Answer Key for Calculus-Based Physics-1: Mechanics (PHYS150-01)

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1 Conceptual Questions

1.1 Kinematics and Angular Kinematics

1. An object accelerates with constant acceleration. The displacement versus time curve is quadratic. The acceleration versus time plot should be ______ and the velocity versus time plot should be ______.
   - quadratic, linear
   - linear, flat
   - **flat, linear**
   - linear, quadratic
2. An object experiences constant *angular* acceleration. The net external torque is ______, and the angular velocity is a ______ function of time.
   - zero, linear
   - **constant, linear**
   - zero, constant
   - constant, constant
3. A battleship fires simultaneously two shells with the same speed at enemy ships (Fig. 1). If the shells follow the parabolic trajectories shown, which ship gets hit first?
   - A, because it has a smaller displacement from the cannon.
   - A, because the overall distance travelled is less.
   - Both at the same time, because the initial projectile velocity is the same.
   - **B, because the projectile does not have to travel as high in the air.**
   - B, because the initial velocity must be higher.

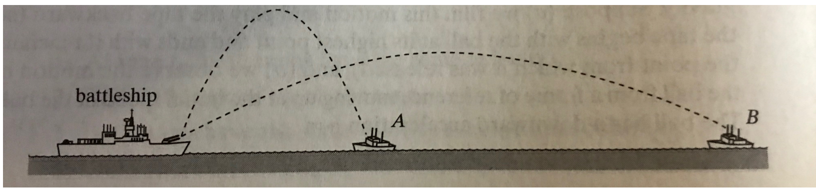

Figure 1: Which ship is hit first?

1.2 Forces and Torque

1. An elevator contains a person standing on a scale. The elevator accelerates downward, then moves at constant velocity, then comes 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. The crate is flipped so that a side with less surface area is on the bottom. If the required force to push it increases, which of the following is the proper conclusion?
   - It's harder to push because there's more pressure now: pressure is force divided by area.
   - **It's harder to push because the new side must have a different coefficient of friction.**
   - It's harder to push because the normal force has increased.
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. An aircraft is in a banked turn, traveling in a circle. Which of the following is most correct?
   - **The craft experiences centripetal acceleration, provided by a component of the lift force.**
   - The craft experiences centripetal acceleration, provided by the thrust, which is tangent to the circle.
   - Moving at constant velocity, the craft 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 train skids to a halt, with the wheels sliding on the tracks.**
2. A force does an amount of work W on an object with initial velocity v to stop it. How much work would have to be done on the object if the initial velocity were $2v$?
   - $2W$
   - $3W$
   - $4W$ **This one.**

1.4 Linear and Angular Momentum

1. When a star undergoes a supernova, matter is blown away by a fusion reaction. The more significant effect for angular momentum is that the star shrinks in size. Suppose the radius decreases by a factor of 10^2. By what factor does the angular velocity increase, if angular momentum is conserved? (Assume the mass doesn't change significantly).
   - 10^3
   - 10^4 **This one.**
   - 10^5
2. A mine cart holding two robbers is moving along a track at constant speed. They're being chased, so one robber dives out the back. The speed of the cart
   - **increases, because momentum is conserved and the jumper has momentum in the opposite direction.**
   - decreases, because momentum is conserved and the mass of the cart has decreased.
   - remains constant, because there were only internal forces, not external forces.
3. If ball 1 in the arrangement shown in Fig. 2 is pulled back and then let go, ball 5 bounces forward. If balls 1 and 2 are pulled back and released, balls 4 and 5 bounce forward, and so on. The number of balls bouncing on each side is equal because
   - of conservation of momentum.
   - **the collisions are elastic.**
   - the collisions are inelastic.
   - neither of the above.

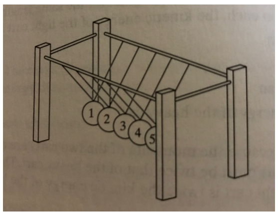

Figure 2: This object is known as a Newton's cradle.

2 Technical Questions

2.1 Kinematics and Angular Kinematics

1. A ball is kicked with an initial velocity of $\vec{v} = 3\hat{i} + 4\hat{j}$ 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).

   The diagram is a concave-down parabola. (a) $v_{\mathrm{y}}(t) = v_{\mathrm{y,i}} - gt$. The total time is therefore $t = 2v_{\mathrm{y,i}}/g = 4/5$ seconds. (b) $\Delta x = v_{\mathrm{x,i}}t = 3(4)/5 = 12/5$ 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 30 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 contains two forces, the weight downward and the thrust upwards, 30 degrees from vertical. From the free-body diagram, we find to balance the forces, we need $T = w/\cos\theta = mg/\cos\theta = 3000/\sqrt{3}$ N.

2.3 Work and Energy

1. A snowboarder descends a hill with a height of 25 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: $\mu = 0.5$. How far does she travel before stopping?

   From energy conservation, we find $v = \sqrt{2gh} = \sqrt{500} = 10\sqrt{5}$ m/s. (b) The acceleration is $a = \mu g$, so kinematically, $\Delta x = v^2/(2\mu g) = 50$ meters.

2.4 Linear and Angular Momentum

1. Two objects each of mass $m = 0.2$ kg rotate around the origin of a coordinate system, both at radius $r = 0.2$ m. If the tangential velocity of each is $v = 2$ 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) $L = 2\frac{2}{10}\frac{2}{10}(1) = \frac{2}{25}$ J s (the two objects have the same angular momentum). (b) $I = 2mr^2 = 2\frac{2}{10}\frac{4}{100} = \frac{16}{1000}$ kg m^2. $\omega = v/r = 1/\frac{2}{10} = \frac{10}{2}$ rad/second. (c) Thus, $I\omega = \frac{16}{1000}\frac{10}{2} = \frac{2}{25}$ J s.