Mass and Energy Balance for Human Weight Change

20 practice problems, worked solutions, reference equations, and scientific interpretation notes

Educational scope: human metabolism, calorie balance, body-mass flow, fat oxidation, respiratory quotient, glycogen-associated water, and scale-weight interpretation.

Use this worksheet to	Do not use this worksheet to
Practice unit-aware conservation calculations and explain their limitations.	Diagnose metabolism, prescribe intake, or replace individualized healthcare advice.

Core reference equations

Ledger	Equation or reference	Interpretation
Energy	Change in energy storage = intake - expenditure	Use one time interval and energy unit.
Static conversion	pounds = kcal / 3,500	Planning reference, not guaranteed tissue loss.
Mass	Change in body mass = matter in - matter out	Include oxygen in and CO_2 out for whole-body accounting.
Respiratory quotient	RQ = CO_2 produced / O_2 consumed	About 0.70 for fat and 1.00 for carbohydrate oxidation.
Triglyceride model	$C_{55}H_{104}O_6 + 78\ O_2 \rightarrow 55\ CO_2 + 52\ H_2O$ + energy	Balances atoms; CO_2 and water carry the matter out.
Glycogen model	about 2.7 g water per 1 g glycogen	Simplified NIDDK model assumption.

Important: kilocalories and kilograms belong to different ledgers. Metabolism connects them through specified reactions and changing body composition; never add or subtract them as though they were the same unit.

Part A - Energy balance calculations

1. Daily energy balance

A person consumes 2,150 kcal and expends 2,600 kcal in one day. Calculate the daily energy balance and label it as a deficit, balance, or surplus.

2. Seven-day static equivalent

A planned energy deficit averages 425 kcal/day for seven days. Calculate the weekly deficit and its static pound equivalent.

3. Thirty-day projection

A static planning model uses a 300 kcal/day deficit for 30 days. Calculate total energy balance and the static pound equivalent. State one reason actual scale change can differ.

4. Reverse planning arithmetic

Using only the historical static reference, how many total kilocalories correspond to 2.5 lb? If spread evenly across 35 days, what is the average daily value?

5. Kilogram reference

A cumulative deficit is 11,550 kcal. Using 7,700 kcal/kg as a rounded static reference, calculate the kilogram equivalent.

Part B - Whole-body mass accounting

6. Measured mass ledger

Listed matter entering the body totals 3.25 kg and listed matter leaving totals 3.50 kg over the same interval. Calculate the listed net mass balance and explain why it may be incomplete.

7. Solve for a missing output

Measured mass entering is 4.10 kg and body mass increases by 0.15 kg. Under the stated boundary, calculate total mass leaving.

8. Classify the ledger

Classify each item as mass, energy, or both through linked metabolic accounting: dietary carbohydrate grams, food kilocalories, inhaled oxygen, exhaled carbon dioxide, body heat, and urine.

9. Triglyceride product split

Using the published approximate split, estimate how much of the original triglyceride mass appears in carbon dioxide and metabolic water when 2.0 kg of triglyceride is oxidized.

10. Explain product mass

A reaction calculation for 10 kg of triglyceride produces about 28 kg CO_2 and 11 kg H_2O after consuming about 29 kg oxygen. Explain why the 39 kg of products does not mean 39 kg of body tissue was lost.

Part C - Respiratory quotient and transient mass

11. Calculate respiratory quotient

Indirect calorimetry measures 280 mL/min CO_2 production and 400 mL/min O_2 consumption under steady-state conditions. Calculate RQ and identify the predominantly represented fuel category.

12. Interpret an RQ of 0.95

Explain what an RQ near 0.95 suggests about substrate oxidation and why it does not prove that body fat is being gained or lost over the full day.

13. Glycogen-associated water

A simplified model adds 400 g of glycogen. Using 2.7 g water per gram of glycogen, calculate associated water and the combined glycogen-plus-water mass in kilograms.

14. Sodium and scale weight

Energy intake and expenditure are unchanged, but sodium intake and extracellular water rise. Explain how scale weight can rise without proving an equivalent increase in body fat.

15. Static estimate versus observation

A seven-day deficit totals 3,500 kcal, while scale weight falls 2.0 lb. Give at least three mass components or measurement factors that could explain the difference from the static 1.0 lb equivalent.

Part D - Integrated interpretation

16. Why static projections bend

Explain why a fixed calorie deficit does not produce perfectly linear weight loss indefinitely. Include at least three variables that change over time.

17. Macronutrient energy

A day includes 140 g protein, 220 g available carbohydrate, and 70 g dietary fat. Using 4, 4, and 9 kcal/g, calculate total macronutrient energy. Explain why 9 kcal/g should not be applied directly to whole adipose tissue.

18. Separate two ledgers

A student writes: '500 kcal deficit - 0.2 kg water = 499.8 net loss.' Identify the dimensional error and rewrite the result as two valid statements.

19. Integrated weekly case

Average intake is 2,050 kcal/day and expenditure is 2,500 kcal/day for seven days. Average weight falls from 180.0 to 178.8 lb. Calculate energy balance and static equivalent, then interpret the observed 1.2 lb change without assuming it is all fat.

20. Critique a breathing claim

Evaluate this statement: 'Because fat leaves mainly as CO_2, breathing faster while sitting will cause fat loss.' Use energy balance, oxidation, mass flow, and safety in your answer.

Answer key - Part A

1. Daily energy balance

2,150 - 2,600 = -450 kcal. This is a 450 kcal deficit for the stated day.

2. Seven-day static equivalent

425 x 7 = 2,975 kcal deficit. 2,975 / 3,500 = 0.85 lb static equivalent.

3. Thirty-day projection

300 x 30 = 9,000 kcal deficit. 9,000 / 3,500 = 2.57 lb static equivalent. Actual scale change can differ because water, glycogen, digestive contents, tissue composition, adherence, and expenditure change.

4. Reverse planning arithmetic

2.5 x 3,500 = 8,750 kcal. 8,750 / 35 = 250 kcal/day as static arithmetic, not an individualized intake recommendation.

5. Kilogram reference

11,550 / 7,700 = 1.50 kg static equivalent.

Answer key - Part B

6. Measured mass ledger

3.25 - 3.50 = -0.25 kg listed net mass balance. It may omit oxygen, carbon dioxide, water vapor, sweat, shed material, or other difficult-to-measure streams.

7. Solve for a missing output

Change = in - out, so 0.15 = 4.10 - out. Output = 3.95 kg.

8. Classify the ledger

Carbohydrate grams: mass. Food kilocalories: energy. Oxygen: mass. Carbon dioxide: mass. Body heat: energy transfer. Urine: mass. Food molecules also participate in linked mass and energy accounting, but each stated measurement retains its own unit.

9. Triglyceride product split

CO_2 share: 2.0 x 0.84 = 1.68 kg. Metabolic-water share: 2.0 x 0.16 = 0.32 kg. These are approximate destinations for the original triglyceride mass.

10. Explain product mass

The products contain both the 10 kg of triglyceride atoms and about 29 kg of inhaled oxygen. Conservation gives about 10 + 29 = 39 kg of reactants and about 28 + 11 = 39 kg of products.

Answer key - Part C

11. Calculate respiratory quotient

RQ = 280 / 400 = 0.70, consistent with predominantly fat oxidation under suitable steady-state conditions.

12. Interpret an RQ of 0.95

It suggests predominantly carbohydrate oxidation with some mixed-fuel contribution. RQ describes fuel use at the measurement time; net daily fat balance also depends on fat intake, storage, oxidation, total energy balance, and timing.

13. Glycogen-associated water

Water = 400 x 2.7 = 1,080 g. Combined mass = 400 + 1,080 = 1,480 g = 1.48 kg.

14. Sodium and scale weight

Greater sodium-related fluid retention can add water mass. Water has mass but does not carry the same stored-energy interpretation as an equal mass of adipose tissue, so scale gain is not automatically fat gain.

15. Static estimate versus observation

Possible contributors include glycogen change, associated water, sodium-related fluid, digestive contents, urine or stool timing, inflammation, menstrual-cycle effects, hydration, and measurement variation.

Answer key - Part D

16. Why static projections bend

Body mass and composition change, resting expenditure changes, activity costs change, spontaneous movement can change, thermic expenditure can change with intake, and adaptive responses can narrow the original deficit. Adherence and water balance also vary.

17. Macronutrient energy

Protein: 140 x 4 = 560 kcal. Carbohydrate: 220 x 4 = 880 kcal. Fat: 70 x 9 = 630 kcal. Total = 2,070 kcal. Whole adipose tissue includes water, cells, connective tissue, and other non-lipid material, so it is not pure dietary fat.

18. Separate two ledgers

The expression subtracts kilograms from kilocalories. Valid statements: energy balance is -500 kcal for the interval; measured water mass changed by -0.2 kg for the interval. Their physiological relationship requires a defined model, not direct subtraction.

19. Integrated weekly case

Daily balance = 2,050 - 2,500 = -450 kcal. Weekly balance = -3,150 kcal. Static equivalent = -3,150 / 3,500 = -0.90 lb. Observed change is -1.2 lb, which can combine fat, water, glycogen, digestive contents, lean tissue, and measurement variation.

20. Critique a breathing claim

Oxidation driven by metabolic demand produces CO_2, and breathing removes it. Deliberately over-breathing while sitting does not meaningfully raise substrate oxidation or create a sustained energy deficit. It can lower blood CO_2 and cause dizziness, tingling, faintness, or other hyperventilation symptoms.

Sources and method notes

Topic	Source
Triglyceride oxidation and product mass	Meerman R, Brown AJ. When somebody loses weight, where does the fat go? The BMJ. https://www.bmj.com/content/349/bmj.g7257
Energy balance equation and dynamic limits	Body Weight Regulation. Endotext, NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK278932/
Dynamic weight modeling	NIDDK Research Behind the Body Weight Planner. https://www.niddk.nih.gov/research-funding/at-niddk/labs-branches/laboratory-biological-modeling/integrative-physiology-section/research/body-weight-planner
Glycogen-associated water model	NIDDK Dynamic Mathematical Model of Body Weight Change in Adults. https://www.niddk.nih.gov/-/media/Files/BWP/Hall_Lancet_Web_Appendix.pdf
Respiratory quotient values	Obesity Medicine Association Clinical Practice Statement. https://pmc.ncbi.nlm.nih.gov/articles/PMC10661987/
Sodium, water, and weight	DASH-Sodium analysis. https://pmc.ncbi.nlm.nih.gov/articles/PMC7278848/

Scope boundary: This worksheet applies conservation concepts to human metabolism and weight change. It is not a chemical-engineering worksheet and does not cover reactors, process streams, unit operations, industrial design, or engineering safety calculations.

Medical disclaimer: This material provides educational estimates and practice calculations. It is not medical advice. Consult a qualified healthcare professional before starting or materially changing a weight-loss program.