# Physics 211 Final Exam

This exam has twenty-seven multiple choice questions.

The exam period begins at 3 PM on May 20 and ends at 5 PM on May 20.

*Exception:* Students who receive an extra-time accommodation through the Center for Disability Resources may take that extra time. If you receive 1.5x time for the exam, you should complete your work by 6 PM; if you receive double time, you should complete it by 7:30 PM, with a half-hour break for dinner. If this timetable does not work for you or you require additional accommodations, please contact Walter or Mario immediately.

**Questions during the exam:** You may reach teaching staff to ask questions during the exam by:

- Joining the course Zoom and asking by chat or voice
- Asking a question in `#quiz-questions` on Discord
- (Only if both of these methods are not available to you) Email to `wafreema@syr.edu`

You may:

- Consult any materials on the course website, video library, any of your notes, notes prepared in collaboration with your classmates, your previous homework, recitation work, quizzes, or the OpenStax textbook for reference
- Contact teaching staff over Zoom, Discord, or email to ask for clarification on any portion of the exam.
- Use a graphing calculator to do arithmetic or graph functions
- Make use of Google Calculator, Desmos, or similar tools to do arithmetic or graph functions
- Use a translation tool or dictionary to translate anything to your native language

You may not:

- Provide assistance to anyone else in our class on this exam while they are taking it
- Seek assistance from anyone other than teaching staff on this exam while you are taking it
- Use a computer program or calculator to do algebra for you
- Consult online references outside the class other than the OpenStax textbook (for example, Chegg and Bartleby) regarding the material on the exam after the exam period begins
- Discuss the contents of this exam with anyone who has yet to complete it

To submit your answers, simply type them into the text box on Blackboard as numbers followed by letters with spaces between them. An example might be `1 A 2 B 3 D 4 F 5 C`. You may also put them on different lines, e.g.

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1 A
2 B
3 C
4 D
5 E
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**Note:** You should use $g = 10\,\mathrm{m/s^2}$ throughout this exam. The answers are calculated with this value.

1. One way for people to make a rapid, controlled descent is to grasp a pole and slide down it. They press against the pole using their arms or legs, using friction to slow their fall. This approach has historically been used by firefighters to quickly descend from their living quarters to a fire engine when called to a fire; more recently it is more commonly used by performers and acrobats.

   Suppose first that a person of mass $m$ descends a pole of length $L$ (imagine that this is around ten meters, as in a firehouse) of height $h$; they grip the pole with both hands and press in opposite directions, with each hand applying a force $F_h$. The coefficient of kinetic friction between their hands and the pole is $\mu_k$.

   What is the work done by friction as they descend?

   (A) $W = -\mu_k F_h$
   (B) $W = 2\mu_k F_h L$
   (C) $W = -2\mu_k F_h L$
   (D) $W = -\mu_k mgL$
   (E) $W = mgL$
   (F) $W = \mu_k F_h$
   (G) $W = \mu_k mgL$

2. How fast will they be traveling after they descend the pole and reach the ground?

   (A) $v_f = \sqrt{2gL + 4\frac{\mu_k F_h L}{m}}$
   (B) $v_f = v_i - gt$
   (C) $v_f = \sqrt{2gL}$
   (D) $v_f = \sqrt{2gL + 2\frac{\mu_k F_h}{m}}$
   (E) $v_f = \sqrt{2gL - 2\frac{\mu_k F_h}{m}}$
   (F) $v_f = \sqrt{2gL - 4\frac{\mu_k F_h L}{m}}$
   (G) None of the above

3. Suppose now that a person of mass 75 kg wants to slide down a very long pole (several kilometers long, perhaps) at a constant rate. They adjust their grip on the pole to maintain their speed at the maximum safe rate possible.

   The energy lost to kinetic friction is converted into heat. Suppose that half of this heat goes into the pole (which we don't care about) and half of it goes into their hands. Suppose that their hands can absorb heat at a power of 300 W safely[a]. What is the fastest that they can slide down the pole without overheating their hands?

   (A) $v_{\text{max}} = 0.8$ m/s
   (B) $v_{\text{max}} = 1.6$ m/s
   (C) $v_{\text{max}} = 0.4$ m/s
   (D) $v_{\text{max}} = 4$ m/s
   (E) $v_{\text{max}} = 0.2$ m/s
   (F) $v_{\text{max}} = 2$ m/s
   (G) None of the above

   [a]Our protagonist has a supernatural tolerance to heat.

4. A stunt motorcyclist, perhaps at a traveling carnival, does a trick with their motorcycle: they ride around the inner surface of a vertical loop so that they are upside down at the top, with their head pointing downward and their wheels touching the road "above their head".

   Suppose they are riding around a loop with a radius of 5 meters. How fast must they ride so that their wheels don't lose contact with the track at the top of the loop?

   (A) 5 m/s
   (B) 7.07 m/s
   (C) 1.41 m/s
   (D) 2.82 m/s
   (E) None of the above are correct

5. Our motorcyclist chooses to ride at a constant speed of 9 m/s around this vertical loop of radius 5 meters.

   If the cyclist has a weight of 1000 N when standing on the ground, what is their apparent weight at the *bottom* of the loop?

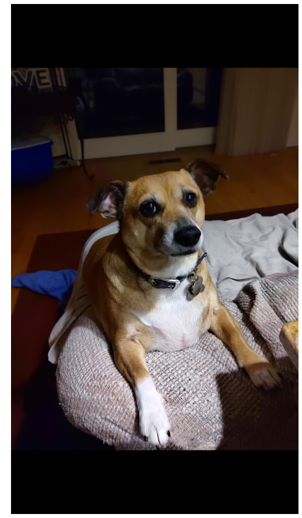
   (A) 380 N
   (B) 1620 N
   (C) 2620 N
   (D) 620 N
   (E) None of the above are correct

6. Which of the following is a valid explanation for why the motorcyclist does not fall at the top of the loop?

   (A) Their velocity pushes them upward at the top of the loop and stops them from falling.
   (B) They really *are* falling; they are accelerating downward not just at $g$, but accelerating downward even faster than that.
   (C) The centripetal force pushes them upward at the top of the loop and stops them from falling.
   (D) The normal force from the track pushes them upward at the top of the loop and stops them from falling.
   (E) The force of their motion pushes them upward at the top of the loop and stops them from falling.
   (F) An assistant must stand backstage and chant "Wingardium leviosa!" over and over to make the trick work

7. Suppose Cocoa the dog wants to walk up a slope that is inclined at an angle $\theta$ above the horizontal.

   What is the minimum coefficient of static friction between their paws and the ground required to do this?



   (A) $\mu_s > \tan\theta$
   (B) $\mu_s > \sin\theta\cos\theta$
   (C) $\mu_s > g\sin\theta - F_N$
   (D) $\mu_s > \sin\theta$
   (E) None of the above is correct.

8. Someone plays two different organ pipes. The short one has a length of 1 meter; the long one has a length of 2 meters. (The speed of sound is about 340 m/s.)

   Which of the following is true?

   (A) The second harmonic ($n = 2$ normal mode) of the long pipe will have the same frequency as the first harmonic ($n = 1$ normal mode, also called the fundamental) of the short pipe.
   (B) The short pipe will produce only a single frequency around 340 Hz; the long pipe will produce only a single frequency around 170 Hz.
   (C) The fundamental frequency of the short pipe will be half of the fundamental frequency of the long pipe.
   (D) The speed $v$ of the sound waves in the long pipe will be half as fast as the speed of the sound waves in the short pipe.
   (E) The short pipe will produce only a single frequency around 170 Hz; the long pipe will produce only a single frequency around 85 Hz.

9. In this question and the next five questions, you will be presented with a mathematical expression, and need to decide what kind of quantity it represents: a distance, a force, an energy, etc.

   All symbols have their conventional meanings: $r$ is a radius, $L$ is a length (not an angular momentum), $\mu$ is a coefficient of friction, and so forth.

   What sort of quantity is $(\mu mg)(at)$?

   (A) Power
   (B) Force
   (C) Energy
   (D) Velocity
   (E) acceleration
   (F) Length
   (G) Momentum
   (H) None of the above

10. What sort of quantity is $\frac{m_1 g - 2m_2 g \sin\theta - \mu_k m_2 g \cos\theta}{2m_1 + m_2}$?

   (A) Velocity
   (B) Energy
   (C) Acceleration
   (D) Momentum
   (E) Power
   (F) Force
   (G) Length
   (H) None of the above

11. What sort of quantity is $\frac{P}{mg\sin\theta}$, where $P$ is a power?

   (A) Power
   (B) Velocity
   (C) Force
   (D) Length
   (E) Energy
   (F) Acceleration
   (G) Momentum
   (H) None of the above

12. What sort of quantity is $\frac{1}{2}\mu F_N a t^2$?

(A) Velocity
(B) Power
(C) Length
(D) Energy
(E) Momentum
(F) Acceleration
(G) Force
(H) None of the above

13. An electric toothbrush has a battery capacity of 30 kJ when the battery is fully charged. New batteries are generally charged to 60% of their full capacity before shipping.

If the toothbrush is accidentally turned on during shipping and begins trying to clean the inside of the package it was shipped in, drawing energy from the battery at a rate of 4 W, how long will it make an annoying buzzing sound?

(A) One hour and fifteen minutes
(B) Four and a half seconds
(C) Four hours and thirty minutes
(D) One hour and twenty-five minutes
(E) However long it takes for Walter to stick it in the room across the hall

14. The coefficient of static friction between a lightweight but very strong table and the floor is $\mu_s = 0.5$; it has a mass $m = 10$ kg.

A person leans on the table, applying a force $\vec{F}$ directed at an angle $\theta = 65°$ below the vertical. (That is, this force has a large downward component and a smaller component to the side.)

How much force can the person apply to the table before it begins to slide?

(A) 220 N
(B) 75.2 N
(C) 200 N
(D) 473 N
(E) The table will not slide no matter how hard the person presses on it.

15. An astronaut on an airless moon throws a rock straight up at some speed $v_0$; it reaches a maximum height of 20 meters above the height they threw it before it falls back down.

    In this problem and the following ones, determine the maximum height that the rock would reach if the following things were changed.

    How high would the rock travel if they instead threw it at speed $2v_0$?

    (A) 80 meters
    (B) 10 meters
    (C) $20\sqrt{2}$ meters
    (D) 40 meters
    (E) 5 meters
    (F) 20 meters (unchanged)
    (G) $10\sqrt{2}$ meters
    (H) None of the above

16. How high would the rock travel if they instead threw it at an angle of $\theta = 45°$ above the horizontal, but at the same speed?

    (A) $20\sqrt{2}$ meters
    (B) 40 meters
    (C) 20 meters (unchanged)
    (D) 10 meters
    (E) 80 meters
    (F) $10\sqrt{2}$ meters
    (G) 5 meters
    (H) None of the above

17. How high would the rock travel if they instead threw it on a moon that had the same mass, but had half the diameter?

    (A) 20 meters (unchanged)
    (B) 10 meters
    (C) $20\sqrt{2}$ meters
    (D) 40 meters
    (E) 80 meters
    (F) $10\sqrt{2}$ meters
    (G) 5 meters
    (H) None of the above

18. How high would the rock travel if they instead threw it on a moon with half the mass, but that was the same physical size?

    (A) 10 meters
    (B) 5 meters
    (C) 20 meters (unchanged)
    (D) $20\sqrt{2}$ meters
    (E) $10\sqrt{2}$ meters
    (F) 40 meters
    (G) 80 meters
    (H) None of the above

19. A forensics ballistics laboratory wants to measure the speed of projectiles from firearms using only simple technology.

    To do this, they have a clay block of mass $m_c = 1$ kg resting on a slippery table. They first need to measure the coefficient of kinetic friction between the clay block and the table.

    They do this by throwing a steel ball at the clay block. The steel ball has a mass of $m_s = 200$ grams, and it is traveling at a velocity of $v_0 = 12$ m/s when it strikes the clay. It sticks into the clay, which then slides one meter before coming to rest.

    What is the coefficient of kinetic friction between the clay block and the table?

    (A) 0.2
    (B) 0.288
    (C) 0.144
    (D) 0.4
    (E) 0.1
    (F) None of the above

20. Before they can do their test, the forensics laboratory gets a new table. This time, they measure the coefficient of friction $\mu_k$ as 0.4.[a] They use the same clay block of mass 2 kg.

    They fire a bullet of mass 4 grams into the block and observe that it slides one meter before coming to rest.

    Which is the closest value to the velocity of the bullet before it struck the block?

    (A) 500 m/s
    (B) 250 m/s
    (C) 1000 m/s
    (D) 125 m/s
    (E) 700 m/s

[a] This is here so you can continue with the problem even if you made a mistake on the previous part.

21. A pigeon of mass 500 grams is flying at 20 m/s horizontally. A falcon of mass 1 kg, perched on a high building, sees the pigeon and decides to catch it.

    The falcon dives on the pigeon and grabs it while it is flying. Just before the falcon catches it, it is moving straight downward at a speed of 40 m/s.

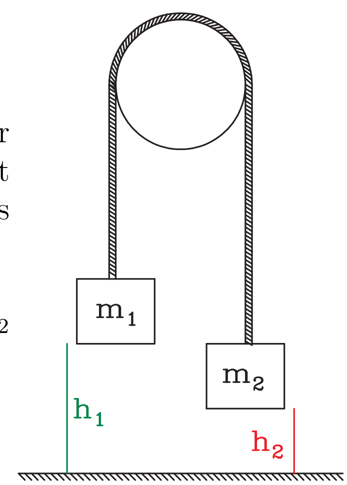
    What direction are the falcon and pigeon moving after the falcon grabs the pigeon?

    (A) 63.4 degrees below the horizontal
    (B) 26.6 degrees below the horizontal
    (C) 14.0 degrees below the horizontal
    (D) 76.0 degrees below the horizontal
    (E) 75.5 degrees below the horizontal
    (F) None of the above

22. Consider a system in which two masses are connected to a cable which runs over a lightweight pulley.

    One mass hangs on one side and the other mass hangs on the other side, as shown to the right. This can be used as a weight/counterweight system in an elevator, for instance. The cable that connects them does not stretch.

    Initially, one mass $m_1$ is a height $h_1$ off the ground; the other mass $m_2$ is a height $h_2$ off of the ground. Assume that $m_2 > m_1$.




    When the masses are released, what will the magnitude of their acceleration be?

    (A) $a = \frac{m_2 g}{m_1}$
    (B) $a = \frac{m_1 g + m_2 g}{m_2 - m_1}$
    (C) $a = \frac{m_2 g - m_1 g}{m_1 + m_2}$
    (D) $a = g$
    (E) $a = \frac{m_2 g - m_1 g}{m_2 - m_1}$
    (F) None of the above is correct.

23. Since $m_2 > m_1$, when the masses are released, $m_2$ will fall down to the ground.

What is the *net work done* by gravity on both masses together as they fall? (You may add the work done on $m_1$ to the work done on $m_2$.)

(A) $m_1gh_2 - m_2gh_2$
(B) 0
(C) $m_2gh_2 - m_1gh_2$
(D) None of the above
(E) $m_1gh_1 + m_2gh_2$
(F) $m_1gh_1 - m_2gh_2$
(G) $m_1gh_2 + m_2gh_2$

24. What is the *total work done by the tension in the rope* on both objects together? (Again, you may add the work done on $m_1$ to the work done on $m_2$.)

(A) $T(h_1 - h_2)$
(B) $\frac{m_1m_2g}{m_1+m_2}(h_2 - h_1)$ $\frac{m_1m_2g}{m_1+m_2}(h_2)$
(C) $\frac{m_1m_2g}{m_1+m_2}(h_1 + h_2)$
(D) $\frac{m_1m_2g}{m_1-m_2}(h_1 + h_2)$
(E) 0

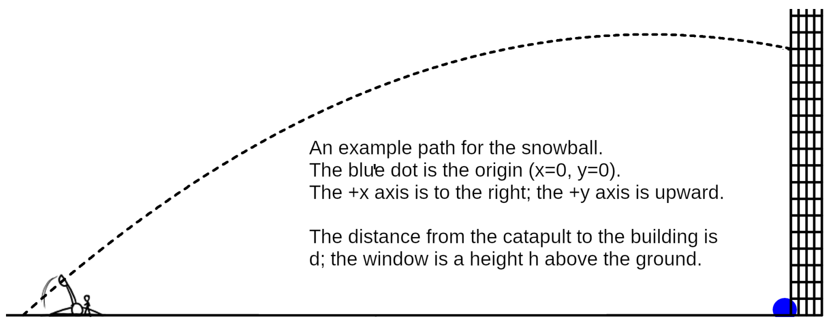
25. How fast will the mass $m_2$ be traveling when it strikes the ground?

(A) $v = \sqrt{2g(h_2 + h_1)\frac{m_2-m_1}{m_2+m_1}}$
(B) $v = \sqrt{2gh_2\frac{m_2-m_1}{m_2+m_1}}$
(C) $v = \sqrt{2g(h_2 - h_1)}$
(D) $v = \sqrt{2gh_2\frac{m_2+m_1}{m_2-m_1}}$
(E) $v = \sqrt{2g(h_2 - h_1)\frac{m_2+m_1}{m_2-m_1}}$
(F) None of the above

26. A Syracuse University student has constructed a catapult that throws snowballs. It launches snowballs at an angle $\theta$ above the horizontal at initial speed $v_0$.

This student would like to hit the center of Walter's second-floor window in the Physics Building with a snowball; the center of the window is a height $h$ above the ground.

They want to calculate the distance $d$ from the edge of the building where they should place the catapult. They choose the base of the Physics Building as their origin of coordinates; the positive $x$-direction points toward the building, and the positive $y$-direction points upward.




Which set of equations correctly describes the path of the snowball?

(A)

$$x(t) = (v_0 \cos\theta)t - d$$
$$y(t) = -\frac{1}{2}gt^2 + (v_0 \sin\theta)t$$

(B)

$$x(t) = (v_0 \cos\theta)t$$
$$y(t) = -\frac{1}{2}gt^2 + (v_0 \sin\theta)t + h$$

(C)

$$x(t) = (v_0)t$$
$$y(t) = -\frac{1}{2}gt^2 + (v_0)t$$

(D)

$$x(t) = \frac{1}{2}gt^2 + (v_0 \cos\theta)t - d$$
$$y(t) = -\frac{1}{2}gt^2 + (v_0 \sin\theta)t$$

(E) None of the above are correct.

27. Which of the following questions would allow you to figure out where to put the catapult on the Quad? *(Remember your choice of coordinate system: the origin of coordinates is at the base of the wall. This means that the catapult is located somewhere else.)*

    (A) "What value of $d$ makes it such that $y = h$ at the same time that $x = 0$?"

    (B) "What value of $d$ makes it such that $y = h$ at the same time that $v_x = 0$?"

    (C) "What value of $v_0$ makes it such that $y = h$ at the same time that $x = d$?"

    (D) "What value of $d$ makes it such that $y = h$ at the same time that $v_y = 0$?"

    (E) None of the above would be useful.

28. In handling the quadratic formula that appears in this calculation, you calculate *two* values for time. How should you handle these?

    (A) You should take the average of the two values.

    (B) You should use the larger value; the smaller value is unphysical.

    (C) There are two different distances from the Physics Building where the snowball will hit the window.

    (D) This means that you have made an error in your mathematics, since there is only one answer.

    (E) You should use the smaller value; the larger value is unphysical.