Last names	Section	Date	Score
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Phys 20.01 Group homework 2

R. Torres

2025 W39

Instructions: For comprehension and conceptual questions, choose the best answer. For problem-solving questions, choose the best answer and show your solution and reasoning. Comprehension is 1 pt each, conceptual is 2 pt each, and problem-solving is 3 pt each.

1. Comprehension

1. What is dynamics?
   a. It is the study of internal forces
   b. It is the study of forces and their effect on motion
   c. It describes the motion of points, bodies, and systems without consideration of the cause of motion
   d. It describes the effect of forces on each other

2. How do you express, mathematically, that no external force is acting on a body?
   a. $\sum F = -1$
   b. $F_{\text{net}} = 0$
   c. $F_{\text{tot}} = 1$
   d. $\sum F = \infty$

3. Which forces cause changes in the motion of a system?
   a. internal forces
   b. external forces
   c. both internal and external forces
   d. neither internal nor external forces

4. The Cavendish experiment marked a milestone in the study of gravity. What important value did the experiment determine?
   a. It measured the acceleration due to gravity
   b. It measured the gravitational constant
   c. It measured the mass of the earth
   d. It directly verified Newton's law of gravitation

5. A rubber ball is thrown horizontally against a brick wall and bounces directly back. At the instant the ball is in contact with the wall, what is the primary direction of the force exerted by the wall on the ball?
   a. Downward, due to gravity
   b. To left, in the direction the ball was initially traveling
   c. To right, away from the wall
   d. Upward, counteracting the ball's weight

6. Which statement is most accurate concerning the forces that should be included in a free-body diagram of a chosen object?
   a. Only forces exerted by the object on its surroundings
   b. Only forces exerted on the object by its surroundings
   c. All forces, both those exerted by the object and on the object, to ensure a complete analysis
   d. Only forces causing object to accelerate; other forces can be ignored for simplicity

7. A crate is resting on the floor of an elevator that is accelerating upwards. When drawing a free-body diagram for the crate, which forces should be included?
   a. Weight of crate and the force elevator exerts on crate
   b. Weight of crate and the force elevator exerts on crate, as well as an additional upward force representing crate's acceleration
   c. Only force elevator exerts on crate, as the weight of crate is an internal force
   d. Weight of crate, the force elevator exerts on crate, and the net force, as net force is key to understanding crate's motion

8. Which statement best describes how the laws of motion behave within inertial frames of reference?
   a. These laws are valid only within a single, uniquely defined inertial frame of reference that is absolutely stationary in the universe
   b. These laws are valid in all inertial frames of reference, regardless of relative velocities, but require adjustments or corrections to account for motion
   c. These laws are valid in all inertial frames of reference moving at constant velocity relative to each other, without need for any additional corrections
   d. These laws are only valid within inertial frames that are not accelerating. In accelerating frames, fictitious forces must be introduced to maintain validity

9. Which statement best describes how Newton's third law relates to forces acting on a system of interest?
   a. It directly describes how external forces cancel out when acting on a system, resulting in equilibrium
   b. It describes equal and opposite internal forces in a system, which are primary drivers of system's motion
   c. It describes relationship between a force the system exerts on its environment and the equal and opposite force the environment exerts back on the system
   d. It only applies to systems that are isolated and not subject to any external forces

10. Which statement best describes the relationship between Newton's first and second laws of motion?
    a. Second law is entirely independent of first law. they describe separate and unrelated aspects of motion

b. First law is a special case of second law where the net force acting on an object is zero, leading to constant velocity
c. First law provides a method to calculate force needed to change the velocity of an object, and then second law will show how the object reacts to the force
d. First law explains why objects resist changes in their state of motion, while second law explains how this resistance affects the acceleration of the object

2. Conceptual

1. The tires you choose to drive over icy roads will create more friction with the road than your summer tires. Give another example where more friction is desirable.
   a. Children's slide
   b. Air hockey table
   c. Ice-skating rink
   d. Jogging track

2. Titan, with a radius of 2.58×10^6 m, is the largest moon of the planet Saturn. If the mass of Titan is 1.35×10^{23} kg, what is the acceleration due to gravity on the surface of this moon?
   a. 1.35 m/s^2
   b. 3.49 m/s^2
   c. 3.49×10^6 m/s^2
   d. 1.35×10^6 m/s^2

3. An object is suspended from a rope and is in equilibrium. Which statement best describes the forces acting on the object?
   a. The object experiences no force due to gravity because it is being supported by the rope
   b. The object experiences a downward force due to gravity, which is balanced by an equal and opposite upward force from the rope
   c. The object experiences only an upward force from rope. The force of gravity is negligible in this scenario
   d. The object experiences a downward force due to gravity that is greater than the upward force from the rope, but the rope is strong enough to prevent the object from falling

4. A child pushes a toy car across a smooth, level floor. The child applies a constant horizontal force to the car until the car reaches a certain speed. At that point, the child removes their hand from the car, but the car continues to move forward for a short distance before eventually coming to a stop. Which statement best explains the forces acting on the car immediately after the child's hand is removed?
   a. The force from the child's hand is still acting on the car, gradually decreasing until the car stops
   b. The only force acting on the car is the force from the child's hand, pushing it forward
   c. The car experiences a forward force equal to its mass times its velocity, keeping it in motion until this motional force dissipates
   d. The car continues moving forward due to its inertia, while frictional forces act on the car, gradually slowing it down. The force from the child's hand is no longer present

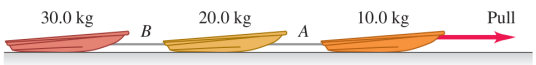
5. A house cat typically weighs 45 N. How many pounds does it weigh, and what is its mass in kilograms?
   a. 10.1 lbs, 4.59 kg
   b. 10.1 lbs, 45 kg
   c. 20.2 lbs, 4.59 kg
   d. 20.2 lbs, 45 kg
   e. 45 lbs, 4.59 kg

6. A car stopped because of the second and third laws. During impact, the car exerted a force on the tree. As per third law, the tree exerted an equally strong force back on the car. As per second law, the force of the tree on the car gave the car an acceleration that changed its velocity to zero. Considering this explanation, which of law is more to blame for the car coming to a stop?
   a. Third law is most responsible, as it describes force exerted by the tree, which directly stopped the car
   b. First law (inertia) is most to blame, as the car's tendency to continue moving forward is what made the collision and subsequent stopping necessary
   c. Second law is most responsible, as it directly links the force exerted on the car to the change in its velocity, causing it to stop. Third law simply describes the interaction
   d. Both second and third laws are equally to blame, as they are both essential for the car to come to a stop

7. An ordinary flea has a mass of 210 mg. How many newtons does it weigh?
   a. $2.06 \times 10^{-3} N$
   b. $2.06 \times 10^{-6} N$
   c. $2.06 \times 10^{-9} N$
   d. 2.10 N

8. The mass of a typical froghopper is 12.3 mg. How many newtons does it weigh?
   a. 12.3 N
   b. 1.20×10^{-7} N
   c. 1.20×10^{-5} N
   d. 1.20×10^{-4} N

9. Three sleds are being pulled horizontally on frictionless horizontal ice using horizontal ropes. The pull is of magnitude 190 N. Find the acceleration of the system.



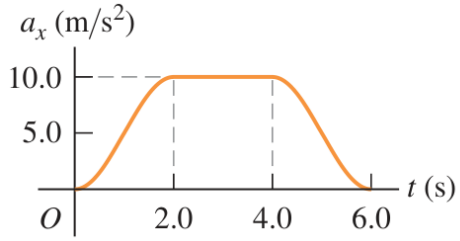
   3.17 m/s^2

10. Using the same figure, calculate the tension in ropes A and B.

    $T_B = 95$ N, $T_A = 158.3$ N

11. A 4.50 kg experimental cart undergoes an acceleration in a straight line (the x-axis). The graph in shows this

acceleration as a function of time. Find the maximum net force on this cart. When does this max force occur?



$F_{max} = 45$ N, from $t = 2$ s to $t = 4$ s

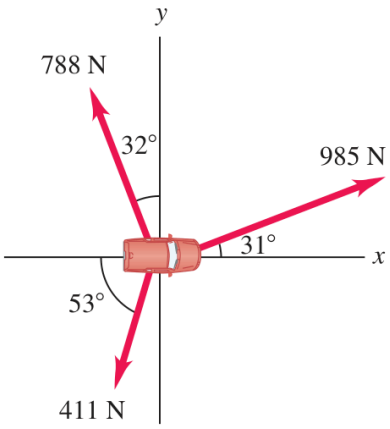
12. Using the same figure, during what times is the net force on the cart a constant?

from $t = 2$ s to $t = 4$ s

13. Using the same figure, when is the net force equal to zero?

at $t = 0$ s and $t = 6$ s

14. To extricate an SUV stuck in the mud, workmen use three horizontal ropes, producing the force vectors shown in the figure. Find the x- and y-components of each of the three pulls.



$F_{1x} = 844$ N, $F_{2x} = -418$ N, $F_{3x} = -247$ N
$F_{1y} = 507$ N, $F_{2y} = 668$ N, $F_{3y} = -328$ N

15. Using the same figure, use the components to find the magnitude and direction of the resultant of three pulls.

$$R_x = F_{1x} + F_{2x} + F_{3x} = 179 \text{ N}$$
$$R_y = F_{1y} + F_{2y} + F_{3y} = 847 \text{ N}$$
$$R = \sqrt{R_x^2 + R_y^2} = 866 \text{ N}$$

$$\tan\theta = \frac{R_y}{R_x} \implies \theta = \tan^{-1}\frac{R_y}{R_x} = 78.1°$$

3. Problem solving

1. **Forces on a dancer's body.** Dancers experience large forces associated with the jumps they make. For example, when a dancer lands after a vertical jump, the force exerted on the head by the neck must exceed the head's weight by enough to cause the head to slow down and come to rest. The head is about 9.4% of a typical person's mass. Video analysis of a 65 kg dancer landing after a vertical jump shows that her head decelerates from 4.0 m/s to rest in a time of 0.20 s.

   a. What is the magnitude of the average force that her neck exerts on her head during the landing?

   Average acceleration of neck is

   $$a_{neck} = \bar{a} = \frac{\Delta v}{\Delta t} = \frac{4 \text{ m/s}}{0.2 \text{ s}} = 20 \text{ m/s}^2.$$

   Two vertical forces act on the head:

   $$ma = \sum F = F_{neck} + (-mg)$$
   $$F_{neck} = m(g + a) = (0.094)(65 \text{ kg})[(9.8 + 20) \text{ m/s}^2]$$
   $$= 180 \text{ N}$$

   b. Describe the relationship between the force her neck exerts on her head during landing and the force her head exerts on her neck.

   The force her neck exerts on her head during landing and the force her head exerts on her neck are an action-reaction pair that are equal in magnitude but opposite in direction, as per Newton's third law.

2. **Friction and climbing shoes.** Shoes made for the sports of bouldering and rock climbing are designed to provide a great deal of friction between the foot and the surface of the ground. Such shoes on smooth rock might have a coefficient of static friction of 1.2 and a coefficient of kinetic friction of 0.90.

   a. Describe the factors that determine the maximum angle (with respect to the horizontal) of the rock that the person can walk on without slipping

   It is determined solely by the coefficient of static friction (μs) between the shoe and the rock surface. It does not depend on the mass of the person or the gravitational acceleration.

   b. Describe what will happen to person's motion. Consider how forces acting on person change as they transition from state of static equilibrium to motion

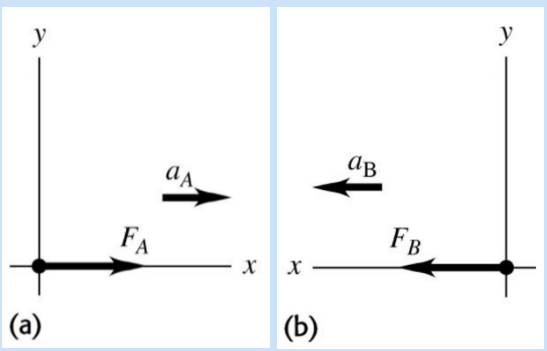
   If the angle of the rock surface exceeds the maximum possible angle for static equilibrium (determined by μ_s), or if an external force causes the person to start moving, the person will slide down the rock surface.

3. **Biceps muscle.** A relaxed biceps muscle requires a force of 25.0 N for an elongation of 3.0 cm. The same muscle under maximum tension requires a force of 500 N for the same elongation. Find Young's modulus for the muscle tissue under each of these conditions if the muscle is assumed to be a uniform cylinder with length 0.200 m and cross-sectional area 50.0 cm^2.

relaxed: 3.3×10^4 Pa, under max tension: 6.7×10^5 Pa

4. **Rendezvous in space!** A couple of astronauts agree to rendezvous in space after hours. Their plan is to let gravity bring them together. One of them has a mass of 65 kg and the other a mass of 72 kg, and they start from rest 20.0 m apart.

a. Make a free-body diagram of each astronaut, and use it to find his or her initial acceleration. As a rough approximation, we can model the astronauts as uniform spheres.



$$F_A = F_B = G\frac{m_A m_B}{r^2}$$

$$= (6.673 \times 10^{-11}\ \text{N m}^2/\text{kg}^2)\frac{(65\ \text{kg})(72\ \text{kg})}{(20\ \text{m})^2}$$

$$= 7.807 \times 10^{-10}\ \text{N}$$

$$a_A = \frac{7.807 \times 10^{-10}\ \text{N}}{65\ \text{kg}} = 1.2 \times 10^{-11}\ \text{m/s}^2$$

$$a_B = \frac{7.807 \times 10^{-10}\ \text{N}}{72\ \text{kg}} = 1.1 \times 10^{-11}\ \text{m/s}^2$$

b. Would their acceleration, in fact, remain constant? If not, would it increase or decrease? Why?

Their acceleration would not remain constant. it would increase as they get closer to each other, as per Newton's law of gravitation.