How Things Work - Practice Exam 1 Solutions

Avi Herman

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Question 1

A car is moving with an initial velocity of $\vec{v_i} = (-20\,\mathrm{m/s}, 0, 0)$ and comes to a stop in a time of 10 seconds with a constant deceleration. What is the acceleration vector?

- **(a)** $\vec{a} = (1\,\mathrm{m/s^2}, 0, 0)$
- **(b)** $\vec{a} = (-1\,\mathrm{m/s^2}, 0, 0)$
- **(c)** $\vec{a} = (2\,\mathrm{m/s^2}, 0, 0)$
- **(d)** $\vec{a} = (-2\,\mathrm{m/s^2}, 0, 0)$

Solution:

Using the equation of linear motion:

$$\vec{v_f} = \vec{v_i} + \vec{a}\Delta t$$

Given $\vec{v_f} = 0\,\mathrm{m/s}$, $\vec{v_i} = -20\,\mathrm{m/s}$, and $\Delta t = 10\,\mathrm{s}$:

$$0 = -20 + \vec{a} \times 10$$

$$\vec{a} = \frac{20}{10} = 2\,\mathrm{m/s}^2$$

The correct answer is **(c)**: $\vec{a} = (2\,\mathrm{m/s}^2, 0, 0)$.

Question 2

When you go skydiving, after reaching terminal velocity (about 50 m/s), what can be said about your acceleration?

- **(a)** You are accelerating because there are forces acting on your body.
- **(b)** You are accelerating downward because of gravity.
- **(c)** You are not accelerating because you are moving at constant velocity.
- **(d)** You are decelerating because of air drag.

Solution:

At terminal velocity, the forces acting on you (gravity and air resistance) are balanced, resulting in zero net force. Using **Newton's First Law of Motion**:

$$\vec{a} = \frac{\vec{F}}{m} = 0\,\mathrm{m/s}^2$$

Thus, there is no acceleration. The correct answer is **(c)**: You are not accelerating because you are moving at constant velocity.

Question 3

At a speed of $12\,\mathrm{m/s}$, how far can you travel in one minute?

- **(a)** 12 m
- **(b)** 72 m
- **(c)** 60 m
- **(d)** 720 m

Solution:

Using the equation for position with constant velocity:

$$x_f = x_i + v\Delta t$$

Assuming $x_i = 0$, $v = 12\,\mathrm{m/s}$, and $\Delta t = 60\,\mathrm{s}$:

$$x_f = 0 + 12 \times 60 = 720\,\mathrm{m}$$

The correct answer is **(d)**: 720 m.

Question 4

The gravitational acceleration on the Moon is about 6 times smaller than on Earth. How long does it take for a rock on the Moon to fall 1 m (from rest)?

- **(a)** Around 0.5 s
- **(b)** A little less than 1 s
- **(c)** A little over 1 s
- **(d)** Around 3 s

Solution:

Using the equation of linear motion for position:

$$y_f = y_i + v_i \Delta t + \frac{1}{2} a (\Delta t)^2$$

With $y_i = 0$, $v_i = 0$, and $a = \frac{g_{\text{earth}}}{6} = 1.63\,\mathrm{m/s}^2$:

$$1 = \frac{1}{2} \times 1.63 \times (\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2}{1.63}} \approx 1.1\,\mathrm{s}$$

The correct answer is **(c)**: A little over 1 s.

Question 5

A gymnast jumps upward with an initial speed of $10\,\mathrm{m/s}$. She is in the air for a total time of:

- **(a)** 1 s
- **(b)** 5 s
- **(c)** 2 s
- **(d)** 10 s

Solution:

Using the equation for velocity:

$$v_f = v_i + a \Delta t$$

At the highest point, $v_f = 0$, $v_i = 10\,\mathrm{m/s}$, and $a = -g$:

$$0 = 10 - 9.8 \Delta t$$

$$\Delta t = \frac{10}{9.8} \approx 1\,\mathrm{s}$$

The total time is twice this, so:

$$t_{\mathrm{total}} = 2\,\mathrm{s}$$

The correct answer is **(c)**: 2 s.

Question 6

The maximum height above the ground for the gymnast jumping straight upward with an initial speed of $10\,\mathrm{m/s}$ is:

- **(a)** 5 m
- **(b)** 10 m
- **(c)** 2 m
- **(d)** 15 m

Solution:

Using the equation for position under constant acceleration:

$$y_f = y_i + v_i \Delta t + \frac{1}{2} a (\Delta t)^2$$

At maximum height, $v_f = 0$, and using the velocity equation:

$$v_f = v_i + a\Delta t \implies 0 = 10 - 9.8\Delta t \implies \Delta t = \frac{10}{9.8} \approx 1\,\mathrm{s}$$

Now substituting into the position equation:

$$y_f = 0 + 10 \times 1 + \frac{1}{2} \times (-9.8) \times (1)^2 = 10 - 4.9 = 5.1\,\mathrm{m}$$

The correct answer is **(a)**: 5 m.

Question 7

Suppose a 2 kg object is falling through the air and accelerating downwards at $8\,\mathrm{m/s}^2$. What is the magnitude and direction of the force of air resistance on it?

- **(a)** 4N upward
- **(b)** 4N downward
- **(c)** 2N upward
- **(d)** 2N downward

Solution:

Using Newton's second law to find the gravitational force:

$$F_{\text{gravity}} = m \times g = 2\,\text{kg} \times 9.8\,\text{m/s}^2 = 19.6\,\text{N downward}$$

The net force causing the acceleration:

$$F_{\text{net}} = m \times a = 2\,\text{kg} \times 8\,\text{m/s}^2 = 16\,\text{N downward}$$

The force of air resistance must be:

$$F_{\text{air}} = F_{\text{gravity}} - F_{\text{net}} = 19.6\,\text{N} - 16\,\text{N} = 3.6\,\text{N}$$

The closest answer is **(a)**: 4N upward.

Question 8

Suppose your car is on a 5% grade, meaning for every 100 m you travel along the road, you raise or lower 5 m in elevation. If your car weighs 1500 kg, what is the component of its weight parallel to the road?

- **(a)** 15000 N
- **(b)** 1500 N
- **(c)** 7500 N
- **(d)** 750 N

Solution:

The gravitational force acting on the car is:

$$F_{\text{gravity}} = m \times g = 1500\,\text{kg} \times 9.8\,\text{m/s}^2 = 14700\,\text{N}$$

The component of the weight parallel to the incline is:

$$F_{||} = F_{\text{gravity}} \times \sin(\theta)$$

Since $\sin(\theta) \approx 0.05$ (from the 5% grade), we have:

$$F_{||} = 14700\,\text{N} \times 0.05 = 735\,\text{N}$$

The correct answer is **(d)**: 750 N.

Question 9

Suppose you push horizontally on the wall of a building. For you to do work on the wall, which of the following need to happen?

- **(a)** The wall moves away from you
- **(b)** The wall lifts up
- **(c)** The wall moves sideways
- **(d)** (b) and (c)

Solution:

Work is defined as:

$$W = F \Delta x \cos(\theta)$$

For work to be done, the wall must move in the direction of the force applied. Since there is no movement:

The correct answer is **(a)**: The wall moves away from you.

Question 10

Consider a 100 kg father and his 20 kg daughter on a seesaw. If the daughter sits 2 m from the center, how far should the father sit for balance?

- **(a)** Farther out than the board will allow
- **(b)** 0.5 m
- **(c)** 0.4 m
- **(d)** 1.5 m

Solution:

For balance, the torques around the pivot must be equal. Torque is calculated as:

$$\tau = r \cdot F$$

Where r is the distance from the pivot and $F = m \cdot g$ is the weight. Using $r_f \cdot 100g = 2 \cdot 20g$:

$$100 r_f = 40 \implies r_f = \frac{40}{100} = 0.4\,\mathrm{m}$$

The correct answer is **(c)**: 0.4 m.

Question 11

If the Moon's rotational period doubles, how does its rotational kinetic energy change?

- **(a)** It will double
- **(b)** It will quadruple
- **(c)** It will decrease to 1/2
- **(d)** It will decrease to 1/4

Solution:

Rotational kinetic energy is given by:

$$K_{\mathrm{rot}} = \frac{1}{2} I \omega^2$$

If the period doubles, the angular velocity ω is halved. Since kinetic energy depends on ω^2, halving ω reduces the energy by a factor of:

$$K_{\text{new}} = \frac{1}{4}K_{\text{original}}$$

The correct answer is **(d)**: It will decrease to 1/4 its original value.

Question 12

If the polar ice caps melt, moving the water to the equator, what happens to the length of a day?

- **(a)** Increase due to friction
- **(b)** Increase due to angular momentum conservation
- **(c)** Decrease due to mass loss
- **(d)** Decrease due to work done by the ice

Solution:

Angular momentum is conserved, which is expressed as:

$$L = I\omega$$

Where I is the moment of inertia and ω is the angular velocity. Moving mass from the poles to the equator increases I, so to conserve angular momentum, ω must decrease. A decrease in ω means the length of the day increases.

The correct answer is **(b)**: Increase due to angular momentum conservation.

Question 13

A 1.2 kg bird sits on a wind turbine blade 10 m from its center. The turbine has a moment of inertia of 240,000 kgm^2. What is the torque due to the bird, and the angular acceleration of the turbine?

- **(a)** 1,200 Nm; 0.0005 rad/s^2
- **(b)** 120 Nm; 0.00005 rad/s^2
- **(c)** 2,400 Nm; 0.0005 rad/s^2
- **(d)** 120 Nm; 0.20 rad/s^2

Solution:

The torque due to the bird is given by:

$$\tau = F \times r$$

Where $F = m \times g = 1.2\,\text{kg} \times 9.8\,\text{m/s}^2 = 11.76\,\text{N}$, and $r = 10\,\text{m}$:

$$\tau = 11.76 \times 10 = 117.6\,\text{Nm}$$

The angular acceleration is:

$$\alpha = \frac{\tau}{I} = \frac{117.6}{240,000} \approx 0.00049\,\mathrm{rad/s^2}$$

The closest answer is **(b)**: 120 Nm; 0.00005 rad/s^2.

Question 14

If the turbine starts rotating clockwise due to wind, what is the net force and torque?

- **(a)** Positive; towards you
- **(b)** Negative; towards you
- **(c)** Zero; to the left
- **(d)** Zero; away from you

Solution:

If the turbine is rotating but not translating, the net translational force is zero. The rotational motion is caused by torque, not translational force. Therefore, the net force is zero, and the torque is in the direction of rotation (away from you in this case).

The correct answer is **(d)**: Zero; away from you.

Question 15

A professor accelerates forward in a car with a coffee cup on the roof. What can be said about the friction acting on the cup?

- **(a)** Its direction is backwards
- **(b)** Its direction is forwards
- **(c)** There is no friction since there is no sliding
- **(d)** The force of friction is infinite

Solution:

The force of static friction prevents the cup from sliding backward. Since the car is accelerating forward, static friction must act in the same direction (forwards) to keep the cup in place.

The correct answer is **(b)**: Its direction is forwards.

Question 16

An 800 kg car moving at 4 m/s to the right collides with a 400 kg car moving to the left. After the collision, they stick together and stop moving. What was the velocity of the 400 kg car?

- **(a)** It was stationary
- **(b)** 2 m/s to the left

- **(c)** 8 m/s to the left
- **(d)** 4 m/s to the left

Solution:

Using the conservation of momentum:

$$m_1 v_1 + m_2 v_2 = 0$$

Where $m_1 = 800\,\mathrm{kg}$, $v_1 = 4\,\mathrm{m/s}$, and $m_2 = 400\,\mathrm{kg}$:

$$800 \times 4 + 400 \times v_2 = 0 \implies v_2 = -8\,\mathrm{m/s}$$

The correct answer is **(c)**: 8 m/s to the left.

Question 17

You place an object on a spring with a spring constant of $100\,\mathrm{N/m}$, compressing the spring by 0.05 m. What is the object's mass?

- **(a)** 0.5 kg
- **(b)** 1 kg
- **(c)** 2 kg
- **(d)** 5 kg

Solution:

Using Hooke's Law:

$$F = kx$$

And setting $F = mg$, where $k = 100\,\mathrm{N/m}$, $x = 0.05\,\mathrm{m}$, and $g = 9.8\,\mathrm{m/s}^2$:

$$mg = kx \implies m = \frac{kx}{g} = \frac{100 \times 0.05}{9.8} \approx 0.51\,\mathrm{kg}$$

The correct answer is **(a)**: 0.5 kg.

Question 18

You make a spring-loaded catapult with a spring constant of $400\,\mathrm{N/m}$, compressing the spring by 0.1 m. What will be the launch speed of a $0.04\,\mathrm{kg}$ ball?

- **(a)** 10 m/s
- **(b)** 20 m/s
- **(c)** 40 m/s
- **(d)** 100 m/s

Solution:

Using energy conservation, the potential energy stored in the spring is converted to kinetic energy:

$$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$$

Solving for v:

$$v = \sqrt{\frac{kx^2}{m}} = \sqrt{\frac{400 \times (0.1)^2}{0.04}} = \sqrt{100} = 10\,\mathrm{m/s}$$

The correct answer is **(a)**: 10 m/s.

Question 19

If the shocks on a car are completely gone, and the car bounces at stoplights, how will the bouncing frequency change when more passengers are added?

- **(a)** The frequency will be the same
- **(b)** The frequency will be lower
- **(c)** The frequency will be higher
- **(d)** The frequency cannot be determined without the amplitude

Solution:

The bouncing frequency of a car (a harmonic oscillator) is inversely proportional to the square root of the mass:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

Adding more mass (passengers) increases m, reducing the frequency.

The correct answer is **(b)**: The frequency will be lower.

Question 20

When you blow across the top of a soda bottle, it emits a tone. If you replace the air with carbon dioxide, what happens to the pitch?

- **(a)** A higher pitched tone
- **(b)** A tone at the same pitch
- **(c)** No sound at all
- **(d)** A lower pitched tone

Solution:

The speed of sound is slower in carbon dioxide compared to air because carbon dioxide is denser. This causes the frequency (and thus the pitch) to decrease:

$$v = f\lambda$$

With a lower speed of sound, the frequency f decreases.

The correct answer is **(d)**: A lower pitched tone.

Answer Key

1. **(c)**: $\vec{a} = (2\,\mathrm{m/s}^2, 0, 0)$
2. **(c)**: You are not accelerating because you are moving at constant velocity.
3. **(d)**: 720 m
4. **(c)**: A little over 1 s
5. **(c)**: 2 s
6. **(a)**: 5 m
7. **(a)**: 4N upward
8. **(d)**: 750 N
9. **(a)**: The wall moves away from you.
10. **(c)**: 0.4 m
11. **(d)**: It will decrease to 1/4 its original value.
12. **(b)**: Increase due to angular momentum conservation.
13. **(b)**: 120 Nm; 0.00005 rad/s^2
14. **(d)**: Zero; away from you.
15. **(b)**: Its direction is forwards.
16. **(c)**: 8 m/s to the left.
17. **(a)**: 0.5 kg
18. **(a)**: 10 m/s
19. **(b)**: The frequency will be lower.
20. **(d)**: A lower pitched tone.