

As with the first exam, you should be able to complete the exam in 50 minutes. However, if you need more time, you are free to stay after class if you'd like. If you anticipate needing more time and cannot stay (due to other classes or conflicts), let me know and perhaps we can work something out (e.g., you can start the exam earlier).

Please email me if you have questions about the exam.

Section A

When working on these, do not spend too much time on each one. A minute or two should be sufficient. You need to leave some time for section B. Remember that you can select two choices if you'd like (and receive half-credit if one of them is correct).

1. c (With a typical mass of around 70 kg and using a value of 9.8 N/kg for g , one gets a gravitational force of about 700 N; from Newton's third law, the gravitational force on me due to the Earth is equal in magnitude and opposite in direction to the gravitational force on the Earth due to me)
2. a (The only force acting in the gravitational force and since the height is small compared to the radius of the Earth the gravitational force won't vary during the flight)
3. e (This is what Newton's third law describes; remember that the effect on each person will be different)
4. b (This is the only value that makes sense, as it is the only one that is small and it is the only one that has the appropriate units; keep in mind that the value of G is universal)
5. c (Once the ball leaves the thrower's hand, there is no longer a force exerted by the thrower on the ball)
6. b (Same reasoning as question 2)
7. c (The tension force is always parallel to the string and away from the object being pulled)
8. e (The coefficient is defined as the ratio of the friction force divided by the normal force; the ratio is unitless)

9. c (we call that force the friction force)
10. c (the key point here is that the elevator is moving at a constant speed and direction, which means the net force on the elevator must be zero; note that to $|i|_{\text{start}}|i|_{\text{end}}$ the elevator moving upward the tension needs to be greater than the gravitational force, but the problem doesn't ask about that)
11. e (there is no force pushing the ball toward the back of the cart; it moves to the back because the cart moved forward)

Section B

1. First, you need to recognize that in addition to the four forces listed there is also a gravitational force (due to the Earth). The magnitude of that force is equal to the object's mass (5 kg) times the conversion of 9.8 N/kg. It is directed downward. That means there is a fifth force equal to 49 N directed downward.

Second, notice that the fourth force is upward (not toward the north) and has a magnitude equal to the gravitational force. Since they are opposite in direction, those two forces will exactly cancel and we are only left with forces F_1 , F_2 and F_3 .

To find the net force, we want to add those three together. To add forces in two dimensions, we must first convert each force into two perpendicular components. At this point, you can choose whatever two component directions you want, as long as they are perpendicular. I'll choose east and north and indicate them as \hat{x} and \hat{y} , respectively.

Relative to my coordinate system, and using 0° and 90° for the \hat{x} and \hat{y} directions, respectively, I can determine the component values of each force as follows:

$$\begin{aligned}
 F_{1,x} &= (10 \text{ N}) \cos 20^\circ = 9.397 \text{ N} \\
 F_{1,y} &= (10 \text{ N}) \sin 20^\circ = 3.420 \text{ N} \\
 F_{2,x} &= (20 \text{ N}) \cos 300^\circ = 10.000 \text{ N} \\
 F_{2,y} &= (20 \text{ N}) \sin 300^\circ = -17.320 \text{ N} \\
 F_{3,x} &= (30 \text{ N}) \cos 220^\circ = -22.981 \text{ N} \\
 F_{3,y} &= (30 \text{ N}) \sin 220^\circ = -19.284 \text{ N}
 \end{aligned}$$

The method you choose may be different, depending on your preferences. However, once the components are determined, you can then add up all the x components to get

$$F_{\text{net},x} = -3.584 \text{ N}$$

and add up all the y components to get

$$F_{\text{net},y} = -33.184 \text{ N}.$$

Notice that both components are negative, which means that the net force is directed west and south rather than east and north.

To get the magnitude, use

$$\begin{aligned} F_{\text{net}} &= \sqrt{F_{\text{net},x}^2 + F_{\text{net},y}^2} \\ &= \sqrt{(-3.584 \text{ N})^2 + (-33.184 \text{ N})^2} \\ &= 33.377 \text{ N}. \end{aligned}$$

To get the direction, use one of the inverse trigonometric functions. For example,

$$\begin{aligned} \hat{F}_{\text{net}} &= \cos^{-1}\left(\frac{F_{\text{net},x}}{F_{\text{net}}}\right) \\ &= \cos^{-1}\left(\frac{-3.584 \text{ N}}{33.377 \text{ N}}\right) \\ &= 96.165^\circ. \end{aligned}$$

As always, when using the inverse trigonometric functions, we should interpret the answer and make sure the calculator has given us the appropriate direction. In this case, we know that the actual direction must be opposite this, since both components are negative. Thus, the direction is 264° (in my coordinate system) or 6° west of south.

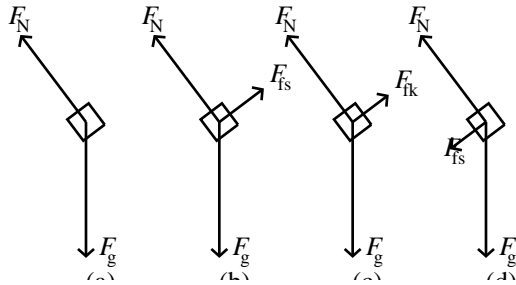
2. (a) To determine the gravitational force, use Newton's universal law of gravitation:

$$F_g = G \frac{m_1 m_2}{r^2}$$

where G is equal to $6.67390 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$, m_1 and m_2 refer to the masses of the two interacting objects (the Earth and the astronaut in

this case) and r is the distance between their two centers, which in this case is the radius of the Earth (6.371×10^6 m) plus the height of the astronaut above the Earth's surface (350 km, or 3.5×10^5 m). Plugging in, I get a force of 618 N, where I used the mass of the Earth from the appendix and the mass of the astronaut given in the problem.

(b) For this part, I could redo the problem without the added 350 km to the distance or I could just use the simplified version of the gravitation law with g equal to 9.8 N/kg. Doing the latter, I get 686 N (using the former, I get 688 N).



3.

4. (a) If there is no friction then the normal force (F_N in the figure) will exactly counter the portion of the weight (F_g in the figure) that is into the incline. The only force that is unbalanced is the portion of the F_g that is down the incline. To find that component, first find the weight by using $W = mg$ (where g is 9.8 N/kg). That gives 98 N. Then, find the portion of that which is directed down the ramp ($F_g \sin \theta$, where θ is 37° in this case). That gives 58.8 N (down the ramp). Since that is the only unbalanced force, that is also the net force.
- (b) If it doesn't slide, the friction must be balancing the result found in (a). So the answer here is 58.8 N (up the ramp).
- (c) The coefficient is the ratio of the friction to the normal force. We've already found the friction. To find the normal force, first realize that the normal force must balance the other component of the weight ($F_g \cos \theta$ in this case). This gives a value of 78.4 N (perpendicular and away from incline surface).