DIGGING DEEPER EXERCISE 4

EXERCISE 4A: BINDER QUESTIONS

Question 1

Two ropes are tied to a ring and pulled in different directions. A third rope must be attached to keep the ring in equilibrium. Explain why the direction of the third rope is uniquely determined by the first two ropes.

Question 2

In an Atwood machine with two unequal masses, the lighter mass accelerates upward. Explain why the tension in the string is **not** equal to the weight of either mass.

Question 3

A block on an inclined plane experiences a normal reaction perpendicular to the surface. Explain why the normal reaction is less than the block's weight.

Question 4

When you stand in a lift that accelerates upward, you feel heavier. Explain what actually changes and what remains constant.

Question 5

Two blocks are connected by a string on a horizontal surface. When pulled by a force F, they accelerate together. Explain why the string tension is less than the applied force F.

Question 6

A block rests on a rough inclined plane at angle θ below the critical angle. Explain why friction acts up the slope even though no other force is pulling the block upward.

Question 7

In a pulley system, the string is described as "light and inextensible." Explain the physical significance of each of these terms.

Question 8

A car tows a trailer on a horizontal road. The tension in the tow-bar is less when traveling at constant velocity than when accelerating. Explain why.

Question 9

A student writes: *"Tension always equals weight for a hanging object."* Give a counter-example using a system in equilibrium and explain why tension can differ from weight.

Question 10

Two strings hold a load at a junction. One string is closer to horizontal than the other. Without calculation, explain which string must have the larger tension and why.

EXERCISE 4B: REAL QUESTIONS

Question 11

A market vendor in Kariakoo hangs a 20 kg bag of rice from a ceiling hook using a single rope. The rope makes a V-shape with both sides going up to the same hook. Explain why the tension in each side of the rope is greater than half the weight of the bag.

Question 12

A bus traveling from Dar es Salaam to Mwanza carries luggage on the roof rack. The ropes tying down the luggage must be tightened periodically during the journey. Explain why the ropes become loose even without any luggage shifting position.

Question 13

Kipute and Kipanga are helping load maize sacks onto a pickup truck using a wooden plank as a ramp.

Kipanga: *"Let's make the ramp steeper; it's shorter, so we'll move the sacks faster!"*

Kipute: *"But won't a steeper ramp make it harder to push the sacks up?"*

Mr. Akilikubwa: *"Kipute has a good point. Let me ask you both: what happens to the force needed to push a sack up the ramp as we increase the angle?"*

Explain why a steeper ramp requires more force to push the same sack at constant velocity, even though the distance is shorter.

Question 14

A traditional water well uses a rope over a pulley to raise a bucket. An experienced well user knows to pull the rope smoothly and steadily rather than in quick jerks. Explain why jerking the rope increases the risk of the rope breaking.

Question 15

A daladala climbs a steep road while carrying many passengers. When it stops on the slope, the driver says, *"If the handbrake is weak, the bus will slide even if the engine is off."* Explain what force must act to prevent sliding and why it is required even when the bus is at rest.

Question 16

Kipanga leans a wooden plank against a rough wall. Sometimes it slips down, but when he pushes the bottom of the plank harder into the floor, the plank stops slipping. Explain why pressing harder can help prevent slipping.

Question 17

A lorry carrying sand is tied down using a rope that slopes downward toward the trailer. The driver claims: *"The rope helps in two ways: it stops the load from sliding sideways and also presses it down more firmly."* Explain how one rope can do both jobs at the same time.

Question 18

A signboard is fixed to a wall using a hinge and supported by a cable at an angle. When the cable is removed, the signboard falls. Explain why the hinge alone cannot keep the signboard in equilibrium.

EXERCISE 4C: HOT QUESTIONS

Take g = 9.8 m/s²

Question 19

A picture frame of mass 2.5kg is suspended from a nail by a string. The string makes an angle of 35° with the vertical on each side of the nail. Calculate:

(a) The tension in the string

(b) The horizontal force exerted by the nail on the string.

Question 20

An Atwood machine consists of masses 4kg and 7kg connected by a light inextensible string over a smooth pulley. The system is released from rest. Calculate:

(a) The acceleration of the system.

(b) The tension in the string.

(c) The distance traveled by the 7kg mass in the first 2 seconds.

Question 21

Two blocks of masses 6kg and 4kg are connected by a light string on a smooth horizontal table. A horizontal force of 35N is applied to the 6kg block.

(a) Calculate the acceleration of the system.

(b) Calculate the tension in the connecting string.

(c) If the surface had coefficient of kinetic friction 0.3, what would be the new acceleration?

Question 22

A block of mass 8 kg rests on an inclined plane at 25° to the horizontal. The coefficient of static friction is 0.45 and the coefficient of kinetic friction is 0.35.

(a) Determine whether the block remains at rest or slides down.

(b) If a force of 40N is applied parallel to and up the incline, calculate the acceleration of the block.

Question 23

An Atwood machine has masses m_1 = 2 kg and m_2. When released, the system accelerates at 2.5m/s² and m_2 moves downward.

(a) Calculate the mass m_2.

(b) The tension in the string.

(c) If the initial separation between the masses is 3m, how long until they are at the same height?

Question 24

A lift of mass 800 kg carries 4 passengers each of mass 70kg. Calculate:

(a) The tension in the lift cable when accelerating upward at 1.5m/s²

(b) The tension when moving upward at constant velocity of 3m/s

(c) The tension when decelerating at 2m/s² while moving upward.

Question 25

Two blocks **A** (5kg) and **B** (3kg) are connected by a string. Block **A** is on a smooth horizontal table and block **B** hangs over the edge via a pulley. Block **B** is initially held at rest 2m above the ground. When released:

(a) Calculate the acceleration of the system.

(b) Calculate the velocity of **B** just before it hits the ground.

(c) How far does **A** travel before **B** hits the ground?

Question 26

Three blocks of masses 2kg, 3kg, and 4kg are connected by light inextensible strings on a smooth horizontal surface. A force of 45N is applied to the 2kg block. Calculate:

(a) The acceleration of the system.

(b) The tension in the string between the 2kg and 3kg blocks.

(c) The tension in the string between the 3kg and 4kg blocks.

Question 27

Two blocks lie on smooth opposite inclines and are connected by a light string over a smooth pulley. Block A has mass 10kg on a 35° incline. Block B has mass 8kg on a 25° incline. An additional force P is applied to block A parallel to the plane to keep the system in equilibrium. Find:

(a) the tension in the string,

(b) the magnitude and direction of P (state whether it acts up or down the plane on A).

Question 28

A 8kg block rests on a smooth plane inclined at 30° and is connected by a light string over a smooth pulley to a hanging 6kg mass. The system is in equilibrium due to friction between the block and the plane. Find:

(a) the tension in the string,

(b) the frictional force on the block (magnitude and direction along the plane),

(c) the minimum coefficient of friction required.

Question 29

A load of 120 N is suspended from a junction by two light strings. The string on the left makes an angle of 30° with the horizontal, while the string on the right makes an angle of 45° with the horizontal.

(a) Without calculation, state which string has the greater tension, and why this is expected.

(b) Calculate the tension in each string.

Question 30

A person stands on a weighing scale in a lift. The scale reading is 20% greater than the person's true weight.

(a) Determine the acceleration of the lift and state its direction.

(b) If the person's mass is 75kg, calculate the force exerted by the scale on the person.

ANSWERS TO DIGGING DEEPER EXERCISE 4

EXERCISE 4A

1. For equilibrium, the vector sum of all forces must be zero. The first two ropes create a resultant force (found by vector addition). The third rope must provide a force equal in magnitude but opposite in direction to this resultant. Therefore, the third rope's direction is uniquely determined as opposite to the resultant of the first two forces.

2. The tension is not equal to either weight because both masses are accelerating. For the heavier mass (accelerating downward), tension must be less than its weight to allow net downward force. For the lighter mass (accelerating upward), tension must be greater than its weight to allow net upward force. The tension has a single value throughout the string that is intermediate between the two weights, allowing both masses to accelerate at the same rate in opposite directions.

3. The normal reaction equals the component of weight perpendicular to the incline surface, which is mgcosθ. This is less than the full weight mg because the weight vector is resolved into two components: one perpendicular to the surface (mgcosθ) and one parallel to the surface (mgsinθ). The perpendicular component determines the normal reaction. As the angle increases, cosθ decreases, so the normal reaction becomes even smaller.

4. Your actual weight (gravitational force = mg) remains constant because your mass and Earth's gravity do not change. What changes is your apparent weight (the normal reaction from the lift floor). When the lift accelerates upward, the floor must push you upward with force greater than your weight to accelerate you. This increased normal reaction is what you feel as "feeling heavier." The sensation of weight comes from normal reaction, not from gravitational force.

5. The applied force F must accelerate both blocks (total mass $m_1 + m_2$). However, the string tension only needs to accelerate one block (the one not directly receiving force F). Since tension accelerates less mass than F does, the tension is smaller. Specifically, if F pulls the first block, tension $= (m_2/(m_1 + m_2)) \times F$, which is always less than F.

6. Friction opposes the tendency of motion, not actual motion. The weight component mgsinθ acts down the slope, creating a tendency for the block to slide downward. Static friction opposes this tendency by acting up the slope. Friction adjusts its magnitude (up to maximum $\mu_s mg\cos\theta$) to exactly balance the downward component, preventing motion. No external upward force is needed because friction provides the balancing force.

7. "Light" means the string has negligible mass compared to the objects connected. This ensures the string does not require force to accelerate itself, so tension is the same throughout its length. "Inextensible" means the string does not stretch, so when one end moves a certain distance, the other end moves the same distance. This ensures connected objects have the same magnitude of acceleration (though possibly in different directions). Both assumptions simplify analysis by ensuring uniform tension and equal acceleration magnitudes.

8. At constant velocity (zero acceleration), the tension only needs to overcome the resistive forces on the trailer (friction, air resistance). When accelerating, the tension must provide both the force to overcome resistance **and** the force to accelerate the trailer's mass (T = ma + resistive forces). Since the acceleration term adds to the required tension, it is greater during acceleration than at constant velocity.

9. Counter-example: a load supported by two strings at angles. Each tension is not equal to weight because only the vertical components add to balance the weight.

10. The string closer to horizontal must have the larger tension because it has a smaller vertical component per unit tension. To supply enough vertical support, it must be pulled harder.

EXERCISE 4B

11. Each side of the rope has both a vertical and horizontal component. Only the vertical components support the bag's weight. Since each rope is at an angle (not vertical), its vertical component is less than the full tension (vertical component = Tcosθ). To provide enough vertical support to balance the weight, the tension must be greater than simply half the weight. The more the rope deviates from vertical, the greater the tension required.

12. Vibrations from the road cause the rope fibers to settle and compress slightly, and the knots to tighten, effectively making the rope shorter between fixed points. Additionally, temperature changes (the rope heats during day, cools at night) cause expansion and contraction. Even small stretching under initial load redistributes tension. These effects accumulate to create slack in the rope, requiring periodic re-tightening to maintain secure load.

13. As the ramp angle increases, the component of the sack's weight parallel to the ramp (mgsinθ) increases. This component acts down the ramp and must be overcome to push the sack up. At steeper angles, sinθ is larger, so more force is needed to balance this component and any friction. While the distance is shorter, the required force is greater, making the work (force × distance) roughly the same but the task more difficult due to the larger force requirement.

14. When the rope is jerked suddenly, the bucket must accelerate rapidly from rest or from a lower velocity to a higher velocity. By Newton's second law (F = ma), rapid acceleration requires a large force, which means very high tension in the rope. This tension can exceed the rope's breaking strength. Pulling smoothly means smaller acceleration, which requires less force (tension), keeping the rope safely below its breaking point while still raising the bucket efficiently.

15. Static friction must act up the slope to balance the component of weight down the slope. Even at rest, that component tends to cause sliding, so friction is required to maintain equilibrium.

16. Pressing the bottom harder increases the normal reactions at the contacts, which increases the maximum possible static friction. With larger available friction, the plank can stay in equilibrium without slipping.

17. The rope tension has components in different directions. Horizontal component opposes sideways slipping, while the downward vertical component increases the normal reaction, which increases friction and thus helps prevent sliding.

18. The hinge provides a reaction but cannot supply the necessary balancing effect on its own. The cable provides an additional force with suitable components that help balance the weight and keep the signboard in equilibrium; without it, the forces cannot balance and the signboard rotates/falls.

EXERCISE 4C

19. (a) T = 15N(b) F = 17.2N

20. (a) a = 2.67 m/s²(b) T = 50.1N(c) s = 5.34m

21. (a) a = 3.5 m/s²(b) T = 14N(c) a = 0.56m/s²

22. (a) Block slides down (mgsinθ = 33.1N $>$ f_{max} = 31.9N (b) a = 0m/s²

23. (a) m_2 = 3.18kg(b) T = 24.6N(c) t = 1.1s

24. (a) 12204N (b) 10584N (c) 8424N

25. (a) a = 3.68m/s² (b) v = 3.83m/s (c) s = 2m

26. (a) a = 5m/s² (b) T = 35N (c) T = 20N

27. (a) T=33.1N (b) P=23N acting up the plane on A.

28. (a) T=58.8N (b) f=19.6N down the plane (c) μ=0.289

29. (a) The string making 30° with the horizontal has the greater tension. Reason: A smaller angle with the horizontal means a smaller vertical component for the same tension. Therefore, a larger tension is required to provide the necessary upward support. (b) Tension in 30° string = 87.8N, Tension in 45° string = 107.6N.

30. (a) a = 1.96m/s² upward (b) R = 882N