $\vec{r}_f =< 0.150, -0.076, 0 >$ m

Section 6. Apply the momentum principle to calculate final momentum.

7. At some instant t, the net force on you as you ride the Ferris Thrill Ride is $< -1352, -439, 0 >$ N and your momentum is $< -349, 1076, 0 >$ kg m/s. What will be your momentum 0.05 s later?

   $\vec{p}_f =< -417, 1054, 0 >$ kg m/s

Section 7. Apply the momentum principle to calculate an unknown force

8. To investigate the effect of air on the motion of a 0.01-kg styrofoam ball, you analyze the motion of the ball in the laboratory. Using position data collected with video analysis, you determine that at $t = 0.50$ s, the momentum of the ball is $< 0.00536, -0.01705, 0 >$ kg m/s. At $t = 0.51$ s, the momentum of the ball is $< 0.00517, -0.0174, 0 >$ kg m/s. What is the force of air on the ball during this time interval?

   $\vec{F}_{air} =< -0.019, 0.063, 0 >$ N

Section 8. Calculate gravitational force

9. A binary star system consists of two stars named $\alpha-$Warde and $\beta-$Warde. $\alpha-$Warde has a mass of 2×10^{30} kg and $\beta-$Warde has a mass of 10×10^{30} kg. At some instant, $\alpha-$Warde is at $< -1.23594e + 11, -3.46579e + 11, 0 >$ and $\beta-$Warde is at $< -9.52812e + 10, 6.93159e + 10, 0 >$. What is the gravitational force on each star? (Note: two answers expected for this answer because the gravitational forces are not equal.)

   $\vec{F}_{\beta on \alpha} =< 5.3 \times 10^{26}, 7.695 \times 10^{27}, 0 >$ N
   $\vec{F}_{\alpha on \beta} =< 5.3 \times 10^{26}, -7.63 \times 10^{27}, 0 >$ N

Section 9. Apply the momentum principle if $\vec{p}(t)$ is known

10. In the lab, you measure the position as a function of time of a 0.2-kg object oscillating on a spring, fit a curve to the data, and find that it satisfies the equation:

$$x(t) = 0.05cos(3t) \text{ m}$$

   What is the momentum of the object as a function of time and what is the net force on the object as a function of time?

   $p_x(t) = -0.03sin(3t)$ kg m/s
   $F_{net_x}(t) = -0.09cos(3t)$ N

Section 10. Momentum principle applied to circular motion

11. A test tube containing a certain fluid sample is placed into a centrifuge and spun in a horizontal circle at a rate of 30 revolutions per second in a radius of 0.10 m. If the density of the fluid is 1.2 grams/ml and the test tube contains 5 ml of fluid. What is the magnitude of the net force on the sample and what is the direction of the net force at any instant of time?

   21.3 N
   it is always directed toward the center of the circle.

12. Consider the plane of the centrifuge to be the x-z plane. The y-axis is vertical and points toward upward, away from Earth. If at some instant, the sample is at a position given by the unit vector $< -0.906, 0, -0.423 >$, what is the force of the test tube on the sample?

$\vec{F}_{tube} =< 19.3, 0.0588, 0.901 >$ N

Section 11. Circular orbit

13. If you want a satellite to orbit Earth in a circle with a period of 24 hours, what must be the radius of its orbit? What would be its altitude? This orbit is called a geosynchronous orbit.

$r = 4.2e7$ m $altitude = 3.6e7$ m

Section 12. Force of a spring on an object

14. If you hang a 0.1-kg object in equilibrium from a spring with stiffness 15 N/m, how much will the spring stretch from its unstretched length?

$s = 0.065$ m

15. Suppose that a 500-kg car has 4 springs, each connected to an axle near a wheel. If the car is in equilibrium and each spring is compressed 0.05 m, what is the stiffness of each spring?

k=2.45e4 N/m

16. While playing around in lab, you place a 0.5-kg object on the end of a 10-N/m spring and swing it above your head in a nearly horizontal circle of radius 0.5 m and a period 2.0 s. Approximately how much will the spring stretch?

$s = 0.25$ m

Section 13. Calculate work done by a force

17. For exercise, you stretch a stiff spring of stiffness 100 N/m by pulling on the spring. One side of the spring is attached to the wall. Presently, you are barely able to stretch it 0.4 m. By the end of the year, you hope to stretch it 0.8 m. How much additional work must you do on the spring to stretch it from s=0.4 m to s=0.8 m?

W=24 J

18. In computer game, Dennis the Menace attaches small boosters to a poor frog. As the frog moves from $< -1, 0, 2 >$ m to $< 4, -5, 3 >$ m. There are two thrusters simultaneously firing with forces $< -10, 0, 0 >$ N and $< 0, 10, 0 >$ N respectively. What is the total work done on the frog?

$W = -100$ J

19. Did the frog in the previous question speed up or slow down?

It slowed down because the total work done on the frog is negative which will decrease the kinetic energy of the frog.

20. Box 1 slides down a ramp of length 5 m and height 4 m. Box 2 is dropped from a height of 4 m and falls straight down. What is the work done by gravity on each box if each box has a mass of 10 kg.

    W=392 J

Section 14. Energy principle

21. A satellite's circular orbit above the earth is increased from an altitude of 400 km to an altitude of 600 km. How much total work must be done on the satellite-Earth system during this process? Assume that the only changes in the energy of the system is kinetic and gravitational potential energy. Assume that the mass of the satellite remains constant and is 250 kg.

    $W = 2.1 \times 10^8$ J

22. How much total work must be done on an electron traveling at a speed of $0.95c$ to accelerate it to $0.99c$? The mass of an electron is 9e-31 kg.

    W=3.15e-13 J

23. Suppose that a certain kayak of mass 120 kg (including the kayaker) on a smooth lake slows down from a speed of 20 m/s to 10 m/s during a displacement of magnitude 20.0 m. What is the work done by water on the kayak?

    $W = -1.8 \times 10^4$ J

24. Assuming the net force on the kayak is constant, what is the force of the water on the kayak in the previous question?

    $\vec{F}_{kayak} =< -900, 1180, 0 >$ N

25. The escape speed from a planet depends on its mass and radius. This speed is the minimum speed so that a spaceship with this kinetic energy will be able to travel infinitely far away (without firing its thrusters at all). If the escape speed for a body is equal to the speed of light, then even light cannot escape it and we call the body a black hole. The radius, in this case, is called the Schwartzchild radius. What is the Schwartzchild radius for a star with 10 times the mass of Sun (2e30 kg)?

    30 km

26. In one type of fusion reaction, 6 hydrogen atoms (each one with 1 proton and no neutrons) eventually form 1 atom of helium (2 neutrons and 2 protons) and two atoms of hydrogen. This is called the proton-proton cycle. The mass of hydrogen is 1.007825 MeV/c^2. The mass of helium is 4.002603 MeV/c^2. What is the change in rest energy, in units of MeV, during this reaction?

    ΔE=-2.87e-2 MeV

27. If a roller coaster at the top of a hill is just barely moving and drops 25 m to the bottom of a hill, how fast will it be moving if the only changes in the energy of the roller coaster–Earth system are its kinetic energy and gravitational potential energy?

    $v_f = 22$ m/s