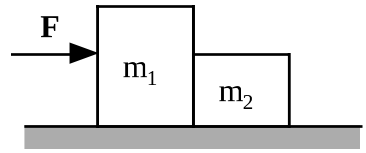
- Exam is closed book, closed notes. Use only your formula sheet.
- Write all work and answers in exam booklets.
- The backs of pages will not be graded unless you so request on the front of the page.
- Show all your work and explain your reasoning (except on #1).
- Partial credit will be given (not on #1). No credit will be given if no work is shown (not on #1).
- If you have a question, raise your hand or come to the front.

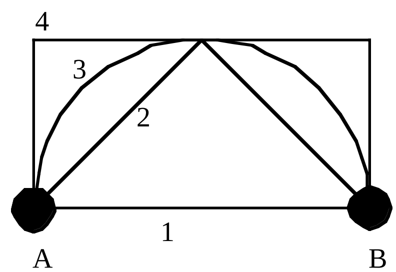
1. (20 points) For each of these multiple choice questions, indicate the correct response (A, B, C, or D (where needed)) on the page for problem 1 in your exam booklet.

i) Two blocks are pushed across a frictionless floor by a horizontal force **F** applied to block 1. Is the magnitude of $\mathbf{F}_{21}$ (the force on block 2 due to block 1), greater than, less than, or the same as the magnitude of **F**?



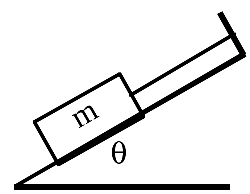
A) Greater than. B) Less than. C) The same as.

ii) To drive from point A to point B, there are four possible routes, shown at right. If the time to drive each route is the same, along which route is the average speed greatest?



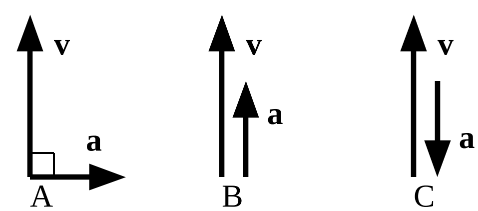
A) 1
B) 2
C) 3
D) 4

iii) The mass *m* is attached by a rope to a post at the upper end of the ramp. What happens to the magnitude of the normal force on the block (due to the ramp) as the angle θ of the ramp is increased?

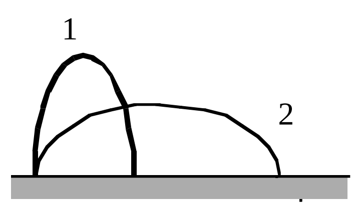


A) It increases.
B) It decreases.
C) It does not change.

iv) The figure at right shows three distinct possibilities for the velocity and acceleration of a particle at a particular instant. For which possibility (A, B, or C) is the speed of the particle not changing at this particular instant?

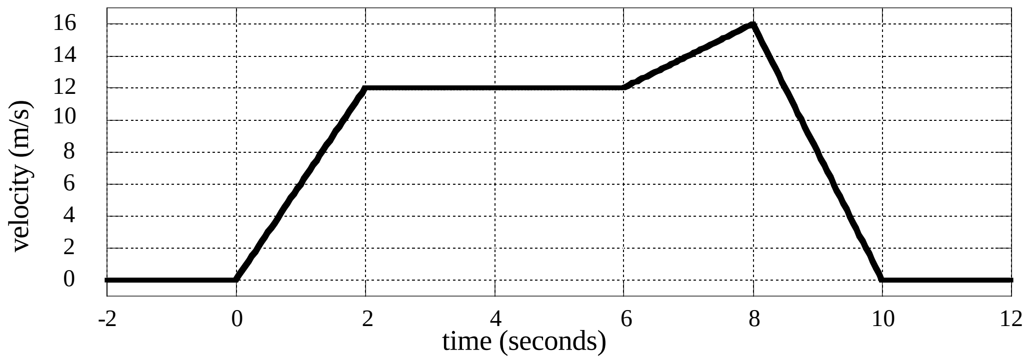


v) Two balls are thrown simultaneously in the air and follow the parabolic trajectories shown at right. Which ball has the largest magnitude of the vertical component of velocity when it hits the ground?



A) 1
B) 2
C) The balls have the same vertical component of velocity.

2. (20 points) The graph below shows the velocity of your car as you travel from home (starting at $t = 0\ s$) to the store (arriving at $t = 10\ s$):

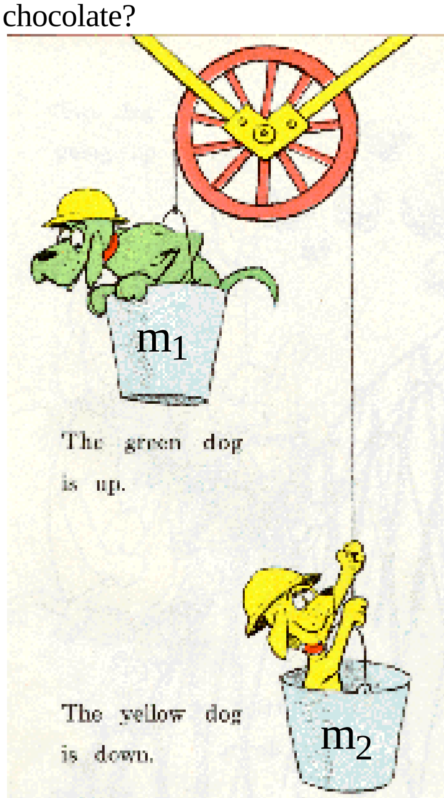


a) Draw a graph of the acceleration of your car during the journey.
b) How far did you travel from your house to the store?
c) What was your average velocity during the time interval 0 -> 10 seconds?
d) What was your average acceleration during the time interval 0 -> 10 seconds?

3. (20 points) A ball is thrown from the ground into the air. When the ball is at a height of 12.8 m, the velocity is observed to be $\vec{\mathbf{v}} = 9.0\, m/s\, \hat{\mathbf{i}} + 12\, m/s\, \hat{\mathbf{j}}$ ($\hat{\mathbf{i}}$ horizontal and $\hat{\mathbf{j}}$ upward). Assume $g = 10\ m/s^2$.

a) To what maximum height above the ground will the ball rise?
b) How far does the ball land from where it was thrown (assuming flat ground)?
c) How long does the ball remain in the air?

4. (20 points) A 5 kg bowling ball is dropped from a tower into a deep vat of melted chocolate. When the ball hits the chocolate it has a speed of 8 m/s. The ball comes to rest in the chocolate after traveling a distance of 8 m. Assume $g = 10\ m/s^2$.
(a) What is the acceleration of the ball in the chocolate, assuming it remains constant?
(b) What is the force exerted by the chocolate on the ball as it is moving in the chocolate?
(c) How long does it take for the ball to come to rest after entering the chocolate?



5. (20 points) Consider a pulley system in the initial state shown at right. The green dog is up. The yellow dog is down. The green dog has a mass (m_1) three times the mass (m_2) of the yellow dog. Ignore the mass of the buckets, the rope, and the pulley. Ignore friction. Gravity (g) points down.
(a) Draw a free-body diagram for each dog.
(b) Find the acceleration of the dogs, in terms of g.
(c) Find the tension in the rope.
(d) Compare (*i.e.*, >, <, or =) the tension in the rope to the weight of the green dog? Is this what you would expect? Why?

1. i) B The force **F** has to accelerate both masses, while the force $\mathbf{F}_{21}$ only has to accelerate mass m_2. Since the blocks both accelerate together, the magnitude of $\mathbf{F}_{21}$ is less than the magnitude of **F**.

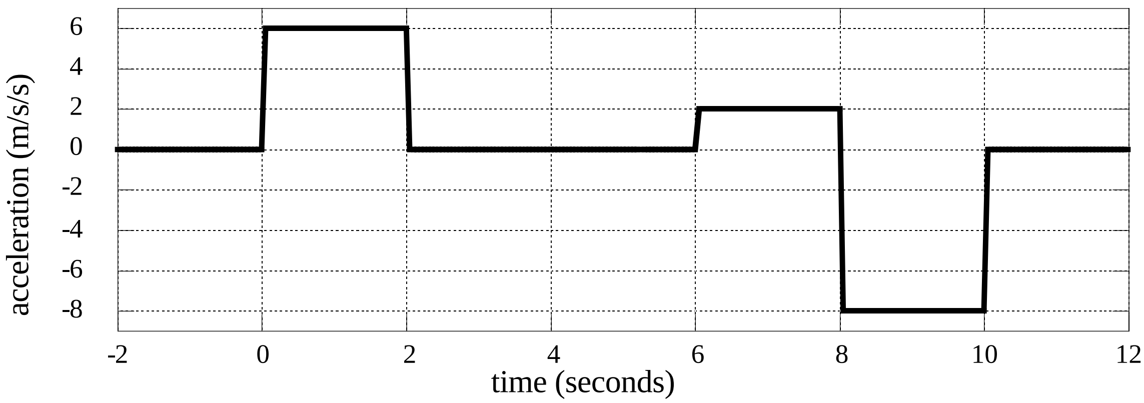
ii) D Route 4 has the longest path from A to B. Since average speed is total distance traveled divided by time taken, route 4 will have the largest speed.

iii) B The normal force balances the component of gravity that is perpendicular to the inclined plane. As the angle θ increases, this component of gravity will decrease, causing the normal force to decrease.

iv) A In case (A), the acceleration is perpendicular to the velocity, which is the situation for uniform circular motion. The velocity changes direction, but the speed is constant.

v) A For any ball thrown up in the air, the vertical component of velocity upon return is opposite the original vertical component of velocity. Since ball 1 goes to a higher height, it must have had a larger initial vertical component of velocity, so it hits the ground with a larger vertical component of velocity.

2. a) The velocity is only changing during three intervals of the motion. During each of these, the acceleration can be found with $a = \Delta v/\Delta t$, which means find the slope. The plot is shown below.



b) Since the position is the integral of the velocity, the total distance traveled can be found by finding the area under the velocity curve. Note that each rectangle in the figure has an area of 4 *m*. There are 26 rectangles under the curve, so the total distance traveled is $\boxed{\Delta x = 26 \times 4\ m = 104\ m}$.

c) The average velocity is the displacement divided by the time:

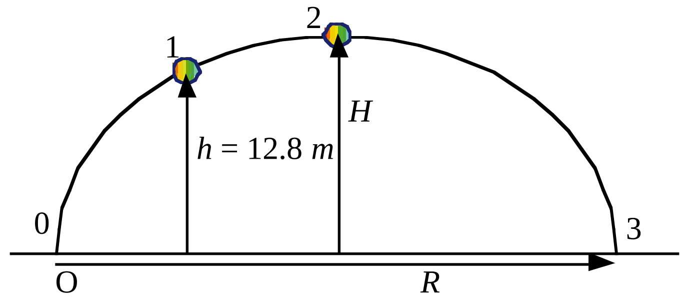
$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{104m}{10s}$$

$$\boxed{\bar{v} = 10.4 m/s}$$

d) The average acceleration is the change in velocity divided by the time, but the initial and final velocities are both zero, so there is no change in velocity and hence no average acceleration.

$$\boxed{\bar{a} = 0 m/s^2}$$

3. Put the origin at the position where the ball was thrown (at $t_0 = 0$). Let t_1 be the time when the velocity is observed, t_2 be the time when the maximum height is reached, and t_3 be the time when the ball returns to the ground.



a) Use the height $y_1 = h$ and the velocity $\vec{\mathbf{v}}_1 = 9.0m/s\,\hat{\mathbf{i}} + 12m/s\,\hat{\mathbf{j}}$ to find the initial velocity, which will help solve the rest of the problem:

$$v_{1y}^2 = v_{0y}^2 + 2a_y(y_1 - y_0)$$
$$v_{1y}^2 = v_{0y}^2 + 2(-g)(h - 0)$$
$$v_{0y}^2 = v_{1y}^2 + 2gh$$
$$v_{0y} = \sqrt{v_{1y}^2 + 2gh} = \sqrt{(12m/s)^2 + 2(10m/s^2)(12.8m)} = 20m/s$$

At the top of the path, $v_{2y} = 0$, so we can solve for the maximum height H:

$$v_{2y}^2 = v_{0y}^2 + 2a_y(y_2 - y_0)$$
$$0 = v_{0y}^2 + 2(-g)(H - 0)$$
$$H = \frac{v_{0y}^2}{2g} = \frac{(20m/s)^2}{2(10m/s^2)}$$
$$\boxed{H = 20m}$$

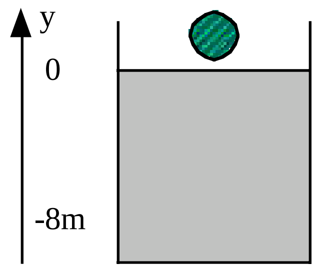
b) We know that for such a parabolic path, $t_3 = 2\,t_2$ (*i.e.*, time up = time down). Since the horizontal velocity is unchanged during the flight, we can solve for the range R:

$$R = v_{0x}t_3 = v_{0x}2t_2$$
$$v_{2y} = v_{0y} - gt_2 \quad \Rightarrow \quad t_2 = \frac{v_{0y}}{g} \quad \text{since } v_{2y} = 0$$
$$R = \frac{2v_{0x}v_{0y}}{g} = \frac{2(9.0m/s)(20m/s)}{10m/s^2}$$
$$\boxed{R = 36m}$$

c) The time of flight can be found using the time equation found above:

$$t_3 = 2t_2 = 2\frac{v_{0y}}{g} = 2\frac{20m/s}{10m/s^2}$$
$$\boxed{t_3 = 4s}$$

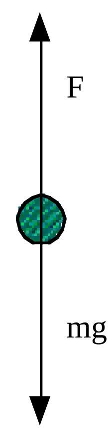
4. Let the 1-dimensional coordinate system have its origin at the surface of the chocolate so that $y_0 = 0$, $v_0 = -8\ m/s$. The ball comes to rest at $y_1 = -d = -8\ m$, so we know that $v_1 = 0$.



a) To find the acceleration use:

$$v_1^2 = v_0^2 + 2a(y_1 - y_0)$$
$$0 = v_0^2 + 2a(-d - 0)$$
$$a = \frac{v_0^2}{2d} = \frac{(-8m/s)^2}{2(8m)} = \frac{64m^2/s^2}{16m}$$
$$\boxed{a = 4m/s^2}$$

b) First draw a free body diagram for the ball. Then write down the equation of motion.

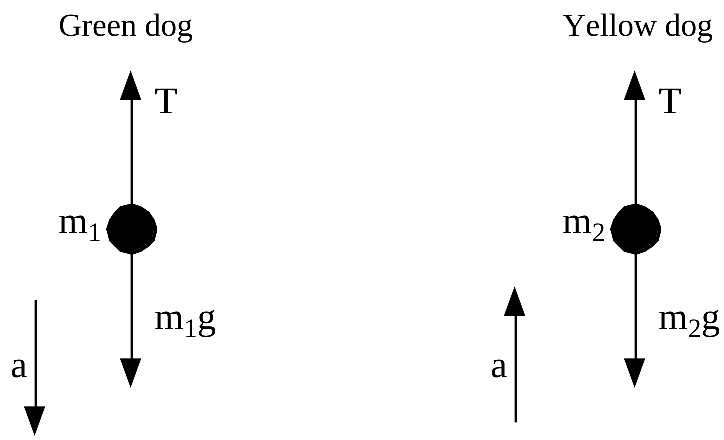


$$F - mg = ma$$
$$F = ma + mg = m(a + g)$$
$$F = 5kg(4m/s^2 + 10m/s^2)$$
$$\boxed{F = 70N}$$

c) The time for the ball to come to rest is found from:

$$v_1 = v_0 + at_1$$
$$0 = v_0 + at_1$$
$$t_1 = -\frac{v_0}{a} = -\frac{(-8m/s)}{4m/s^2}$$
$$\boxed{t_1 = 2s}$$

5. a) Call the tension in the rope *T*, which is the same for each dog. Since the green dog is heavier, we expect it to go down, and so we assume its acceleration *a* to be down as shown, which means that the yellow dog will go up with the same acceleration, also shown.



b) The equations of motion for the two dogs are

$$m_1 g - T = m_1 a$$

$$T - m_2 g = m_2 a$$

Adding the two equations together, and using $m_1 = 3\ m_2$, we can find a:

$$m_1 g - m_2 g = (m_1 + m_2)a$$

$$a = \frac{m_1 - m_2}{m_1 + m_2} g = \frac{3m_2 - m_2}{3m_2 + m_2} g = \frac{2m_2}{4m_2} g$$

$$\boxed{a = \frac{g}{2}}$$

c) We can find the tension from either of the equations of motion:

$$T = m_1(g - a) = m_1(g - \frac{g}{2})$$

$$\boxed{T = \frac{m_1 g}{2}} \quad \text{or} \quad \boxed{T = \frac{3m_2 g}{2}}$$

d) From above we see that

$$T = \frac{m_1 g}{2}$$

$$\boxed{T < m_1 g}$$

So the tension is less than the weight of the green dog. This is what we expected, since we said originally that we expected the green dog to fall down. This must mean that the force down, $m_1 g$, is greater than the force up, T, giving a net force down.