Year 12 Science: Forces, torque and circular motion

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What net force gives a 1500 kg car an acceleration of 2.4 m s^{-2}?

2. A box is pushed with 30.0 N east and 40.0 N north at the same time. What is the resultant force?

3. A 40.0 N force pushes at right angles on the end of a spanner 0.250 m long. What torque does it make?

4. A 30.0 kg child sits 1.50 m from the pivot of a seesaw. How far from the pivot, on the other side, must a 45.0 kg child sit to balance it?

5. A 0.200 kg puck on a string moves in a horizontal circle of radius 0.800 m at 3.00 m s^{-1} on a frictionless table. What is the tension in the string?

Exam-style question: the diving board

At the pools, a uniform diving board is 3.00 m long and weighs 300 N. Its left end, A, is bolted to the ground, and it rests on a support B, 1.00 m from A. A diver weighing 600 N stands at the far right end. Use g = 9.8 m s^{-2}.

6. State the two conditions for the board to be in equilibrium.

7. By taking torques about B, calculate the size and direction of the force the bolt at A exerts on the board.

8. Calculate the force from support B.

9. The diver walks slowly from above B to the far end. Discuss how the forces at A and B change, and why.

Fix the mistake

10. Correct this statement: "Drawing friction, then a separate centripetal force arrow, on a car going round a corner."

11. Correct this statement: "Torque of the plank's weight = 200 N × 4.00 m, using the plank's length."

12. Correct this statement: "The table pushes up on the book and the book pushes down on the table, so those balance and the book stays still."

13. Correct this statement: "In a circle, the object flies outwards when the string breaks."

Answer key (for parents and tutors)

1. What net force gives a 1500 kg car an acceleration of 2.4 m s^{-2}?
   $F = ma = 1500 \times 2.4 = 3600$ N.

2. A box is pushed with 30.0 N east and 40.0 N north at the same time. What is the resultant force?
   $F = \sqrt{(30.0^2 + 40.0^2)} = \sqrt{2500} = 50.0$ N; $\tan\theta = 40.0 \div 30.0$, $\theta = 53.1°$, so 50.0 N at 53.1° north of east.

3. A 40.0 N force pushes at right angles on the end of a spanner 0.250 m long. What torque does it make?
   $\tau = Fd = 40.0 \times 0.250 = 10.0$ N m.

4. A 30.0 kg child sits 1.50 m from the pivot of a seesaw. How far from the pivot, on the other side, must a 45.0 kg child sit to balance it?
   Weights: $30.0 \times 9.8 = 294$ N and $45.0 \times 9.8 = 441$ N; anticlockwise torque $= 294 \times 1.50 = 441$ N m, so $441 \times d = 441$ and $d = 1.00$ m.

5. A 0.200 kg puck on a string moves in a horizontal circle of radius 0.800 m at 3.00 m s^{-1} on a frictionless table. What is the tension in the string?
   The tension is the centripetal force: $F = mv^2 \div r = 0.200 \times 3.00^2 \div 0.800 = 2.25$ N.

6. State the two conditions for the board to be in equilibrium.
   The net force is zero (up forces = down forces) and the net torque about any point is zero (clockwise torques = anticlockwise torques) (Achieved).

7. By taking torques about B, calculate the size and direction of the force the bolt at A exerts on the board.
   About B, the board's weight acts $1.50 - 1.00 = 0.50$ m to the right and the diver 2.00 m to the right, both clockwise: $300 \times 0.50 + 600 \times 2.00 = 150 + 1200 = 1350$ N m. The bolt is 1.00 m to the left of B, so $F_A \times 1.00 = 1350$ and $F_A = 1350$ N, and it must act downwards to make an anticlockwise torque on that side (Merit).

8. Calculate the force from support B.
   Up = down: $F_B = 1350 + 300 + 600 = 2250$ N upwards. Check about A: $F_B \times 1.00 = 300 \times 1.50 + 600 \times 3.00 = 450 + 1800 = 2250$ N m (Merit for one force, Excellence for both with directions).

9. The diver walks slowly from above B to the far end. Discuss how the forces at A and B change, and why.
   With the diver x metres right of B, $F_A = 150 + 600x$: the diver's distance from B grows, so the clockwise torque grows, and the bolt must pull down harder, from 150 N above B up to 1350 N at the end. F_B balances everything, $F_B = F_A + 900$, so it rises from 1050 N to 2250 N. Excellence links each change to the torque and force conditions.

10. Correct this statement: "Drawing friction, then a separate centripetal force arrow, on a car going round a corner."
    The centripetal force is the friction here, so draw one arrow, labelled friction, pointing to the centre.

11. Correct this statement: "Torque of the plank's weight = 200 N × 4.00 m, using the plank's length."
    A uniform plank's weight acts at its centre, so use the distance from the pivot to the centre: 200×2.00.

12. Correct this statement: "The table pushes up on the book and the book pushes down on the table, so those balance and the book stays still."
    Those are a third-law pair on different objects; the book stays still because its weight and the table's support force on it balance.

13. Correct this statement: "In a circle, the object flies outwards when the string breaks."
    With no force it moves in a straight line along the tangent, the direction it was moving at that instant.