

MODULE 15**FINAL CHALLENGE: EXAMINATION QUESTIONS**

You have now completed the core ideas of motion and Newton's laws, building the essential foundations for Advanced Physics. This Final Challenge is an opportunity to bring those ideas together, test your understanding, and see how comfortably you can apply them in unfamiliar situations. Treat these questions not simply as an examination, but as a checkpoint of your growing confidence and physical reasoning skills. Work carefully, think logically, and remember that strong understanding develops through practice. **Complete solutions are provided at the end** so that you can review your progress, learn from any mistakes, and move forward with greater assurance.

Question 1

- (a) A vehicle travels along a straight horizontal road for several minutes while its velocity remains constant. During this interval, fuel consumption continues and engine sound remains noticeable. Give a physical account of the force situation consistent with this observation.
- (b) When the same vehicle enters dense traffic, passengers experience repeated forward and backward jolts even though the average velocity of the journey is not high. Account for these sensations using principles of motion.
- (c) A car of mass 1400kg moving at 28m/s on a level road is brought uniformly to rest after travelling 84m. Determine:
- the braking force acting on the car and
 - the time taken to stop.

Question 2

- (a) A small object released inside a smoothly moving train appears to fall vertically to a passenger inside, while an observer beside the track describes its path

differently. Account for this difference without assuming either observation is incorrect.

- (b) A cyclist maintains nearly the same pedalling effort but notices increasing difficulty in sustaining the same velocity when facing a strong headwind. Explain.
- (c) A body of mass 3.0kg moves along a straight line under a constant driving force of 18N. A resistive force $R = 3v$ acts simultaneously, where R is in Newton and v in m/s. Determine the acceleration at the instant when $v = 4\text{m/s}$.

Question 3

- (a) A puck set in motion on a nearly frictionless horizontal surface continues moving for a long time after the initial push has ceased. Account for this observation.
- (b) A passenger in a lift experiences brief changes in apparent weight when the lift starts moving upward and again when it slows near the top. Give an account of these sensations.
- (c) A lift of mass 800kg carries a passenger of mass 70kg. At a certain instant, the lift is moving upward but slowing uniformly at 1.5m/s^2 . Determine the normal reaction on the passenger.

(Take $g = 9.8\text{m/s}^2$)

Question 4

- (a) Two skaters initially at rest on frictionless ice push apart. The lighter skater is observed to gain velocity more rapidly. Account for this observation.
- (b) A runner accelerates forward while pushing backward on the ground. Give a physical explanation of how forward motion arises in this situation.

- (c) On frictionless ice, Kipute (55kg) and Kipanga (75kg) are initially at rest. Kipute pushes Kipanga for 0.40s. Immediately after the interaction, Kipute moves backward at 2.5m/s. Determine:
- Kipanga's velocity and
 - the magnitude of the force exerted during the push.

Question 5

- (a) A ball projected vertically upward eventually returns to its starting level. Give a physical account of this motion.
- (b) Athletes landing on sand often bend their knees, whereas landing stiffly on rigid ground frequently causes injury. Account for this difference.
- (c) A ball is projected vertically upward from the ground at 26m/s. At the same instant, another ball is released from rest from a point 35m directly above the ground. Determine:
- the time and
 - height at which the two balls are at the same level.

(Take $g = 9.8\text{m/s}^2$)

Question 6

- (a) A ball is released from a moving vehicle travelling along a straight road. Relative to the ground, the ball lands some distance ahead of the point vertically below where it was released. Explain this observation.
- (b) A runner on a smooth surface finds it difficult to accelerate compared with running on rough ground. Explain this observation.
- (c) A body of mass 5.0kg initially at rest is acted upon by a constant horizontal force of 20N while a resistive force of 4N opposes the motion. Calculate the velocity attained after 5.0s and the displacement during this time.

Question 7

- (a) During circular motion at constant speed, an object is still described as accelerating. Explain how this statement is physically consistent.
- (b) When a car rounds a bend at steady speed, passengers tend to lean sideways. Discuss the physical reason for this behaviour.
- (c) A car of mass 1200kg travels at 18m/s along a straight horizontal road. A constant braking force brings it to rest in 9.0s. Calculate the braking force and obtain the stopping distance.

Question 8

- (a) A vehicle moves along a straight horizontal road while its engine power remains roughly constant, yet its velocity gradually approaches a steady value instead of increasing indefinitely. Explain physically why continuous acceleration does not persist.
- (b) A crate is pushed across a warehouse floor. Initially it resists motion strongly, but once moving it slides more easily even though the applied push is unchanged. Discuss the physical reasons behind this behaviour.
- (c) A car of mass 1200kg accelerates uniformly from 12m/s to 30m/s while travelling 270m along a straight level road. Calculate the resultant force acting on the car.

Question 9

- (a) Two observers describe the same moving object but assign different velocities to it. Clarify how both descriptions can remain physically valid.
- (b) A passenger standing in a bus notices that when the driver suddenly changes lanes, unsecured objects inside the bus shift sideways. Give a physical explanation for this effect.

- (c) A ball is projected vertically upward from the edge of a 40m-high cliff with velocity 18m/s. Calculate the time taken to reach the ground below.

(Take $g = 9.8\text{m/s}^2$)

Question 10

- (a) A student claims that whenever a body is moving, some net force must be acting in the direction of its motion. Explain why this claim is not generally valid.
- (b) A box is pushed along a rough floor at constant velocity by a person whose push remains steady. Explain what must be true about the horizontal forces during the motion.
- (c) A 0.25kg ball strikes a wall normally with velocity 10m/s and rebounds with velocity 8m/s in the opposite direction. The contact time is 0.030s. Calculate:
- the change in momentum of the ball and
 - the average force exerted on the ball by the wall.

Question 11

- (a) A body can be accelerating even when its velocity magnitude remains constant. Explain how this can occur.
- (b) A passenger standing in a daladala feels a sideways “pull” when the vehicle turns suddenly at a junction. Explain why this sensation is experienced.
- (c) A stone is projected vertically upward from the ground with velocity 24m/s. Find:
- the time when it is at a height of 20m on its way downward and
 - its velocity at that instant.

(Take $g = 9.8\text{m/s}^2$)

Question 12

- (a) Two forces can be equal in magnitude and opposite in direction yet fail to cancel. Explain why this can happen.
- (b) When walking on a slippery surface, a person struggles to move forward effectively. Explain this observation using force ideas.
- (c) On a smooth horizontal surface, two blocks A and B of masses 3kg and 5kg are in contact. A horizontal force of 16N is applied to block A, pushing both blocks together. Neglect friction. Calculate:
- the common acceleration and
 - the force exerted by A on B.

Question 13

- (a) A body may momentarily have zero velocity without being at rest for any finite time. Explain this statement.
- (b) A passenger inside a bus feels pressed sideways when the bus negotiates a roundabout at nearly constant velocity magnitude. Explain the sensation.
- (c) A stone is projected vertically upward from ground level with velocity 22m/s. Calculate the time interval during which the stone is above a height of 15m. (Take $g = 9.8\text{m/s}^2$)

Question 14

- (a) Explain why a constant resultant force does not always imply constant acceleration for every possible situation.
- (b) A driver applies the brakes on a wet road and notices the stopping distance becomes much longer than on a dry road at the same initial velocity. Explain why.

- (c) A car of mass 1200kg is moving at 20m/s on a straight road. The driver notices danger and reacts for 0.70s before braking begins. During braking, the resultant retarding force is constant at 3600N until the car stops. Calculate:
- the braking time after braking begins,
 - the braking distance,
 - the total stopping distance from the instant the danger is noticed.

Question 15

- (a) Explain why two bodies in collision experience equal and opposite forces yet can undergo different accelerations.
- (b) A person in a moving vehicle is safer wearing a seatbelt during sudden braking. Explain why this is physically expected.
- (c) A ball is projected vertically upward from the ground with velocity 28m/s. Exactly 1.2s later, a second ball is projected vertically upward from the same point with velocity 34m/s. Calculate:
- the time after the first launch when the two balls meet,
 - the height above the ground at which they meet.

(Take $g = 9.8\text{m/s}^2$)

Question 16

- (a) A student claims that *if two forces are equal in magnitude and opposite in direction, then they must form a Newton's third-law pair*. Explain why this is not necessarily true.
- (b) In many road accidents, two drivers claim they were travelling at the "same velocity" because their speedometers showed the same reading. Explain why this claim can still be wrong in physics terms.

- (c) A car of mass 1000kg moves along a straight road with velocity 12m/s. The engine provides a constant driving force of 2200N. The resistive force is given by $R = 400 + 50v$, where R is in N and v is in m/s. Calculate:
- the acceleration at $v = 12\text{m/s}$,
 - the velocity at which acceleration becomes zero.

Question 17

- (a) Two different force descriptions are proposed for a moving body: “*forces are absent*” and “*forces balance.*” Explain why only one of these descriptions matches ordinary motion on Earth most of the time.
- (b) A form five student claims that in any interaction, the “bigger force” must act on the object that accelerates more. Explain why this claim is not compatible with Newton’s third law.
- (c) A motorcycle and a car move along the same straight road. At a certain instant the motorcycle has velocity 18m/s and the car has velocity 30m/s in the same direction. The motorcycle begins to accelerate uniformly at 2m/s^2 at that instant, while the car begins to decelerate uniformly at 3m/s^2 at the same instant. Find:
- the time after that instant when their velocities become equal,
 - the separation between them at that instant if they were at the same point initially.

Question 18

- (a) Kipute argues that *if two opposing forces act on a body and the body moves, then those forces cannot be equal in magnitude.* Explain why her reasoning can fail even when the body is moving.
- (b) A diver steps off a platform into water. The diver comes to rest, yet serious injury is uncommon when the water is deep. Explain the physical reason using force and motion ideas.
- (c) A stone is projected vertically upward from ground level with velocity 28m/s. Calculate the time interval during which the stone is below a height of 18m. (Take $g = 9.8\text{m/s}^2$)

SOLUTIONS TO EXAMINATION QUESTIONS

Question 1

- (a) Constant velocity means acceleration is zero. By Newton's second law, zero acceleration implies the resultant force on the vehicle is zero. Fuel is still consumed because the engine must provide a forward driving force to balance resistive forces such as air resistance and rolling friction. The engine sound and fuel consumption therefore indicate that forces are present but balanced, giving zero resultant force.
- (b) In dense traffic the vehicle repeatedly accelerates and decelerates, so its velocity changes frequently. Because of inertia, passengers' bodies tend to maintain their previous state of motion while the vehicle's velocity changes. When the vehicle accelerates forward, passengers tend to lag behind relative to the vehicle; when it brakes, they tend to continue forward. These effects are felt as repeated forward and backward jolts.
- (c) Given: $m = 1400\text{kg}$, $u = 28\text{m/s}$, $v = 0\text{m/s}$, $s = 84\text{m}$.

Using $v^2 = u^2 + 2as$:

$$0 = (28\text{m/s})^2 + 2a(84\text{m})$$

$$a = -4.67\text{m/s}^2$$

- (i) Braking force: $F = ma$

$$F = 1400\text{kg} \left(-\frac{4.67\text{m}}{\text{s}^2} \right) = -6.54 \times 10^3\text{N}$$

The braking force has magnitude $6.54 \times 10^3\text{N}$ and acts opposite the motion.

- (ii) Time to stop: $v = u + at$

$$0 = 28\text{m/s} + (-4.67\text{m/s}^2)t; t = 6.0\text{s}$$

The time to stop is 6.0s.

Question 2

- (a) The difference arises because motion is described relative to a reference frame. The passenger inside the train shares the train's horizontal motion, so relative to the passenger the object has no horizontal velocity and appears to fall straight down under gravity. To the observer beside the track, the object retains the train's horizontal velocity at the moment of release while also

accelerating downward due to gravity, so the path is curved. Both descriptions are correct in their own reference frames.

(b) A headwind increases the resistive force due to air resistance acting opposite to the cyclist's motion. If the cyclist's driving force (from pedalling) remains nearly the same while the opposing resistive force increases, the resultant forward force decreases. With a smaller resultant force, acceleration reduces and sustaining the previous velocity becomes more difficult.

(c) At $v = 4\text{m/s}$, resistive force: $R = 3v = 3(4) = 12\text{N}$.

Resultant force: $F = 18\text{N} - 12\text{N} = 6\text{N}$ (forward).

Acceleration: $a = \frac{F}{m} = \frac{6\text{N}}{3.0\text{kg}} = 2.0\text{m/s}^2$.

The acceleration is 2.0m/s^2 .

Question 3

(a) With negligible friction, the horizontal resistive force is very small, so after the push there is approximately zero resultant horizontal force. By Newton's first law, the puck continues moving with constant velocity due to inertia. It is not kept moving by a continuing push; it continues because no significant resultant force acts to change its motion.

(b) Apparent weight depends on the normal reaction between the lift floor and the passenger. When the lift accelerates upward, the passenger must accelerate upward, requiring a larger upward normal reaction than weight, so the passenger feels heavier. When the lift slows while moving upward, its acceleration is downward; the required normal reaction becomes smaller than weight, so the passenger feels lighter.

(c) The lift is moving upward but slowing at 1.5m/s^2 , so its acceleration is downward with magnitude 1.5m/s^2 .

So $a = -1.5\text{m/s}^2$.

For the passenger: $N - W = ma$ or $N - mg = ma$

$N = mg + ma = m(g + a) = 70\text{kg}(9.8\text{m/s}^2 - 1.5\text{m/s}^2) = 581\text{N}$

The normal reaction on the passenger is 581N .

Question 4

- (a) During the push, each skater experiences an interaction force equal in magnitude and opposite in direction. However, acceleration depends on mass through $a = F/m$. The lighter skater has smaller mass, so the same force produces a larger acceleration, causing the lighter skater to gain velocity more rapidly.
- (b) When the runner's foot pushes backward on the ground, the ground exerts an equal and opposite frictional force forward on the foot. That forward force acts on the runner's body and produces forward acceleration. Without this forward force from the ground, forward acceleration would not occur.
- (c) During the push, the interaction forces on the two skaters are equal in magnitude (Newton's third law). But since force is equal to the momentum change divided by time taken and they act for the same time interval (0.40s), the change in momentum on the two skaters are also equal in magnitude.

$$|\Delta p| \text{ in Kipute} = m(v - u) = 55\text{kg}(2.5\text{m/s} - 0) = 55 \times 2.5\text{kgm/s}$$

$$|\Delta p| \text{ in Kipanga} = m(v - u) = 75\text{kg}(v - 0) = 75\text{kg}(v)$$

$$|\Delta p| \text{ in Kipute} = |\Delta p| \text{ in Kipanga or } 55 \times 2.5\text{kgm/s} = 75\text{kg}(v); v = 1.83\text{m/s}$$

- (i) The Kipanga's velocity is 1.83m/s.

Kipute changes from 0 to 2.5m/s in 0.40s.

It follows that:

$$a = \frac{\Delta v}{\Delta t} = \frac{2.5\text{m/s}}{0.40\text{s}} = 6.25\text{m/s}^2$$

$$\text{Magnitude of force: } F = ma = 55\text{kg}(6.25\text{m/s}^2) = 344\text{N}$$

- (ii) The magnitude of the force exerted during the push is 344N.

Question 5

- (a) The ball is projected upward with an initial upward velocity. Gravity provides a constant downward acceleration throughout the motion. While the ball moves upward, its upward velocity decreases because the acceleration due to gravity is opposite to the motion. At the highest point the velocity becomes momentarily zero, but the acceleration remains downward, so the ball then gains downward velocity and returns to its starting level.

(b) The change in momentum needed to come to rest is fixed, but the average force depends on the stopping time: $F = \Delta p / \Delta t$. Bending the knees increases the time over which the body is brought to rest, reducing the average force during the impact. A smaller force reduces the risk of injury, while a stiff landing produces a shorter stopping time and therefore a larger force.

(c) Using $s = ut + \frac{1}{2}at^2 = ut + \frac{1}{2} \times (-9.8)t^2 = ut - 4.9t^2$

Ball A (projected upward from ground): $s = 26t - 4.9t^2$

The two balls will be at the same level after ball B travelling a distance of $35 - s$.

So, for ball B (released from rest 35m above ground): $35 - s = \frac{1}{2}at^2 = \frac{1}{2} \times (9.8)t^2 = 4.9t^2$

From which:

$$s = 35 - 4.9t^2$$

It follows that:

$$26t - 4.9t^2 = 35 - 4.9t^2$$

$$26t = 35; t = 1.35\text{s}$$

(i) The time is 1.35s.

Height: substitute into s for ball A:

$$s = 26(1.35) - 4.9(1.35)^2$$

$$s = 35.1 - 8.93 = 26.2\text{m}$$

(ii) The height is 26.2m above the ground.

Question 6

- (a) The ball already has the forward velocity of the moving vehicle at the instant it is released. After release it continues moving forward due to inertia while gravity pulls it downward. Hence, relative to the ground it travels forward as it falls and lands ahead of the release point.
- (b) On a smooth surface the frictional force between the runner's foot and the ground is small, so the ground cannot provide a large forward reaction force on the runner. Since forward acceleration requires a forward resultant force, the runner cannot accelerate effectively. On rough ground, greater friction allows a larger forward reaction force, making acceleration easier.

(c) Resultant force: $F = 20\text{N} - 4\text{N} = 16\text{N}$

$$\text{Acceleration: } a = \frac{F}{m} = \frac{16\text{N}}{5.0\text{kg}} = 3.2\text{m/s}^2$$

$$\text{Velocity after 5.0s: } v = u + at = 0 + (3.2\text{m/s}^2)(5.0\text{s}) = 16\text{m/s}$$

$$\text{Displacement in 5.0s: } s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(3.2\text{m/s}^2)(5.0\text{s})^2 = 40\text{m}$$

Question 7

- (a) Acceleration depends on change of velocity, and velocity changes if either magnitude or direction changes. In circular motion, the direction of velocity changes continuously even when speed is constant, so the object has acceleration directed toward the centre of the circle.
- (b) Passengers tend to continue in their original straight-line motion due to inertia while the car changes direction. Relative to the turning car, this gives the sideways leaning effect. The actual resultant force required for turning is directed toward the centre of the bend, and the passenger's body must be forced sideways to follow the curved path.

(c) Acceleration: $a = \frac{v-u}{t} = \frac{(0 - 18\text{m/s})}{9.0\text{s}} = -2.0\text{m/s}^2$

$$\text{Braking force: } F = ma = 1200\text{kg}(-2.0\text{m/s}^2) = -2400\text{N}$$

Magnitude of braking force = 2400N (opposite to the motion)

$$\text{Stopping distance: } s = ut + \frac{1}{2}at^2 = (18\text{m/s})(9.0\text{s}) + \frac{1}{2}(-2.0\text{m/s}^2)(9.0\text{s})^2 = 81\text{m}$$

Question 8

- (a) As velocity increases, resistive forces (especially air resistance and rolling resistance) increase. With roughly constant engine power, the driving force available at higher velocity does not keep increasing, while the opposing forces grow. The resultant force therefore decreases and may reach zero, so acceleration reduces and eventually becomes zero, giving a steady (terminal) velocity on the road.
- (b) Before motion begins, static friction adjusts up to a maximum value and can be large, so the crate strongly resists starting. Once the crate is moving, kinetic friction acts and is typically smaller and more nearly constant. With the same applied push, the resultant forward force becomes larger after slipping begins, so the crate moves more easily.
- (c) Using $v^2 = u^2 + 2as$; where: $u = 12\text{m/s}$, $v = 30\text{m/s}$, $s = 270\text{m}$

$$a = (v^2 - u^2)/(2s) = ((30)^2 - (12)^2)/(2 \times 270)$$

$$a = (900 - 144)/540 = 756/540 = 1.40\text{m/s}^2$$

$$\text{Resultant force: } F = ma = 1200\text{kg} \times 1.40\text{m/s}^2 = 1.68 \times 10^3 \text{ N}$$

Question 9

- (a) Velocity is defined relative to a reference frame. Different observers may use different frames (ground, vehicle, train etc), so they can assign different velocities to the same object without contradiction. Each velocity is correct within its own chosen reference frame.
- (b) When the bus changes lanes, it accelerates sideways. Unsecured objects tend to continue in their original straight-line motion due to inertia. Relative to the bus, they appear to shift sideways opposite to the bus's sideways acceleration. The sideways shift is therefore a consequence of inertia during change of direction.
- (c) Initial velocity: $u = +18\text{m/s}$, Acceleration: $a = -9.8\text{m/s}^2$, Displacement to ground: $s = -40\text{m}$

$$\text{Using } s = ut + \frac{1}{2}at^2$$

$$-40 = 18t + \frac{1}{2}(-9.8)t^2$$

$$-40 = 18t - 4.9t^2$$

$$\text{Rearrange: } 4.9t^2 - 18t - 40 = 0; t = 5.23\text{s}$$

The time taken to reach the ground is 5.23s.

Question 10

- (a) Motion does not require a net force; only a change in motion (acceleration) requires a net force. A body can move with constant velocity while the resultant force is zero. Net force is linked to acceleration, not to the existence of velocity.
- (b) Constant velocity means zero acceleration, so resultant horizontal force must be zero. Therefore, the forward push must be equal in magnitude to the frictional (and any other resistive) force acting backward.
- (c) Take initial direction toward the wall as positive: $m = 0.25\text{kg}$, $u = +10\text{m/s}$, $v = -8\text{m/s}$, $t = 0.030\text{s}$
- (i) Change in momentum:

$$\Delta p = m(v - u) = 0.25(-8 - 10) = 0.25(-18) = -4.5 \text{ kgm/s}$$

The change in momentum of the ball is 4.5kgm/s opposite to the initial motion's direction.

(ii) Average force:

$$F = \Delta p / \Delta t = (-4.5) / 0.030 = -150 \text{ N}$$

The average force exerted on the ball by the wall is 150N opposite to the initial motion's direction (away from the wall).

Question 11

(a) Acceleration depends on change of velocity, and velocity changes if direction changes even when magnitude is constant. Thus, an object moving with constant speed in a curved path can still accelerate because its direction of motion changes continuously.

(b)

Reason:

A change in direction of motion requires a resultant force toward the centre of the turn.

Explanation:

When the daladala turns, it accelerates sideways toward the centre of the curve. The passenger's body tends to continue moving in a straight line due to inertia. Relative to the turning vehicle, this makes the passenger appear to be pushed sideways outward.

(c) Using $s = ut + \frac{1}{2}at^2$; where: $u = 24\text{m/s}$, $a = -9.8\text{m/s}^2$, $s = 20\text{m}$

$$20 = 24t - 4.9t^2 \text{ or } 4.9t^2 - 24t + 20 = 0$$

Solving the quadratic equation gives: $t = 1.07\text{s}$ or $t = 3.83\text{s}$

(i) On the way downward \rightarrow larger time: $t = 3.83\text{s}$

(ii) Velocity then: $v = u + at = 24 - 9.8(3.83) = -13.5\text{m/s}$ (downward)

Question 12

(a)

Reason:

Forces cancel only when they act on the same body.

Explanation:

Equal and opposite forces can act on different bodies as part of a Newton's third-law interaction pair. Since these forces act on separate objects, they do not combine to give zero resultant force on any single body. Cancellation occurs only when opposite forces act on the same object.

(b) Forward motion while walking requires a forward frictional force from the ground. On a slippery surface, friction is too small, so the ground cannot provide a strong forward force on the foot. The foot slips backward and the person cannot generate sufficient forward acceleration.

(c) Total mass = 3kg + 5kg = 8kg

(i) Common acceleration: $a = \frac{F}{m_{\text{total}}} = \frac{16\text{N}}{8\text{kg}} = 2.0\text{m/s}^2$

(ii) Force exerted by A on B is the one that makes B to accelerate. Thus;

$$F_{AB} = m_B a = 5\text{kg}(2.0\text{m/s}^2) = 10\text{N}$$

Question 13

(a) In motions such as a vertical throw, the body slows down as it rises because acceleration remains downward. At the highest point the velocity becomes zero only momentarily (instantaneous), but acceleration is still present, so the velocity immediately changes again and the body continues moving in the opposite direction. Hence zero velocity at an instant does not mean the body is at rest for a finite time.

(b) As the bus goes around the roundabout, its velocity direction changes continuously even if the magnitude stays nearly constant. The passenger's body tends to continue in a straight line due to inertia, so relative to the turning bus the passenger feels pushed sideways. The actual force required is inward (toward the centre) to make the passenger follow the curved path.

(c) Given: $u = 22\text{m/s}$, $a = -9.8\text{m/s}^2$, height $h = 15\text{m}$.

Solve for times when $s = 15\text{m}$ using: $s = ut + \frac{1}{2}at^2$

$$15 = 22t - 4.9t^2 \text{ or } 4.9t^2 - 22t + 15 = 0$$

Solving the quadratic equation gives two values of t which are:

$$t_1 = 0.84\text{s (on the way upward)}$$

$$t_2 = 3.65\text{s (on the way downward)}$$

Time interval above 15m = $t_2 - t_1 = 3.65\text{s} - 0.84\text{s} = 2.81\text{s}$

So the stone is above 15m for **2.81s**.

Question 14

(a)

Reason:

A constant resultant force does not always guarantee constant acceleration unless the mass of the body remains constant.

Explanation:

Newton's second law in its most general form states that the resultant force equals the rate of change of momentum. If the mass of a body changes with time (for example, systems losing mass), a constant force can produce a non-uniform change in velocity. Therefore, constant force implies constant acceleration only when the mass of the body is constant.

(b)

Reason:

The maximum braking force depends on the friction between the tyres and the road.

Explanation:

On a wet road, the friction between tyres and the road surface is reduced. This limits the maximum braking force that can act on the vehicle. With a smaller braking force, the deceleration is smaller ($a = F/m$), so the vehicle takes more time and travels a longer distance before stopping. Hence the stopping distance increases on wet roads.

(c) Reaction distance: $s = vt$

$$s = (20 \text{ m/s})(0.70 \text{ s}) = 14\text{m}$$

Braking acceleration: $a = \frac{F}{m} = -\frac{3600}{1200} = -3\text{m/s}^2$

(i) Using $v = u + at$

$$0 = 20 - 3t; t = 6.67\text{s}$$

The braking time is 6.67s.

(ii) Using $v^2 = u^2 + 2as$

$$0 = 20^2 + 2(-3)s; s = 66.7\text{m}$$

The braking distance is 66.7m.

(iii) Total distance = Reaction distance + Braking distance = (14 + 66.7)m

The total stopping distance is 80.7m.

Question 15

(a)

Reason:

Acceleration depends on both force and mass.

Explanation:

During a collision, the two bodies exert equal and opposite forces on each other according to Newton's third law. However, acceleration is given by force divided by mass. **If the masses of the two bodies are different**, the same force produces different accelerations. Therefore, equal and opposite forces do not always lead to equal accelerations.

(b)

Reason:

A seatbelt increases the time over which a passenger's momentum changes.

Explanation:

When a vehicle brakes suddenly, the passenger tends to continue moving forward due to inertia. A seatbelt applies a stopping force over a longer time and distance compared with an abrupt stop against the dashboard or seat. Since average force equals change in momentum divided by time, increasing the stopping time reduces the force on the passenger, lowering the risk of injury.

(c) Using $s = h = ut - \frac{1}{2}gt^2 = ut - 4.9t^2$

If t is the time from the first launch.

Height of first ball: $h = 28t - 4.9t^2$

Height of second ball (launched 1.2 s later): $h = 34(t - 1.2) - 4.9(t - 1.2)^2$

Equating heights and simplifying gives: $t = 2.69\text{s}$

- (i) Time after first launch is 2.69s.
- (ii) Height: $h = 28(2.69) - 4.9(2.69)^2 = 39.9\text{m}$

Question 16

(a)

Reason:

Equal and opposite forces can act on the same body.

Explanation:

A Newton's third-law pair must act on two different bodies. Two forces can be equal and opposite yet both act on the same object (balanced forces). In that case they are not a third-law pair.

(b)

Reason:

Velocity includes direction as well as magnitude.

Explanation:

Two bodies can have the same speedometer reading yet have different velocities if their directions differ. Even if directions are opposite, the magnitudes can match but velocities are not the same

(c) Resistive force: $R = 400 + 50v$

(i) At $v = 12\text{ m/s}$; $R = 400 + 50(12) = 1000\text{ N}$

Resultant force: $F = 2200\text{N} - 1000\text{N} = 1200\text{N}$

Acceleration: $a = \frac{F}{m} = \frac{1200\text{N}}{1000\text{kg}} = 1.2\text{ m/s}^2$

The acceleration is 1.2 m/s^2 .

(ii) Acceleration becomes zero when driving force equals resistance:

$$2200 = 400 + 50v; v = 36\text{m/s}$$

The velocity is 36m/s .

Question 17(a) **Choice:** Forces balance**Reason:**

On Earth, resistive forces and contact forces are almost always present.

Explanation:

In ordinary motion, forces are rarely absent because bodies interact with the ground, air, and other surfaces. What commonly happens is that several forces act but balance so that the resultant force is zero, giving constant velocity or rest. Therefore “forces balance” matches ordinary motion more often than “forces are absent”.

(b)

Reason:

Newton’s third law requires interaction forces to be equal and opposite.

Explanation:

In an interaction, the force on A by B equals the force on B by A in magnitude. Therefore, there is no “bigger force” between the two interacting bodies. The body that accelerates more does so because it has smaller mass, not because it experiences a bigger interaction force.

(c) Velocities become equal when; $v_{\text{motorcycle}} = v_{\text{car}}$ For motorcycle: $v = u + at$

$$v = 18\text{m/s} + (2\text{m/s}^2)t$$

For car: $v = u + at$

$$v = 30\text{m/s} + (-3\text{m/s}^2)t$$

If velocities become equal:

$$18 + 2t = 30 - 3t; t = 2.4\text{s}$$

(i) Time when velocities become equal is 2.4s.

Motorcycle displacement: $s = ut + \frac{1}{2}at^2$

$$s_m = (18\text{m/s})(2.4\text{s}) + \frac{1}{2}(2\text{m/s}^2)(2.4\text{s})^2 = 48.96\text{m}$$

Car displacement: $s = ut + \frac{1}{2}at^2$

$$s_c = \left(\frac{30\text{m}}{\text{s}}\right)(2.4\text{s}) + \frac{1}{2}\left(-\frac{3\text{m}}{\text{s}^2}\right)(2.4\text{s})^2 = 63.36\text{m}$$

Separation = $s_c - s_m = 63.36\text{m} - 48.96\text{m} = 14.4\text{m}$

(ii) The separation between them is 14.4m.

Question 18

(a)

Reason:

Motion does not require a non-zero resultant force.

Explanation:

A body can move with constant velocity when the resultant force is zero. If two forces on the body are equal in magnitude and opposite in direction, the resultant force is zero, so the body does not accelerate but it can still continue moving if it already had velocity. Therefore, movement does not imply unequal forces; unequal forces are required only for changing velocity.

(b)

Reason:

Injury risk depends on the size of the stopping force, which depends on how quickly velocity is reduced.

Explanation:

When the diver enters deep water, the diver is brought to rest over a longer time and distance because the water yields and allows the body to decelerate gradually. Since the change in momentum is spread over a longer time, the average resultant force is smaller. A smaller stopping force reduces the likelihood of serious injury compared with coming to rest in a very short time on a rigid surface.

(c) Use vertical motion equation: $s = ut - \frac{1}{2}gt^2$ (From $s = ut + \frac{1}{2}at^2$; where $a = -g$)

Substituting:

$$18 = 28t - \frac{1}{2}(9.8)t^2 \text{ or } 18 = 28t - 4.9t^2$$

Rearranging:

$$4.9t^2 - 28t + 18 = 0$$

Solving the quadratic equation gives two values of t which are:

$$t_1 = 0.74\text{s (on the way upward)}$$

$$t_2 = 4.98\text{s (on the way downward)}$$

$$\text{Time interval above 18m} = t_2 - t_1 = 4.98\text{s} - 0.74\text{s} = 4.24\text{s}$$

So the stone is above 18m for 4.24s.

$$\text{Total time of flight: } T = \frac{2u}{g} = \frac{2 \times 28\text{m/s}}{9.8\text{m/s}^2} = 5.71\text{s}$$

Time interval below given height = Total time of flight – Time interval above the height

$$\text{Time interval below 18m} = (5.71 - 4.24)\text{s} = 1.47\text{s}$$

The stone is below the height of 18m for **1.47s** in total.