Do not turn the pages of the exam until you are instructed to do so.

Exam rules: You may use **only** a writing instrument while taking this test. You may **not** consult any calculators, computers, books, nor each other.

Problems 1 - 10 must be answered on the scantron form. Problems 11 and 12 must be answered in exam booklet 1. Problem 13 must be answered in exam booklet 2. The answers need to be well motivated and expressed in terms of the variables used in the problem. You will receive partial credit where appropriate, but only when we can read your solution. Answers that are not motivated will not receive any credit, even if correct.

At the end of the exam, you must hand in your exam, the scantron form, the blue exam booklets, and the equation sheet. All items must be clearly labeled with your name, your student ID number, and the day/time of your recitation. **If any of these items are missing, we will not grade your exam, and you will receive a score of 0 points.**

You are required to complete the following *Honor Pledge for Exams*. Copy and sign the pledge before starting your exam.

"I affirm that I will not give or receive any unauthorized help on this exam, and that all work will be my own."

Name: ______________________

Signature: ______________________

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$$\cos(30°)=\frac{1}{2}\sqrt{3} \quad \sin(30°)=\frac{1}{2} \quad \tan(30°)=\frac{1}{3}\sqrt{3}$$

$$\cos(45°)=\frac{1}{2}\sqrt{2} \quad \sin(45°)=\frac{1}{2}\sqrt{2} \quad \tan(45°)=1$$

$$\cos(60°)=\frac{1}{2} \quad \sin(60°)=\frac{1}{2}\sqrt{3} \quad \tan(60°)=\sqrt{3}$$

$$\cos\left(\frac{1}{2}\pi-\theta\right)=\sin(\theta) \quad \sin\left(\frac{1}{2}\pi-\theta\right)=\cos(\theta)$$

$$\cos(2\theta)=1-2\sin^2(\theta) \quad \sin(2\theta)=2\sin(\theta)\cos(\theta)$$

	Circle	Sphere
circumference	$2\pi r$	
(surface) area	πr^2	$4\pi r^2$
volume		$\frac{4}{3}\pi r^3$

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Good Luck !

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Problem 1 (2.5 points) **Answer on Scantron form**

How many times did the Yankees win the AL East since it was created in 1969?

Figure 1: https://www.youtube.com/watch?v=9aYhxISaAMA

1. 11.
2. 13.
3. 17.
4. 19.
5. 21.
6. 23.
7. 25.
8. 28.
9. 31.
10. 39.

Problem 2 (2.5 points) **Answer on Scantron form**

Two blocks of mass m_1 and m_3, connected by a rod of mass m_2, are sitting on a low-friction surface. You push to the left on the right block with a constant force of magnitude F, as shown in Fig. 2.

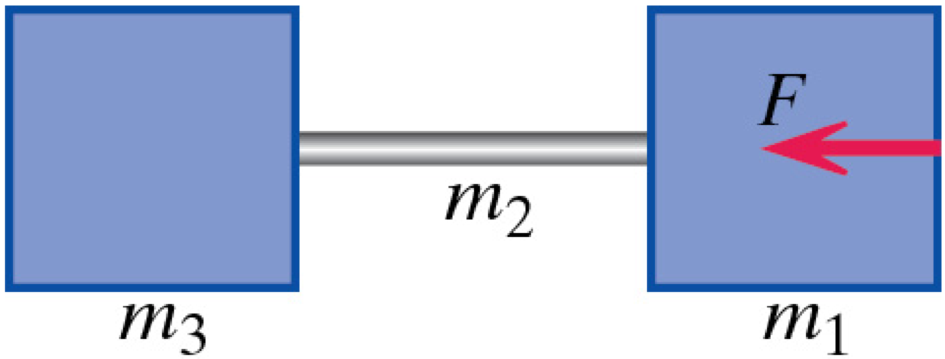

Figure 2: Blocks being pushed.

What is the net force acting on the right block (mass m_1)?

1. $m_1 F/(m_1 + m_2 + m3)$
2. $m_2 F/(m_1 + m_2 + m3)$
3. $m_3 F/(m_1 + m_2 + m3)$.
4. $(m_1 + m_2)F/(m_1 + m_2 + m3)$
5. $(m_1 + m_3)F/(m_1 + m_2 + m3)$
6. $(m_2 + m_3)F/(m_1 + m_2 + m3)$
7. F

Problem 3 (2.5 points) **Answer on Scantron form**

Figure 3 shows a portion of a graph of energy vs. time for a mass on a spring, subject to air resistance.

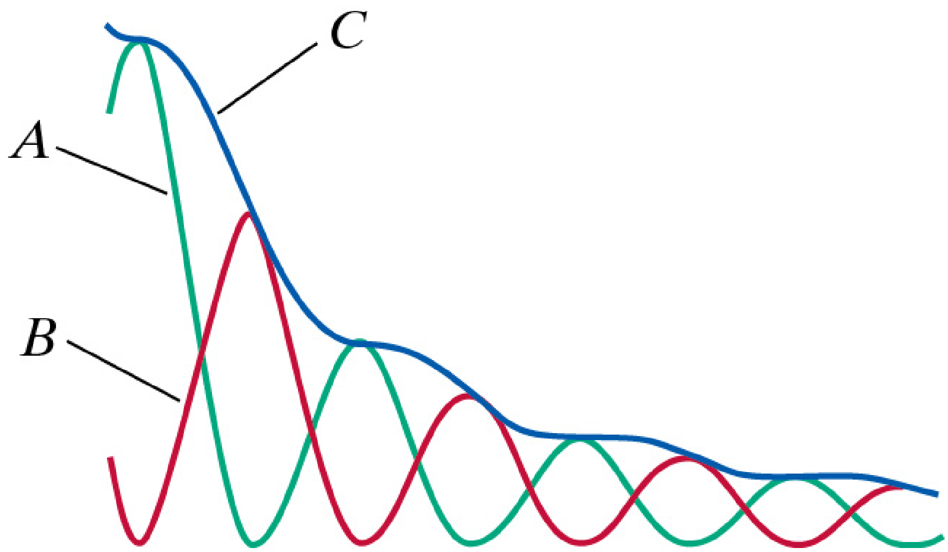

Figure 3: Energy curves for a mass on a spring.

Identify the three curves as to what kind of energy each represents.

1. A = Kinetic energy, B = Potential energy, C = Total energy.
2. A = Kinetic energy, C = Potential energy, B = Total energy.
3. B = Kinetic energy, C = Potential energy, A = Total energy.
4. B = Kinetic energy, A = Potential energy, C = Total energy.
5. C = Kinetic energy, A = Potential energy, B = Total energy.
6. C = Kinetic energy, B = Potential energy, A = Total energy.

Problem 4 (2.5 points) **Answer on Scantron form**

Figure 4 shows the potential energy distribution for the interaction of two neutral atoms. The two-atom system is in a vibrational state indicated by the the solid horizontal line.

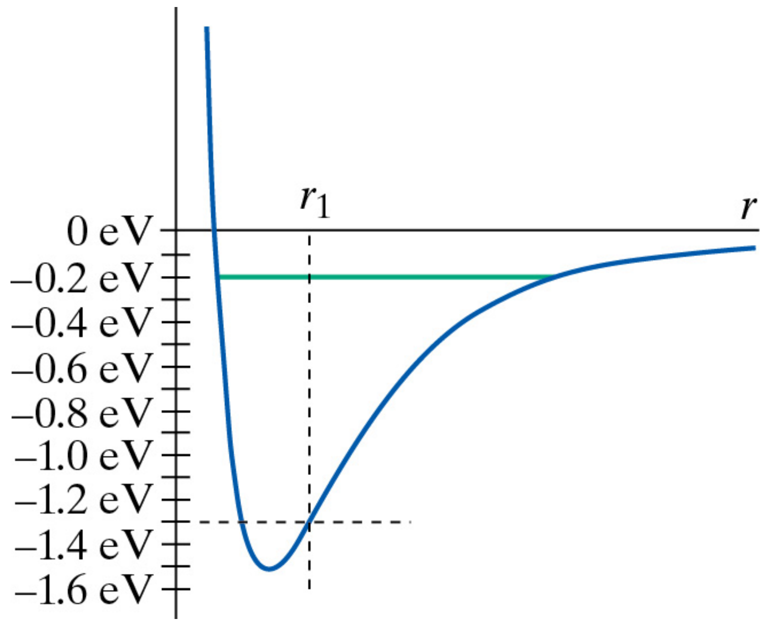

Figure 4: The potential energy distribution between two neutral atoms.

What is the minimum energy that must be supplied to cause the two atoms to separate when the system is in this vibrational state?

1. 0.1 eV.
2. 0.2 eV.
3. 0.4 eV.
4. 0.5 eV.
5. 0.6 eV.
6. 0.7 eV.
7. 0.9 eV.
8. 1.1 eV.
9. 1.3 eV.
10. 1.5 eV.

Problem 5 (2.5 points) **Answer on Scantron form**

Figure 5 shows the path of a comet orbiting a star.

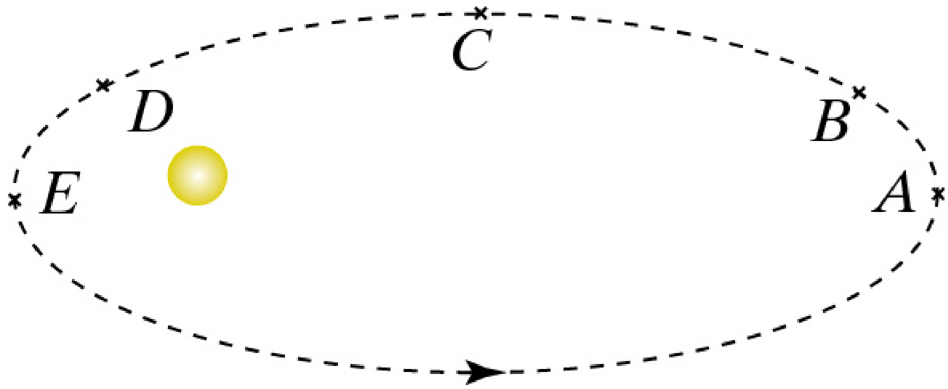

Figure 5: The path of a comet orbiting a star.

At what location on the path has the comet its lowest linear momentum?

1. A.
2. B.
3. C.
4. D.
5. E.

Problem 6 (2.5 points) **Answer on Scantron form**

Consider an electron moving from location A to location B in the vicinity of a proton that remains fixed at the origin of our coordinate system, as shown in Fig. 6.

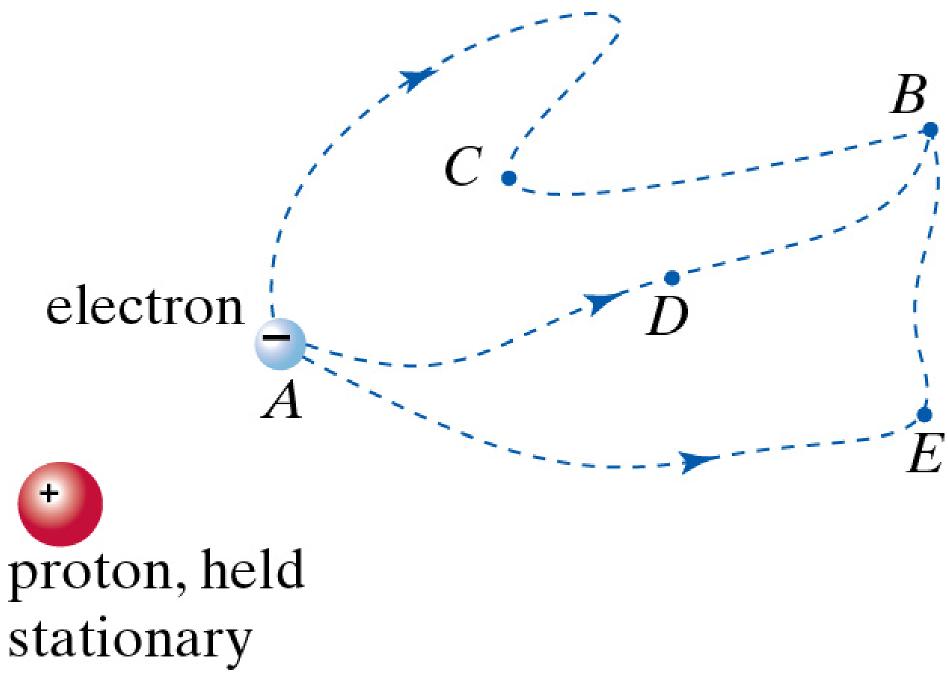

Figure 6: An electron moving in the vicinity of a proton.

Figure 6 shows three possible paths the electron can follow: the path that goes through location C, the path that goes through location D, and the path that goes through location E. Which path maximizes the magnitude of the work done by the electromagnetic force when the the electron moves from location A to location B?

1. The path through location C.
2. The path through location D.
3. The path through location E.
4. The work done is the same for all three paths.
5. Insufficient information available to answer this question.

Problem 7 (2.5 points) **Answer on Scantron form**

A proton moving in a magnetic field follows the curving path shown in Fig. 7, travelling at constant speed in the direction shown in Fig. 7. The dashed circle is the kissing circle tangent to the path when the proton is at location A. Refer to the directional arrows shown on at the right in Fig. 7 when answering this question.

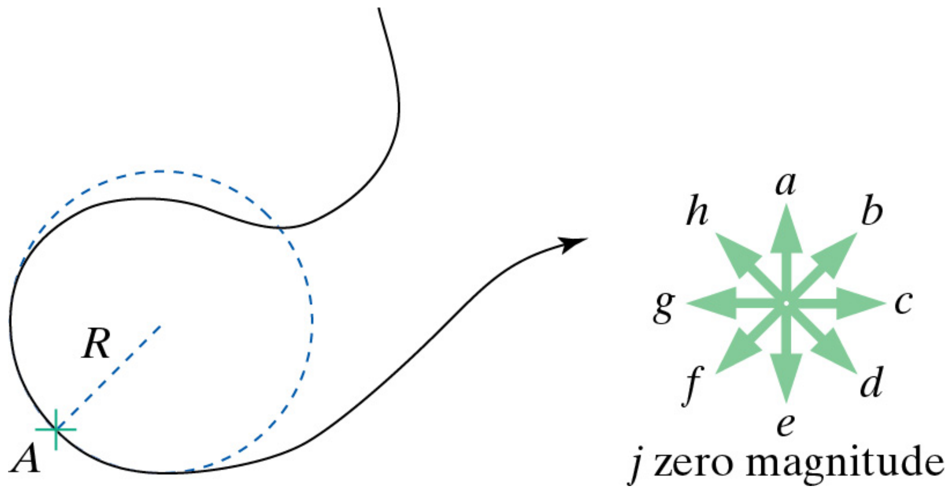

Figure 7: A proton moving in a magnetic field.

When the proton is at location A, what is the direction of $d\vec{p}/dt$?

1. Arrow a.
2. Arrow b.
3. Arrow c.
4. Arrow d.
5. Arrow e.
6. Arrow f.
7. Arrow g.
8. Arrow h.
9. Arrow j.

Problem 8 (2.5 points) **Answer on Scantron form**

You pull and push a sled through the snow with the same force F at the same angle θ, as shown in Fig. 8.

Figure 8: Pushing and pulling a sled.

In which situation (Fig. 8 left or Fig. 8 right) is the friction force between the sled and the snow the largest?

1. Figure 8 left.
2. Figure 8 right.
3. Insufficient information available to answer this question.

Problem 9 (2.5 points) **Answer on Scantron form**

You have two identical springs. When you hang a mass m from one of these springs, the equilibrium position of the system is a distance d below the equilibrium position when no mass is connected to the spring.

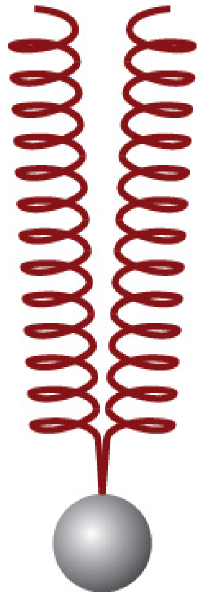

Figure 9: A parallel spring system.

Now you connect the two springs in parallel and connect a mass m to the end of the springs, as shown in Fig. 9. What is the displacement of mass m when it has reached its new equilibrium position?

1. $4d$
2. $2d$
3. $\sqrt{2}d$
4. d
5. $d/\sqrt{2}$
6. $d/2$
7. $d/4$

Problem 10 (2.5 points) **Answer on Scantron form**

Two springs with spring constants k_1 and k_2 are connected as shown in Fig. 10.

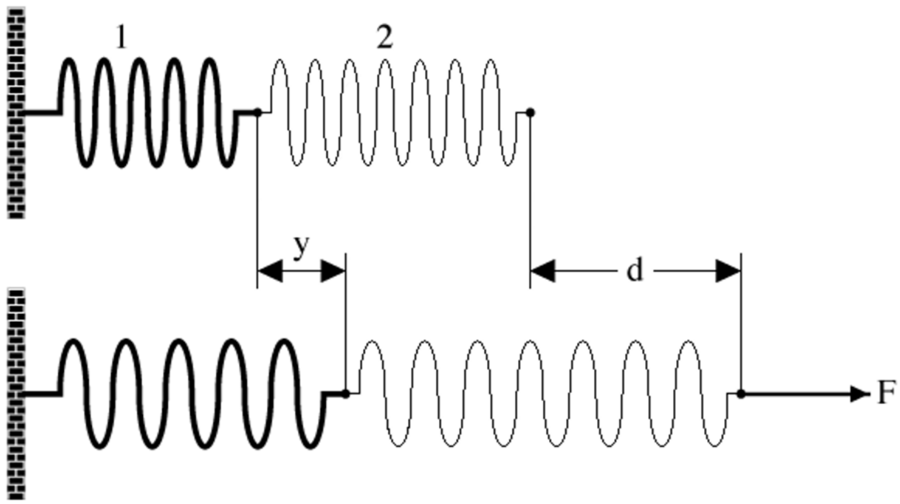

Figure 10: Two springs in series.

What is the displacement y of the connection point from its initial equilibrium position when the two springs are stretched a distance d as a result of the application of force F? You may assume that $d > y$.

1. $y = d\frac{k_1}{k_1+k_2}$
2. $y = d\frac{k_1}{k_2}$
3. $y = d\frac{k_2}{k_1+k_2}$
4. $y = d\frac{k_2}{k_1}$
5. d

Problem 11 (25 points) **Answer in booklet 1**

The Stanford Linear Accelerator Center (SLAC), located at Stanford University in Palo Alto, California and shown in Fig. 11, accelerates electrons through a vacuum tube of length L.

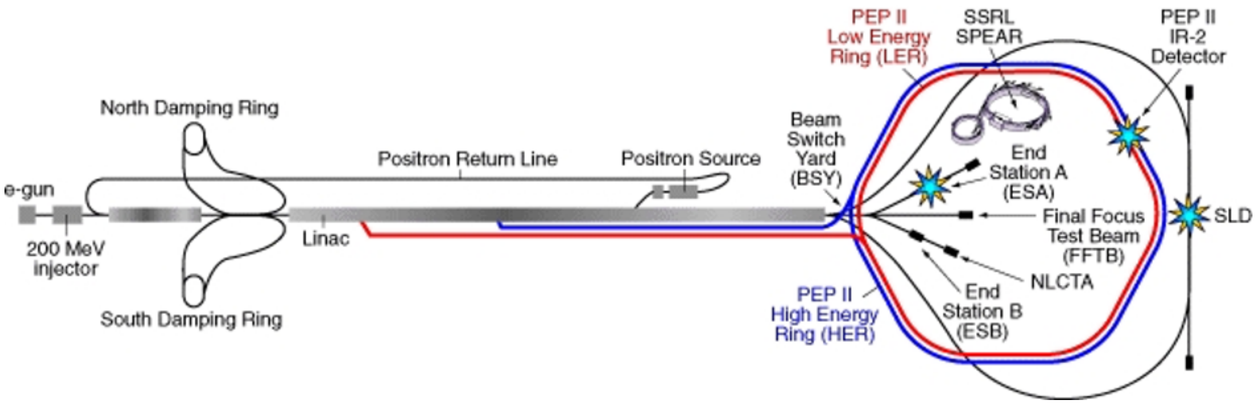

Figure 11: The Stanford Linear Accelerator Center (SLAC)

Electrons of mass m, which are initially at rest, are subjected to a continuous force F along the entire length L of the tube and reach speeds very close to the speed of light

a) **(5 points)** Calculate the final energy of the electrons.

b) **(5 points)** Calculate the final linear momentum of the electrons.

c) **(7.5 points)** Calculate the final speed of the electrons.

d) **(7.5 points)** Calculate the time required to travel the distance L.

Your answer needs to be well motivated and expressed in terms of the variables provided.

Problem 12 (25 points) **Answer in booklet 1**

An block of mass m is attached to two stretched springs (spring constants k and relaxed lengths L_0) to rigid walls as shown in Fig. 12.

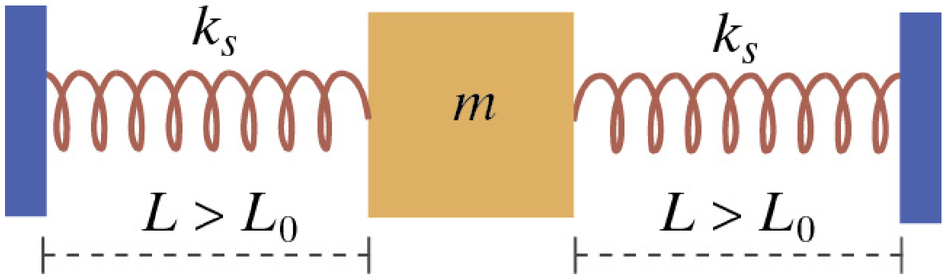

Figure 12: Mass oscillating between two springs.

The springs are initially stretched by an amount $L - L_0$. When the object is displaced to the right and released, it oscillated horizontally.

a) **(5 points)** When the block is displaced by a distance x, what is the net force acting on it? **You need to specify magnitude and direction.**

b) **(10 points)** Find the displacement of the block as function of time t, assuming it is released from rest at time $t = 0$ s with an initial displacement of x_0 from its equilibrium position.

c) **(5 points)** What is the period of the motion of the block?

d) **(5 points)** If the rest length L_0 of each spring were shorter, would the period be larger, smaller, or the same?

Your answer needs to be well motivated and expressed in terms of the variables provided.

Problem 13 (25 points) **Answer in booklet 2**

A block of mass m_2 is placed on top of a blocks of mass m_1, as shown in Fig. 13. A force F is applied to the right on the lower block, and the upper block slips on the lower block (the acceleration of the upper block is less than the acceleration of the lower block). The coefficient of kinetic friction between block m_2 and block m_1 is μ_2; the coefficient of kinetic friction between block m_1 and the floor is μ_1.

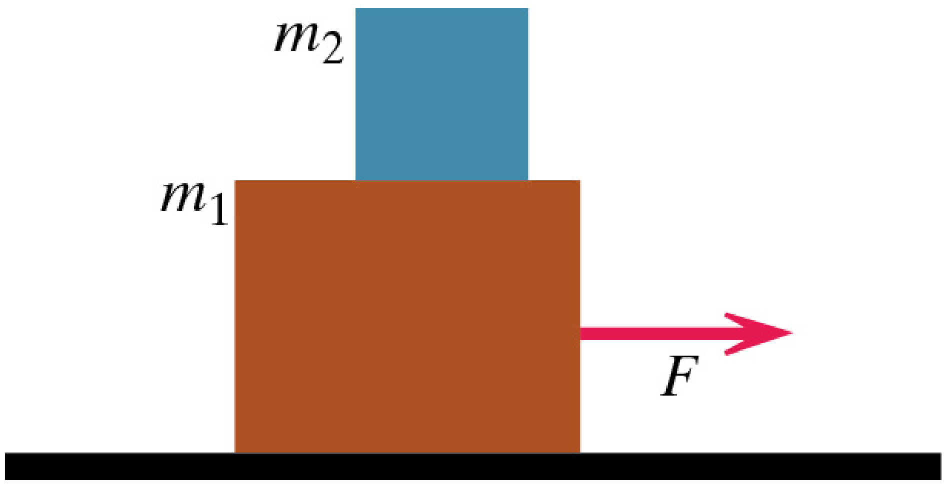

Figure 13: A force F applied to two stacked blocks

a) **(10 points)** What is the acceleration of the upper block? **You need to specify magnitude and direction.**

b) **(10 points)** What is the acceleration of the lower block? **You need to specify magnitude and direction.**

c) **(5 points)** How big would the coefficient of static friction between the upper and lower block have to be so that the upper block does not slip on the lower block when the force F is applied?

Your answer needs to be well motivated and expressed in terms of the variables provided.

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Figure 14: A dreamliner of the KLM that was delivered when the KLM celebrated its 100^{th} birthday in 2019. This photo was taken by Jeanie Wolfs on August 2^{nd}, 2024, at Schiphol. You can follow this airplane at https://www.flightaware.com/live/flight/PHBKA.