Midterm 2

Step-by-step solutions with brief concept explanations

Bonus Question

Question: Superman applies a constant force of 10000 N to stop a 20000 kg train moving at 10 m/s in the opposite direction. How long does it take to stop the train?

A. 10 s

B. 20 s

C. 30 s

D. 40 s

E. 50 s

Solution:

1. Use Newton's second law: $F = ma$, so $a = F/m = 10000/20000 = 0.5\,\mathrm{m/s^2}$.
2. The force is opposite to the train's motion, so this is a deceleration of $0.5\,\mathrm{m/s^2}$.
3. Use $v = u + at$ with final speed $v = 0$:

$$0 = 10 + (-0.5)t$$

4. Solve for time:

$$t = \frac{10}{0.5} = 20\,\mathrm{s}$$

5. **Answer: 20 s.**

Concept note: For a fixed force, a larger mass gets a smaller acceleration, so it takes longer to stop.

Question 2

Question: Two masses are connected by a string over a frictionless pulley. The heavier mass is 5 kg, and the lighter mass is 3 kg. What is the acceleration of the 5 kg mass when released? (Use $g = 10\,\mathrm{m/s^2}$.)

A. 1 $\mathrm{m/s^2}$ downward

B. 2 $\mathrm{m/s^2}$ downward

C. 2.5 m/s^2 downward

D. 3 m/s^2 downward

E. 4 m/s^2 downward

Solution:

1. For an Atwood machine:
$$a = \frac{(m_h - m_l)g}{m_h + m_l}$$
2. Substitute values:
$$a = \frac{(5-3)\cdot 10}{5+3} = \frac{20}{8} = 2.5\,\text{m/s}^2$$
3. The 5 kg mass is heavier, so it moves downward.
4. **Answer: 2.5 m/s^2 downward**.

Concept note: The difference in weight drives the motion, while the total mass resists acceleration.

Question 3

Question: Two magnets attract each other, one with mass 10 kg and the other with mass 2 kg. Initially at rest, after a short time Δt, which magnet has the higher speed? (Assume the force is equal and opposite.)

A. The 10 kg magnet

B. The 2 kg magnet

C. Both have the same speed

D. Neither moves, as masses differ

E. The heavier one due to greater momentum

Solution:

1. By Newton's third law, each magnet feels equal and opposite force.
2. Acceleration is $a = F/m$, so the smaller mass gets the larger acceleration.
3. Over the same time interval, speed change is $\Delta v = a\Delta t = (F/m)\Delta t$.
4. Because m is smaller for the 2 kg magnet, its Δv is larger.
5. **Answer: The 2 kg magnet**.

Concept note: Equal forces do not imply equal accelerations; mass determines acceleration.

Question 4

Question: A 10 kg mass experiences a 30 N force east and a 40 N force north. What is the magnitude of its acceleration?

A. 3 m/s^2

B. 4 m/s^2

C. 5 m/s^2

D. 7 m/s^2

E. 50 m/s^2

Solution:

1. The forces are perpendicular, so net force magnitude is

$$F_{\text{net}} = \sqrt{30^2 + 40^2} = \sqrt{900 + 1600} = 50\,\text{N}$$

2. Apply Newton's second law:

$$a = \frac{F_{\text{net}}}{m} = \frac{50}{10} = 5\,\text{m/s}^2$$

3. **Answer: 5 m/s^2.**

Concept note: This is the classic 3-4-5 right triangle in vector form.

Question 5

Question: When a person jumps off a boat onto a dock, the boat moves backward. This is an example of:

A. Newton's first law, as the boat resists change

B. Newton's second law, with acceleration proportional to force

C. Newton's third law, with equal and opposite forces between person and boat

D. Gravitational attraction between person and dock

E. Inertia of the dock

Solution:

1. The person pushes backward on the boat while jumping.

2. The boat pushes forward on the person with equal magnitude and opposite direction.
3. This action-reaction pair is Newton's third law.
4. **Answer: Newton's third law, with equal and opposite forces between person and boat**.

Concept note: Interaction forces always come in pairs on different objects.

Question 6

Question: When a cannon fires a cannonball, the cannon recoils backward due to:

A. The cannonball's smaller mass compared to cannon's mass

B. Air resistance on the canonball during flight

C. Conservation of momentum of the system

D. Projectile motion's property

E. Conservation of mass

Solution:

1. Initially, total momentum of cannon + cannonball is zero.
2. After firing, the cannonball has forward momentum.
3. To keep total momentum unchanged, the cannon gains equal backward momentum.
4. **Answer: Conservation of momentum of the system**.

Concept note: In a closed system with no external net force, total momentum is constant.

Question 7

Question: In projectile motion ignoring air resistance, what are the horizontal and vertical components of velocity at the highest point of the trajectory?

A. Horizontal: 0, vertical: initial velocity $\cdot \sin\theta$

B. Horizontal: initial velocity $\cdot \cos\theta$, vertical: 0

C. Horizontal: initial velocity, vertical: 0

D. Horizontal: 0, vertical: 0

E. Horizontal: initial velocity $\cdot \sin\theta$, vertical: initial velocity $\cdot \cos\theta$

Solution:

1. In ideal projectile motion, horizontal velocity remains constant: $v_x = v_0 \cos\theta$.
2. At the highest point, vertical velocity is momentarily zero: $v_y = 0$.
3. **Answer: Horizontal** $= v_0 \cos\theta$**, vertical** $= \mathbf{0}$.

Concept note: Gravity changes only the vertical component (ignoring air resistance).

Question 8

Question: A 5 kg object moves with velocity 3 m/s east and 4 m/s north. What is the magnitude of its momentum?

A. 15 kg m/s

B. 20 kg m/s

C. 25 kg m/s

D. 35 kg m/s

E. 5 kg m/s

Solution:

1. Find speed magnitude:
$$v = \sqrt{3^2 + 4^2} = 5\,\text{m/s}$$
2. Momentum magnitude is
$$p = mv = 5 \cdot 5 = 25\,\text{kg m/s}$$
3. **Answer: 25 kg m/s**.

Concept note: Momentum is a vector; here we are asked only for its magnitude.

Question 9

Question: An object is launched with an initial velocity of 20 m/s at an angle of 60 degrees to the horizontal. Ignoring air resistance, what is the horizontal range of the projectile? (Use $g = 10\,\text{m/s}^2$ and $\sqrt{3} \approx 1.73$.)

A. 20 m

B. 30 m

C. 35 m

D. 40 m

E. 45 m

Solution:

1. Use the range formula:
$$R = \frac{v_0^2 \sin(2\theta)}{g}$$
2. Substitute:
$$R = \frac{20^2 \sin(120^\circ)}{10} = \frac{400 \sin(60^\circ)}{10}$$
3. Since $\sin(60^\circ) = \frac{\sqrt{3}}{2} \approx \frac{1.73}{2} = 0.865$,
$$R \approx \frac{400 \cdot 0.865}{10} = 34.6\,\text{m}$$
4. Round to nearest option: **35 m**.

Concept note: Range depends on launch speed, angle, and gravity.

Question 10

Question: Two forces act on a 4 kg object: 12 N to the right and 4 N to the left. What is the net acceleration?

A. 1 m/s^2 right

B. 2 m/s^2 right

C. 3 m/s^2 left

D. 4 m/s^2 right

E. 0 m/s^2

Solution:

1. Take right as positive. Net force:

$$F_{\text{net}} = 12 - 4 = 8\,\text{N} \quad \text{(to the right)}$$

2. Apply $a = F/m$:

$$a = \frac{8}{4} = 2\,\text{m/s}^2$$

3. Direction is right.

4. **Answer: 2 m/s^2 right**.

Concept note: Acceleration always points in the direction of net force.

Question 11

Question: Momentum is conserved in a closed system provided that:

A. All objects have the same mass

B. Velocities are constant and opposite to each other

C. No external forces act on the system

D. The collision is elastic only

E. Gravity is absent

Solution:

1. The rule for momentum conservation is: external net force on the system must be zero.

2. Internal forces can redistribute momentum between objects, but total momentum stays constant.

3. **Answer: No external forces act on the system**.

Concept note: Momentum conservation is not limited to elastic collisions.

Question 12

Question: According to Newton's first law, an object in motion continues at constant velocity unless:

A. gravity is zero

B. masses are very light

C. acted upon by a net force

D. we are in vacuum in outer space

E. gravity is super strong

Solution:

1. Newton's first law says velocity remains constant if net force is zero.
2. So motion changes only when a nonzero net force acts.
3. **Answer: acted upon by a net force**.

Concept note: Constant velocity includes moving in a straight line at constant speed.