

Worksheet — Connected Blocks Simulation

Use with *Simulation - Connected blocks.html* · touching blocks, strings and tow bars · Newton's 3rd law and the whole-system method (Block 4)

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Name: _____ Class: _____ Date: _____

How to use this worksheet

Scan the QR code or open school.taneski.com/physics/dp/25-connected-blocks/ in a browser (offline: *Simulation - Connected blocks.html*). Choose how the blocks are joined at the top: ① touching (pushed) · ② strings (pulled) · ③ tow bar · ④ mixed. Pick an **Example** or set the masses, the force and the surface yourself (▼ ▲ next to a box, or type a value).

Press ► **Go**; ◀/▶ step through the motion; 🖐 **Let go** and 🛑 **Brake** work while the blocks move; = **const. v** sets the force for a constant velocity. The coloured arrows above the blocks are the **3rd-law pairs**; the middle column shows the FBD of every block and of the whole system.

Part 1 before the lab (≈ 15 min) · **Part 2** during the lab (≈ 20 min) · **Part 3** homework (≈ 30 min) · **Part 4** stacked blocks (≈ 20 min). $g = 9.81 \text{ N kg}^{-1}$. Answers to 3 s.f.



Scan to open

Part 1 — Pre-lab: predict, then test

Question	My prediction (before)	What the simulation showed	Physics explanation
1. ① An 18 N push on box A (4.0 kg) makes A push box B (2.0 kg). Is the force of B on A smaller than, equal to or bigger than the force of A on B?			
2. ① Slide 20: 24 N on A (4.0 kg) gives a contact force of 8.0 N. The same 24 N now pushes B (2.0 kg) from the right. Does the contact force get bigger, smaller or stay the same?			
3. ① Three boxes are pushed at a constant velocity on a rough floor. Is the force of A on B zero, or not? Why?			
4. ④ A string joins A to B, and B touches C. You pull C to the right. What happens to A and B?			

5. (Card C1★) Boxes A (4.0 kg) and B (2.0 kg) are pushed across a frictionless floor by an 18 N force on A. Calculate (a) the acceleration and (b) the force of A on B. State the size and direction of the force of B on A. Check: ① → Example Card C1★.

Working: whole system → a; then the FBD of B alone

6. (Problem set Q16) Blocks of 5.0 kg and 3.0 kg on a frictionless table are joined by a string. A 24 N force pulls the 3.0 kg block. Calculate the tension. Check: ② → Problem set Q16.

Working

Part 2 — During the lab

A • Smart Cart demo: two force sensors (PASCO 03)

Your teacher runs two Smart Carts with force sensors; the two force–time graphs appear on the projector. Before each run, vote: which sensor reads more? Then set the same situation in the simulation (Examples *Smart Carts*) and compare.

situation	my vote	max F on A / N (sensor)	max F on B / N (sensor)	simulation: force on A / on B
A (0.75 kg) pushes B (0.25 kg)				
the push acts on B, from the right				
pull B; a thread tows A (tug)				
heavy cart runs into light cart				(not in this sim)

7. A 2.0 N push on cart A (0.75 kg), which pushes cart B (0.25 kg); no friction. Calculate the force of A on B. Then calculate the force between the carts when the same 2.0 N pushes B from the right.

Working

8. Pull B (0.25 kg) with 1.0 N; a thread tows A (0.75 kg). Calculate the tension in the thread.

Working

B • Simulation investigation: how big is the force between the carts?

① Example *Smart Carts*. Keep the masses. Set F, press  Go, then ● **Record** (Data tab). Repeat for six forces.

F / N	0.5	1.0	1.5	2.0	2.5	3.0
a / m s ⁻²						
F _{A on B} / N						

9. Plot F_{A on B} (y-axis) against F and draw the best-fit line. Gradient = _____. Show that the gradient equals $m_B / (m_A + m_B)$. (Data tab → *link-F*.) What would the gradient be if you pushed B instead?

Working

C • Predict, then test: letting go

10. ① Example *Let go*: box A ($\mu_d = 0.40$) pushes box B ($\mu_d = 0.10$). Press  Go and then  Let go. Prediction: after you let go the boxes ☐ stay together ☐ separate, B slides further ☐ separate, A slides further. Result and explanation:

Prediction · result · explanation

11. ② Example *Let go (string)*: the back block has $\mu_d = 0.05$, the front one 0.40. Let go while they move. Prediction: the string ☐ stays tight ☐ goes slack ☐ snaps. Result and explanation:

Prediction · result · explanation

Part 3 — Homework: analyse

12. (Problem set Q24) A 10 kg box and a 6.0 kg box are in contact on a floor. A 60 N horizontal force pushes the 10 kg box, which pushes the 6.0 kg box in front of it. $\mu_d = 0.20$ for both. Draw the FBD of each box and calculate (a) the acceleration and (b) the contact force. Check: ① → Problem set Q24.

Working

13. Three boxes of 1.0 kg, 2.0 kg and 3.0 kg touch in a row on a frictionless floor. (a) 12 N pushes the 1.0 kg box. Calculate the force of B on C. (b) The same 12 N now pushes the 3.0 kg box from the other side. Calculate the force between the 1.0 kg and the 2.0 kg box. Explain the difference.

Working

14. (Card C1★ ★ ★) A car (1200 kg) tows a trailer (400 kg) with acceleration 1.5 m s^{-2} . Resistive forces: 300 N on the car, 100 N on the trailer. (a) Calculate the driving force. (b) Calculate the force in the tow bar. (c) The car now brakes so that both slow down at 2.0 m s^{-2} ; the trailer has no brakes. Find the force in the tow bar. Is it a pull (tension) or a push (compression)? Check: ③ → Card C1★ ★ ★ and (c).

Working

15. A 150 N force at 30° above the horizontal pulls a 40 kg sled, which tows a 20 kg sled on a horizontal rope. $\mu_d = 0.20$ for both. Calculate (a) the normal force on the front sled, (b) the acceleration and (c) the tension in the rope. Check: ② → Two sleds.

Working

16. (Exit question) A truck tows a 1000 kg car with a rope; both accelerate at 0.80 m s^{-2} (ignore friction). (a) Calculate the tension in the rope. (b) State the Newton's third-law partner of the rope's pull on the car. (c) The truck now tows the car at a constant velocity. What is the resultant force on the car?

Working

17. "The horse pulls the cart forwards, and the cart pulls the horse backwards with an equal force. So they can never start to move." Explain what is wrong with this argument. Use a free-body diagram of the cart and of the horse.

Working

Part 4 — Stacked blocks (5)

Choose ⑤ **Stacked** at the top. A is the bottom block, B rests on A (C on B). The only horizontal force between two blocks is **friction**; vertically they push on each other with a normal force. Both come in 3rd-law pairs (same colour in the scene).

Question	My prediction (before)	What the simulation showed	Physics explanation
18. ⑤ You pull the bottom block A; B rests on top. Which force makes B speed up?			
19. ⑤ You pull A much harder (situation 23, 30 N). Does B move with A, slide back on A while still moving forwards, or stay at rest?			
20. ⑤ You pull the top block B; A stands on a floor with $\mu_s = 0.20$. Does A move?			

21. (Forces in 30 situations, 23) A (4.0 kg) is on a smooth floor; B (1.0 kg) rests on it; between them $\mu_s = 0.40$, $\mu_d = 0.30$. (a) A is pulled with 15 N and B moves with it. Calculate the acceleration and the friction force on B. State its 3rd-law partner. (b) Calculate the largest pull for which B does not slide. (c) The pull is 30 N. Calculate the acceleration of each block. Check: ⑤ → *Situation 23* (15 N, the limit, 30 N).

Working: FBD of B (only friction acts on it horizontally) → whole system

22. (Card M★ ★★) A 50 kg box sits on the flat bed of a truck, 2.0 m behind the cab; $\mu_s = 0.40$, $\mu_d = 0.30$. (a) Calculate the largest acceleration of the truck for which the box does not slide. Which force accelerates the box? (b) The truck brakes at 5.0 m s^{-2} . Show that the box slides. (c) Calculate the box's acceleration relative to the truck and the time until it hits the cab. Check: ⑤ → *Card M★ ★★* (a) and (b, c).

Working

23. Three books (2.0 kg, 1.5 kg and 1.0 kg from the bottom) are pushed along a table at a constant velocity by a force on the bottom book; $\mu_d = 0.30$ between the table and the book. Calculate the push, the normal force of the middle book on the bottom book, and the friction force between the books. Check: ⑤ → *Three books*.

Working