Answer Key for Final Exam for Algebra-Based Physics-1: Mechanics (PHYS135A-01)

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December 13th, 2017

1 Conceptual Questions

1.1 Kinematics and Angular Kinematics

1. An object accelerates with constant acceleration. The displacement versus time curve is quadratic. The velocity versus time plot should be ______ and the acceleration versus time plot should be ______.

   - quadratic, linear
   - **linear, flat**
   - flat, linear
   - linear, quadratic

2. An object experiences constant *angular* acceleration. The angular velocity is a ______ function of time, and the net external torque is ______.

   - **linear, constant**
   - linear, zero
   - quadratic, constant
   - quadratic, zero

3. A battleship fires simultaneously two shells at enemy ships (Fig. 1). If the shells follow the parabolic trajectories shown, which ship gets hit first?

   - A
   - Both at the same time
   - **B**

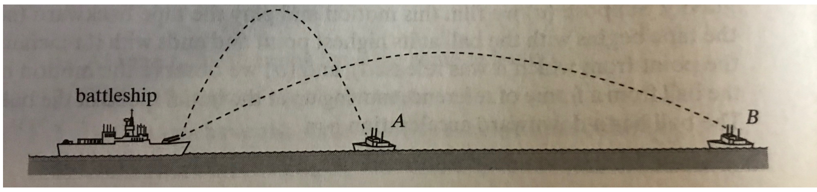


Figure 1: Which ship is hit first?

1.2 Forces and Torque

1. An elevator contains a person standing on a scale. The elevator accelerates upward, then moves at constant velocity, then decelerates to a stop. The scale reads a weight that is ______, then ______, and then ______ the person's actual weight.

   - **More than, equal to, less than**
   - Less than, equal to, more than
   - equal to, equal to, equal to
   - More than, equal to, equal to

2. A crate is pushed across a floor at constant velocity against friction. If the crate is flipped so that a side with less surface area is on the bottom, and pushed again at constant velocity, the required force is
   - More than the first side
   - Less than the first side
   - **Equal to the first side**
3. A man needs to pull a rusty lever to release a mechanism, but he can't. Which of the following will increase torque on the lever?
   - Tying a rope to the end of the lever, and pulling on the rope perpendicular to the lever.
   - **Bolting a metal rod to the lever, and pulling the rod perpendicular to the lever.**
   - Tying a rope to the end of the lever, pulling the rope parallel to the lever.
   - Bolting a metal rod to the lever, and pulling the rod parallel to the lever.
4. A racecar makes a turn at constant velocity, and the road is flat. There is friction between the road and tires. Which of the following is true?
   - **The car experiences centripetal acceleration, provided by friction.**
   - The car experiences centripetal acceleration, provided by the normal force.
   - Moving at constant velocity, the car experiences no acceleration.

1.3 Work and Energy

1. In which of the follow situations would energy *not* be conserved?
   - An object is dropped from some height and experiences free-fall, neglecting air-resistance.
   - An external force compresses a mass against an oscillator for a given displacement and then the mass is released.
   - A pendelum is pulled away from equilibrium and then released.
   - **A rock slowly skids to a stop on top of a frozen pond.**
2. A ball rolls down a hill that has a height h, attaining a speed v at the bottom. In order to attain a speed of $2v$ at the bottom, how tall would the hill have to be?
   - $2h$
   - $3h$
   - $4h$ **This one.**

1.4 Linear and Angular Momentum

1. A star undergoes a supernova, in which significant matter is blown away by a fusion reaction. The remaining also shrinks in size. Suppose the radius decreases by a factor of 10^3. By what factor does the angular velocity increase, if angular momentum is conserved? (Assume the mass doesn't change significantly).
   - 10^4
   - 10^5
   - 10^6 **This one.**
2. A mine cart is moving along a track at constant speed, and passes under a vertical waterfall. Because the cart is filled with water, the speed of the cart
   - increases
   - **decreases**
   - remains constant (no net forces)
3. If ball 1 in the arrangement shown in Fig. 2 is pulled back and then let go, ball 5 bounces forward with the same velocity. If balls 1 and 2 are pulled back and released, balls 4 and 5 bounce forward with the same velocity, and so on. The number of balls bouncing on each side is equal because
   - of conservation of momentum. (1/2 point for this answer, because it is necessary but not sufficient).
   - **the collisions are elastic.**
   - the collisions are inelastic.
   - neither of the above.

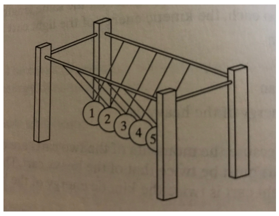


Figure 2: This object is known as a Newton's cradle.

2 Technical Questions

2.1 Kinematics and Angular Kinematics

1. A ball is kicked with an initial velocity of $\vec{v} = 4\hat{i} + 3\hat{j}$ m/s. (a) For how long does the ball remain in the air? (b) Where does the ball land? ($g = 10$ m/s^2). ($\frac{1}{3}$ point for correct diagram, $\frac{2}{3}$ point for numerical answers).

   (a) $v_{\mathrm{f,y}} = v_{\mathrm{i,y}} - gt$, so if the final velocity in the y-direction is zero, then $v_{\mathrm{i}} = gt_{1/2}$, where $t_{1/2}$ is the time it takes to reach the peak of the trajectory. The time aloft is $t = 2v_{\mathrm{i}}/g = 6/10$ seconds. (b) We need the x-component of the velocity: $d = 4(6/10) = 2.4$ meters.

2.2 Forces and Torque

1. A 900 kg lunar probe hovers above the surface of the Moon. On the Moon, $g \approx 5/3$ m/s^2. An engine is pointed at a 45 degree angle from straight down, spraying propellant. What force does the engine produce to keep the probe from decreasing in height? ($\frac{1}{3}$ point for correct free-body diagram, $\frac{2}{3}$ point for answer).

   The free body diagram has the following forces: weight (gravity) and the propulsion force at a 45 degree angle with respect to vertical. If the vertical component of the propulsion force is to balance gravity, then we need $F_{\mathrm{p}} \cos\theta = mg$, so $F_{\mathrm{p}} = mg/\cos\theta = \sqrt{2}(1500)$ N.

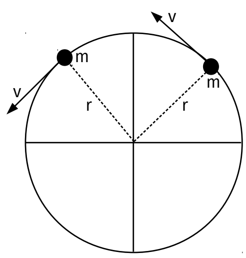
2.3 Work and Energy

1. A snowboarder descends a hill with a height of 50 meters (neglect friction). (a) What is her final speed? (b) After descending, she travels along a flat stretch of snow. She turns the board sideways, the coefficient of friction becomes relevant: $\mu = 0.8$. How far does she travel before stopping?

   Set gravitational potential energy equal to kinetic energy: $mgh = \frac{1}{2}mv^2 \rightarrow v = \sqrt{2gh}$. We find that $v = \sqrt{1000}$ m/s. (b) We are not interested in time in this problem, but we do need to know the acceleration. $F = ma = \mu mg$, so $a = \mu g$. Using $v_{\mathrm{f}}^2 = v_{\mathrm{i}}^2 - 2\mu g\Delta x$, we find about 62.5 meters for Δx. This assumes the final velocity is zero (coming to a stop).

2.4 Linear and Angular Momentum

1. Two objects each of mass $m = 0.1$ kg rotate around the origin of a coordinate system, both at radius $r = 0.1$ m. If the tangential velocity of each is $v = 1$ m/s ($p = mv$), (a) what is $L = L_1 + L_2 = r_1 p_1 \sin\theta_1 + r_2 p_2 \sin\theta_2$, the total angular momentum? (b) What is the value of the total *moment of inertia*, $I = 2mr^2$, and the *angular speed* $\omega = v/r$ of the particles? (c) Show numerically that $I\omega = L$ from part (a).



   (a) $L = 2rmv$, because each particle contributes and $\theta = 90°$, because it is the angle between $\vec{r}$ and $\vec{p}$. $L = 2 \times 10^{-2}$ J s. (b) Plugging in numbers, $I = 2 \times 10^{-3}$ kg m^2, and $\omega = 10$ rad/sec. (c) $I\omega = 2 \times 10^{-2}$ J s.