Solutions

Thursday, November 16, 2023 2:36 PM

Name:______________________________ ID:______________________________

Physics 201

Midterm 2

11/15/2023

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 60 minutes to complete this exam.

For questions 1 through 4 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **5** correct answers in this section and only the first **5** filled in answers will be graded. There is no partial credit.

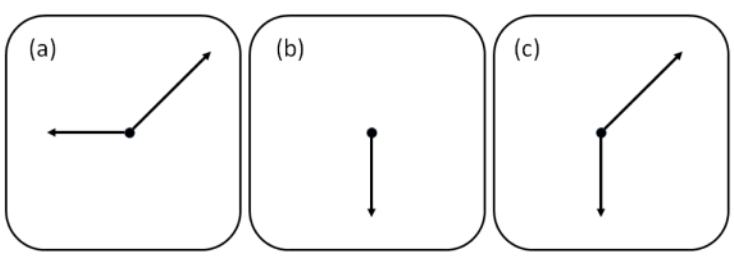
1. Which of the following statements must be true?

☑ (a) The normal force acting on an object is **never a third law force pair** with the gravitational force acting on the same object.
☐ (b) The normal force acting on an object is **never equal and opposite** to the gravitational force acting on the same object.
☐ (c) The normal force acting on an object is **always equal and opposite** to the gravitational force acting on the same object.
☐ (d) For a stationary object, the normal force acting on it is **equal and opposite** to the gravitational force acting on it.

2. Driving your car you hit an icy patch in the road experiencing very little friction. The road turns to the right but your car goes straight, sliding off the road. Which of the following statements are true regarding this situation?

☑ (a) This is an example of Newton's 1st law.
☐ (b) This is an example of Newton's 3rd law.
☐ (c) The car going off the road is due to the force of acceleration provided by the icy patch.
☐ (d) The car doesn't have inertia because it's moving.

For questions 3 and 4, please refer to the free body diagrams depicted below. You may assume that any vectors which look to be the same length are the same length. Assume a standard coordinate system.



3. Which of the free body diagrams show an object which must have **zero** acceleration in the x-direction?

☑ (a)

4. Which of the free body diagrams show an object which must have **zero** acceleration in the y-direction?

☐ (a)

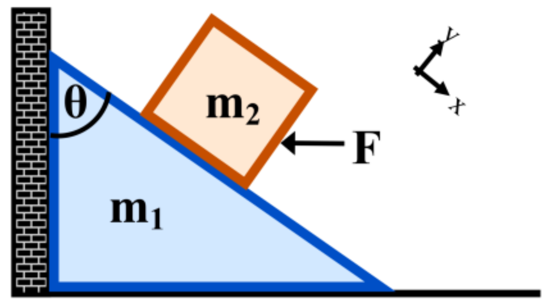
object which must have **zero** acceleration in the x-direction?

- ☑ (a)
- ☑ (b)
- ☐ (c)

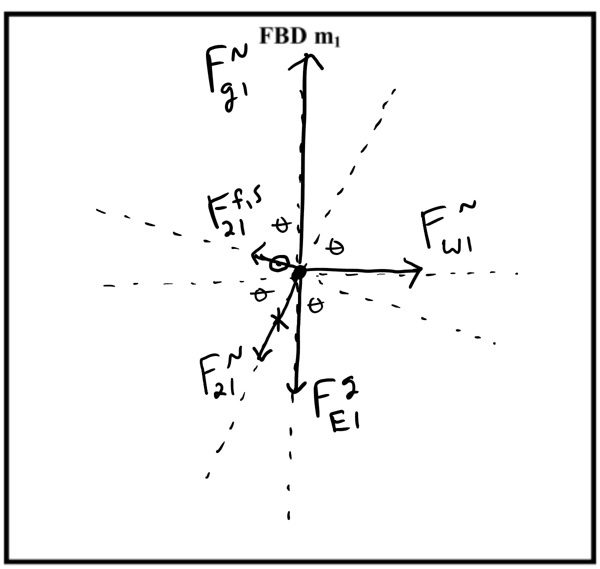
object which must have **zero** acceleration in the y-direction?

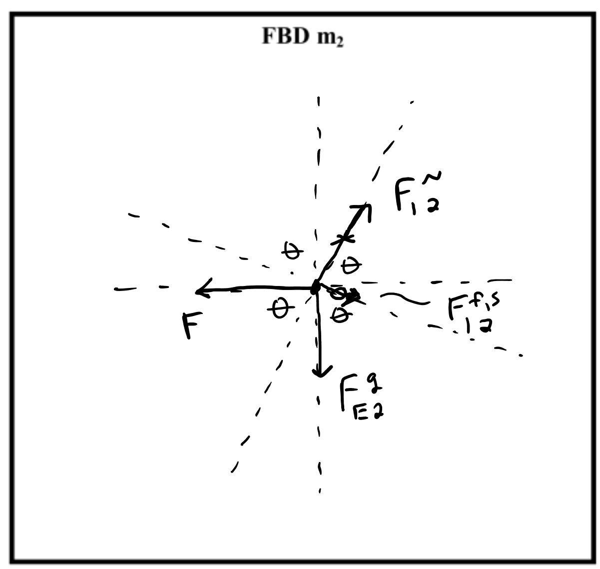
- ☐ (a)
- ☐ (b)
- ☑ (c)

5. (12 points) A square box (**m₂**) is sitting on top of a triangular wedge (**m₁**). The wedge sits on flat ground against an immovable wall and makes an angle of **θ** with respect to the vertical. There is a force **F** applied horizontally to the box, which if any stronger, would cause the box to slide up the wedge incline. The coefficient of static friction between the box and the wedge is **μ_s**. The entire system is in equilibrium on a planet with an acceleration due to gravity equal to **g**.



(a) Draw a free-body-diagram (FBD) for both the box and wedge separately. Make sure each FBD represents an object in equilibrium. Label any normal forces $\mathbf{F^N}$ and add two subscripts that indicate the agent acting on the object (for example: the normal force from the ground on m_1 would be F^N_{g1}).





(b) Identify all Newton's third law force pairs between the box and wedge. Be sure to identify both forces in each pair.

$\vec{F}^N_{21} = -\vec{F}^N_{12}$, $\vec{F}^{f,s}_{12} = -\vec{F}^{f,s}_{21}$

(c) Write out Newton's second law equation for the box in a rotated x and y coordinate system (as shown in the figure). Your equations for the x- and y-direction should be in terms of some or all of the variables given in the problem statement (**m₂**, **g**, **F**, **θ**, **μ_s**), as well as the normal force (**F^N_{12}**) from the FBD of the box. These should be the only variables in your final equation. You do not have to solve for anything.

$$\Sigma F_x = m a_x^{\,0} \Rightarrow \underbrace{m_2 g\cos\theta}_{F^g_x} + \underbrace{\mu_s F^N_{12}}_{F^{f,s}} - \underbrace{F\sin\theta}_{F_x} = 0$$

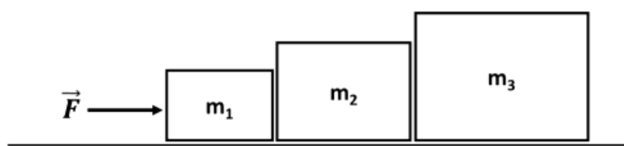
$$\sum F_x = m a_x^{\,0} \Rightarrow m_2 g\cos\theta + \mu_s F_{12}^N - F\sin\theta = 0$$

$$\sum F_y = m a_y^{\,0} \Rightarrow F_{12}^N - \underbrace{m_2 g\sin\theta}_{F_y^g} - \underbrace{F\cos\theta}_{F_y} = 0$$

Rubric

Part (a)	Part (c)
3 pts - FBD m_1: Identify forces, directions, labels, equilibrium 3 pts - FBD m_2: Identify forces, directions, labels, equilibrium **Part (b)** 1 pt - Force pairs	1 pt - 2nd law equation 2 pts - 2nd law applied to x: mg, components, friction in terms of $\mu * F^N$, acceleration = 0 2 pts - 2nd law applied to y: mg, components, acceleration = 0

6. (8 points) Three blocks of mass $\mathbf{m_1 = 1\ kg}$, $\mathbf{m_2 = 2\ kg}$, **and** $\mathbf{m_3 = 3\ kg}$ are initially placed at rest on a frictionless surface as shown. A constant force $\mathbf{F = 12\ N}$ is then applied to m_1. Please show your work for partial or full credit.

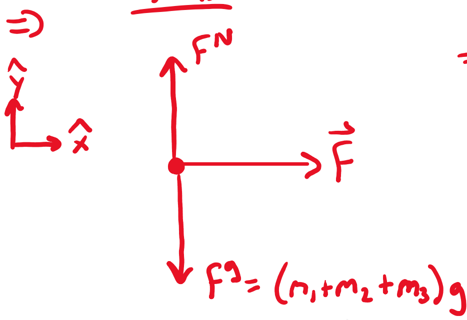


(a) What is the acceleration of $\mathbf{m_1}$?

$a_1 = a_2 = a_3 = a_{1+2+3}$

analyze system including all three blocks

$\Rightarrow$ FBD



$\Rightarrow$ x: $\sum F_x = m a_x$

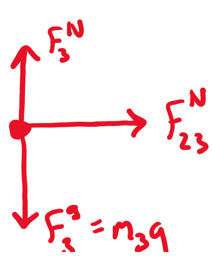
$+|\vec{F}| = (m_1+m_2+m_3)a_x$

$\Rightarrow a_x = \frac{12\ N}{6\ kg} = 2\ m/s^2$

$\Rightarrow \boxed{a_1 = 2\ m/s^2}$

(b) What is the magnitude of the normal force from $\mathbf{m_3}$ which pushes back onto $\mathbf{m_2}$?

FBD 3



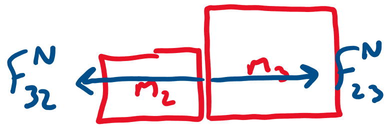
$\Rightarrow$ x: $\sum F_x = m_3 a_3$

$F_{23}^N = m_3 a_3$

$F_{23}^N = (3\ kg)(2\ m/s^2) = 6\ N$

$\downarrow F_3^g = m_3 g$

$F_{23}^N = (3\,kg)(2\,m/s^2) = 6N$



$\Rightarrow$ third law force pair

$$\Rightarrow F_{23}^N = \boxed{F_{32}^N = 6N}$$

★ note: we could also approach this problem by analyzing m_1

$\Rightarrow \Sigma F_x = m_1 a \Rightarrow |\vec{F}| - |F_{21}^N| = m_1 a$ to find $|F_{21}^N|$, then analyze m_2

$\Rightarrow \Sigma F_x = m_2 a \Rightarrow |F_{12}^N| - |F_{32}^N| = m_2 a$ to find $F_{32}^N = 6N$