Answer Key and Rationale

1. **Answer: (B) 50 m**
Rationale: The car accelerates uniformly from rest. Given: initial velocity $v_0 = 0\,\mathrm{m/s}$, final velocity $v_f = 20\,\mathrm{m/s}$, time $t = 5\,\mathrm{s}$. First, find the acceleration using $v_f = v_0 + at$: $a = (v_f - v_0)/t = (20\,\mathrm{m/s} - 0\,\mathrm{m/s})/5\,\mathrm{s} = 4\,\mathrm{m/s^2}$. Now, use the kinematic equation for distance: $d = v_0 t + \frac{1}{2}at^2$. $d = (0\,\mathrm{m/s})(5\,\mathrm{s}) + \frac{1}{2}(4\,\mathrm{m/s^2})(5\,\mathrm{s})^2 = 0 + \frac{1}{2}(4)(25) = 2 \times 25 = 50\,\mathrm{m}$. Alternatively, for constant acceleration, distance can be found using $d = \frac{1}{2}(v_0 + v_f)t$: $d = \frac{1}{2}(0\,\mathrm{m/s} + 20\,\mathrm{m/s})(5\,\mathrm{s}) = \frac{1}{2}(20)(5) = 50\,\mathrm{m}$.

2. **Answer: (C) 45 m**
Rationale: At the maximum height, the final vertical velocity v_f is 0 m/s. The acceleration is due to gravity, $a = -g = -10\,\mathrm{m/s^2}$ (taking upwards as the positive direction). Given: initial velocity $v_0 = 30\,\mathrm{m/s}$, $v_f = 0\,\mathrm{m/s}$, $a = -10\,\mathrm{m/s^2}$. Use the kinematic equation $v_f^2 = v_0^2 + 2ad$: $0^2 = (30\,\mathrm{m/s})^2 + 2(-10\,\mathrm{m/s^2})d$ $0 = 900 - 20d$ $20d = 900$ $d = 900/20 = 45\,\mathrm{m}$.

3. **Answer: (D) Both $\vec{v}$ and $\vec{a}$ are non-zero.**
Rationale: At the highest point of its trajectory, a projectile's vertical component of velocity (v_y) is momentarily zero. However, its horizontal component of velocity (v_x) remains constant throughout the flight (assuming no air resistance). Thus, the overall velocity vector $\vec{v}$ is non-zero and points horizontally. The acceleration $\vec{a}$ acting on the projectile is solely due to gravity, which is constant ($g \approx 10\,\mathrm{m/s^2}$) and directed downwards throughout the entire trajectory, including the highest point. Therefore, both velocity and acceleration are non-zero.

4. **Answer: (B) 200 m**
Rationale: This is a projectile motion problem where the initial vertical velocity is zero. Vertical motion: The time it takes to fall $h = 80$ m can be found using $y = v_{0y}t + \frac{1}{2}a_y t^2$. Here, $y = -80\,\mathrm{m}$ (if upwards is positive), $v_{0y} = 0$, $a_y = -g = -10\,\mathrm{m/s^2}$. $-80 = (0)t + \frac{1}{2}(-10)t^2 \implies -80 = -5t^2 \implies t^2 = 16 \implies t = 4\,\mathrm{s}$. Horizontal motion: The horizontal distance x is covered at a constant horizontal velocity $v_x = 50\,\mathrm{m/s}$. $x = v_x t = (50\,\mathrm{m/s})(4\,\mathrm{s}) = 200\,\mathrm{m}$.

5. **Answer: (B) Continue to move forward relative to the car.**
Rationale: This is an application of Newton's First Law of Motion (the law of inertia). An object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced external force. When the car suddenly brakes, it decelerates due to the force of braking. The passenger, not being rigidly attached to the car (no seatbelt), continues to move forward with the velocity the car had before braking, due to their inertia. Relative to the decelerating car, the passenger appears to be thrown forward.

6. **Answer: (B) 2.0 m/s^2**
Rationale: According to Newton's Second Law, the net force F_{net} acting on an object is equal to its mass m times its acceleration a ($F_{net} = ma$). Given: $F_{net} = 20$ N, $m = 10$ kg.

$a = F_{net}/m = 20\,\text{N}/10\,\text{kg} = 2.0\,\text{m/s}^2$. Since the surface is frictionless, the applied horizontal force is the net horizontal force.

7. **Answer: (B) The magnitude of the force of friction is equal to the magnitude of the force exerted by the person.**
Rationale: The crate is moving at a constant velocity. According to Newton's First Law, if an object moves at a constant velocity, its acceleration is zero. From Newton's Second Law ($F_{net} = ma$), if acceleration is zero, the net force acting on the crate must also be zero. The horizontal forces acting on the crate are the pushing force exerted by the person (F_{push}) and the force of kinetic friction (f_k) opposing the motion. For the net force to be zero, these two forces must be equal in magnitude and opposite in direction: $F_{push} = f_k$. (A) is incorrect because if it were true, there would be a net force and acceleration. (C) is incorrect because the net force is zero. (D) is incorrect; on a horizontal floor with no other vertical forces, the normal force is equal to the weight.

8. **Answer: (C) 30 N**
Rationale: To start the box moving, the applied horizontal force must overcome the maximum static friction. The maximum static friction force ($f_{s,max}$) is given by $f_{s,max} = \mu_s N$, where μ_s is the coefficient of static friction and N is the normal force. On a horizontal surface, the normal force N is equal to the weight of the box, mg. $N = mg = (5\,\text{kg})(10\,\text{m/s}^2) = 50\,\text{N}$. $f_{s,max} = \mu_s N = (0.6)(50\,\text{N}) = 30\,\text{N}$. Therefore, the minimum horizontal force required to start the box moving is 30 N.

9. **Answer: (B)** 5.5 **m/s**^{2}
Rationale: First, calculate the normal force N. Since the surface is horizontal and the pull is horizontal, $N = mg = (2\,\text{kg})(10\,\text{m/s}^2) = 20\,\text{N}$. Next, calculate the force of kinetic friction $f_k = \mu_k N = (0.2)(20\,\text{N}) = 4\,\text{N}$. The net horizontal force F_{net} is the applied force minus the kinetic friction force (since friction opposes motion): $F_{net} = F_{applied} - f_k = 15\text{ N} - 4\text{ N} = 11\text{ N}$. Finally, use Newton's Second Law ($F_{net} = ma$) to find the acceleration a: $a = F_{net}/m = 11\,\text{N}/2\,\text{kg} = 5.5\,\text{m/s}^2$.

10. **Answer: (C) 8 N**
Rationale: The magnitude of the centripetal force (F_c) required to keep an object of mass m moving in a circle of radius r at a constant speed v is given by the formula $F_c = \frac{mv^2}{r}$. Given: $m = 0.5\,\text{kg}$, $v = 4.0\,\text{m/s}$, $r = 1.0\,\text{m}$. $F_c = \frac{(0.5\,\text{kg})(4.0\,\text{m/s})^2}{1.0\,\text{m}} = \frac{(0.5\,\text{kg})(16.0\,\text{m}^2/\text{s}^2)}{1.0\,\text{m}} = \frac{8.0\,\text{kg}\cdot\text{m/s}^2}{1.0\,\text{m}} = 8.0\,\text{N}$. The tension in the string provides this centripetal force.