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91171



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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Physics 2025

91171 Demonstrate understanding of mechanics

Credits: Six

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of mechanics.	Demonstrate in-depth understanding of mechanics.	Demonstrate comprehensive understanding of mechanics.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Make sure that you have Resource Sheet L2-PHYSR.

In your answers use clear numerical working, words, and/or diagrams as required.

Numerical answers should be given with an appropriate SI unit.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in the margins (✂/✂/✂). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 23

QUESTION ONE: ACCELERATION

A rugby player accelerates uniformly from rest at 0.680 m s^{-2} and runs 22.0 m.



Source: <https://www.odt.co.nz/sport/rugby/black-ferns-sevens-win-cape-town>

- (a) How long did it take to run the 22.0 m?

$$d = 22.0 \text{ m} \quad a = 0.680 \text{ m s}^{-2} \quad v_i = 0 \text{ m s}^{-1} \quad t = ?$$

$$d = v_i t + \frac{1}{2} a t^2$$

$$22.0 = (0)(t) + \frac{1}{2}(0.680)(t^2)$$

$$22.0 = (0.34)(t^2)$$

$$t^2 = \frac{22.0}{0.34}$$

$$t = \sqrt{64.70588235}$$

$$t = 8.0439966$$

$$t = 8.04 \text{ s (2 s.f.)}$$

- (b) While stopping, a player runs into a tackle bag at speed v . The tackle bag compresses a distance x like a spring as the player comes to a stop.



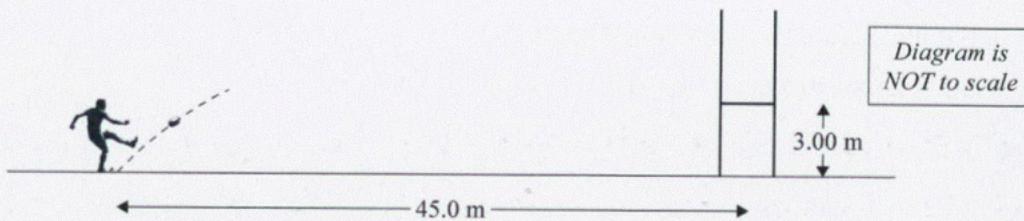
Source: <https://www.canterburysports.co.nz/product/silver-fern-tackle-bag-junior/>

Assuming all the player's energy is transferred to the bag, state and justify what would happen to the distance the bag was compressed if the player was moving at twice the speed.

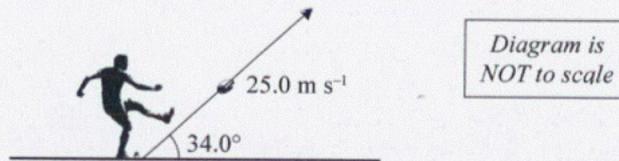
When we assume all the player's energy is transferred to the bag, we assume that all the kinetic energy becomes elastic potential energy. If the player is moving at twice the initial speed, kinetic energy will increase by four times as much. Since $E_k = E_p$, then $\frac{1}{2}mv^2 = \frac{1}{2}kx^2$. Since the mass of

The player and the spring constant will not change (will remain constant), the bag will compress twice as much as before, since $\frac{1}{2} m (2v)^2 = \frac{1}{2} k (2x)^2$.

- (c) To take a penalty shot, the ball is placed on the ground and kicked towards the goal posts. To make the penalty shot, the ball must go over the crossbar, which is 3.00 m above the ground and 45.0 m from where the ball is kicked.



A player taking a penalty shot kicks the ball at 25.0 m s^{-1} at 34.0° to the ground.



By performing appropriate calculations, decide whether the ball makes it over the crossbar before hitting the ground.

Vertical component of velocity:

$$\begin{aligned} \sin(34^\circ) &= \frac{v_v}{25.0} \\ v_v &= \sin(34^\circ)(25) \\ v_v &= 13.9798 \\ v_v &= 13.98 \text{ m s}^{-1} \end{aligned}$$

$$t = 2.619275$$

$$v_h = \cos(34^\circ)(25)$$

$$v_h = 20.725$$

$$d = v_h t$$

$$d = (20.7)(2.619)$$

$$d = 54.28 \text{ which}$$

is further than 45m so the ball goes over the bar. (The ball is 3m high when it is 54.28m from where it was kicked).

Finding Total time:

Time to max height:

$$v_i = 13.97 \quad v_f = 0 \text{ m s}^{-1} \quad a = -9.8 \quad t = ?$$

$$v_f = v_i + at$$

$$0 = 13.9798 + (-9.8)t$$

$$t = \frac{-13.9798}{-9.8}$$

$$t = 1.4265125$$

~~Time from max height to 3m~~

~~$$v_i = 0 \text{ m s}^{-1} \quad a = 9.8 \quad d = 3 \text{ m} \quad t = ?$$~~

~~d = v_i t + \frac{1}{2} a t^2~~

Total time found on

spare paper, and question solved a better way on spare paper.

- (d) The player from part (c) replaces the ball with one from a different manufacturer. The new ball is heavier.

The player kicks the new ball towards the posts so that it leaves the ground at the same speed and angle as before.

Ignoring any effects from air friction and without using calculations compare the path of the new ball to that of the original ball.

Your answer should consider:

- the time in the air
- the acceleration of the balls in the air
- the initial vertical and horizontal speeds
- the horizontal distances travelled.

The new ball is a projectile, so the only force acting on the ball is gravity. ~~Since it has a greater mass, the ball will accelerate faster, as the force of gravity is constant at 9.8 ms^{-2} , and $F=ma$~~
 Acceleration of a projectile is always constant 9.8 ms^{-2} due to gravity. Since it was kicked at the same initial speed, its initial vertical and horizontal speeds will be the same. Mass has no effect on the projectile's motion, since the only force acting is gravity, and mass does not have any impact on the four kinematic equations (as mass is not a variable). Therefore, since acceleration is not affected by the mass (only affected by gravity), and the ball leaves the ground at the same speed and angle as before, it will have the same vertical and horizontal speeds, and travel the same distance, and have the same air time. The ball's motion as a projectile will not change, because its mass will only affect factors like ~~momentum~~ momentum and kinetic energy, which do not affect projectile motion.

QUESTION TWO: MOMENTUM

A 80.0 kg player moves at 4.30 m s^{-1} .

- (a) Calculate the player's momentum and give the correct unit.

$$P = mv \quad p = (80.0)(4.30) \quad p = 344 \text{ kg}\cdot\text{m}\cdot\text{s}^{-1} \text{ (3 s.f.)}$$

Momentum: 344 Unit: $\text{kg}\cdot\text{m}\cdot\text{s}^{-1}$

- (b) Explain why using momentum to study collisions is more useful than using kinetic energy.

If we ignore the effects of unbalanced forces like friction, momentum is always conserved in collisions. This means that the total momentum before the collision occurs will be equal to the total momentum after the collision occurs. This is compared to kinetic energy, which is not always conserved in collisions. Kinetic energy is only conserved in elastic collisions, and not in inelastic collisions. It is often converted into heat or sound energy in a collision. Since momentum is always conserved ~~but not~~ and kinetic energy usually is not conserved, it is more useful to use conservation of momentum laws when studying collisions than using kinetic energy.

- (c) The mass of the All Black scrum is 883 kg. The mass of the Argentinian scrum is 850 kg. As the scrum is set, the All Blacks move forward at 0.354 m s^{-1} , and the Argentinians move forward at 0.378 m s^{-1} . The two scrums collide and stick together.



Argentina: 850 kg , 0.378 m s^{-1} All Blacks: 883 kg , 0.354 m s^{-1}

Source: <https://www.florugby.com/articles/6006062-round-3-in-the-rugby-championship-looms>

Calculate the speed and direction of the combined scrums immediately after they collide and stick together.

$$\begin{array}{l} \text{Before collision} \qquad \qquad \text{After collision} \\ \text{P}_{\text{total}} = \text{P}_{\text{total}} \\ \text{P}_{\text{All blacks}} + \text{P}_{\text{Argentina}} = \text{P}_{\text{All blacks}} + \text{P}_{\text{Argentina}} \\ mV + mV = M_{\text{total}}V \end{array}$$

$$(883)(-0.354) + (850)(0.378) = (883 + 850)(V)$$

$$-312.582 + 321.3 = (1733)(V)$$

$$8.718 = (1733)(V)$$

$$V = (8.718) / (1733)$$

$$V = 5.030582804 \times 10^{-3} \text{ m s}^{-1}$$

$$V = 5.03 \times 10^{-3} \text{ m s}^{-1} \text{ (3 s.f.)}$$

TO the right (direction Argentina is pushing)

- (d) The ball comes out of the scrum and a player sprints towards the line. The player is tackled and brought to a stop by colliding with thick pads (cushions) that are on the bottom of the goalpost.



Source: <https://www.perennial.co.nz/products/rugby-post-pads>

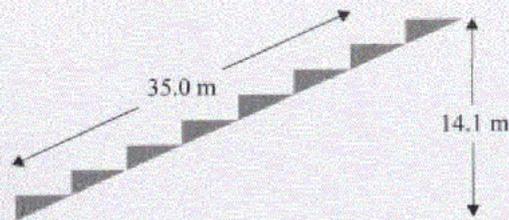
Explain how having these pads on the post help protect a player when they collide with the post.

The padding on the posts will increase the time over which a collision with the posts occurs (as the padding will compress). For the same change in momentum during a collision, an increased duration of collision will decrease the resultant force exerted on a player, since $\Delta F = \frac{\Delta p}{\Delta t}$. This decreased force experienced by the player means a decreased risk of injury for them during the collision.

Therefore, in increasing the duration of collision, having pads on the posts will decrease the force experienced by the player during a collision, protecting them from harm.

QUESTION THREE: ENERGY

When warming up, players run up the stairs.



Source: <https://www.abc.net.au/news/2016-10-07/top-three-exercises-youre-probably-doing-wrong/7909150>

- (a) Calculate the work done by a 68.3 kg player who runs up the stairs once.

Work done = Δ gravitational potential energy.

$$\Delta E_p = mgh$$

$$\Delta E_p = (68.3)(9.8)(14.1 - 0)$$

$$\Delta E_p = 27509.874$$

$$W = 27500 \text{ J (3 s.f.)}$$

(done against gravity).

- (b) Another warm up activity is short sprints.

During one sprint, the 68.3 kg player accelerates from rest to 7.52 m s^{-1} in 4.35 s.

Calculate the average power produced by the player during this sprint.

$$W = \Delta E_k$$

$$\Delta E_k = E_{k_f} - E_{k_i}$$

$$\Delta E_k = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$\Delta E_k = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$\Delta E_k = (68.3)(7.52^2 - 0^2)(0.5)$$

$$\Delta E_k = 1931.19616$$

$$W = 1930 \text{ J}$$

$$P = \frac{W}{t}$$

$$P = \frac{1931.19616}{4.35}$$

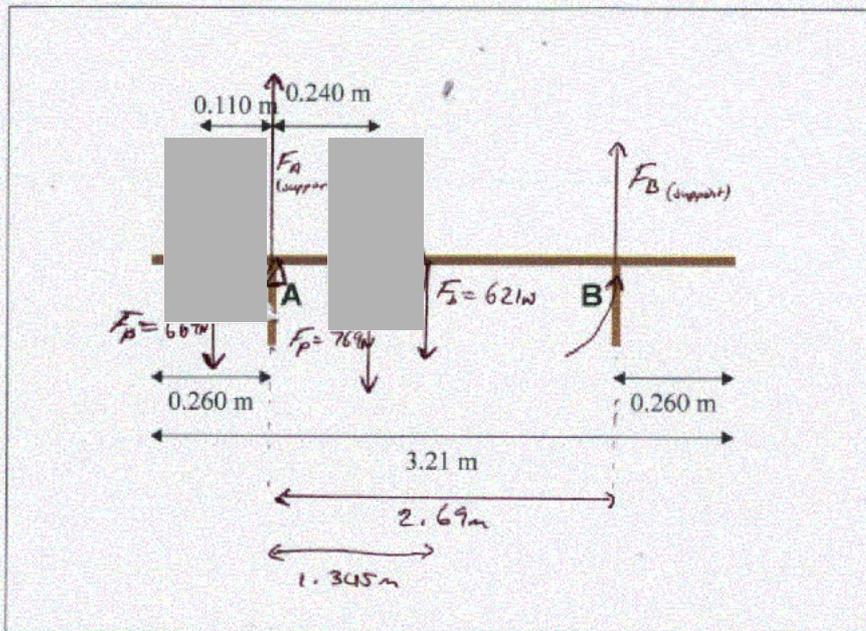
$$P = 443.9531602$$

$$P = 444 \text{ W (3 s.f.)}$$

Source: <https://www.bbc.com/sport/rugby-union/61819827>

- (c) While waiting to play, two players sit on a uniform bench.

The bench is 621 N and 3.21 m long. A 669 N player sits 0.110 m to the left of support A, and a 769 N player sits 0.240 m to the right of support A.



If you need to redraw your response, use the diagram on page 11.

Source: <https://www.gettyimages.co.nz/detail/news-photo/england-womens-rugby-players-celia-quansah-and-megan-jones-news-photo/1248571622>

- (i) Add labelled arrows to the above diagram, to show all the forces acting on the bench.
 (ii) By calculating torques about support A, calculate the value of the forces acting on the bench at A and B.

$$T_{\text{ccw}} = T_{\text{cw}}$$

$$T_{\text{player}(669\text{N})} + T_{\text{A}} = T_{\text{player}(769\text{N})} + T_{\text{bench}}$$

$$F_{\text{p}} d_{\text{r}} + F_{\text{A}} d_{\text{A}} = F_{\text{p}} d_{\text{r}} + F_{\text{B}} d_{\text{B}}$$

$$(669)(0.110) + (F_{\text{A}})(2.69) = (769)(0.240) + (621)(1.345)$$

$$73.59 + (F_{\text{A}})(2.69) = 184.56 + 835.245$$

$$(F_{\text{A}})(2.69) = 1019.805 - 73.59$$

$$F_{\text{A}} = 966.215 / 2.69$$

$$F_{\text{A}} = 351.7527881 \text{ N} = 352 \text{ N (3s.f.)}$$

$$F_{\text{up}} = F_{\text{down}}$$

$$F_{\text{A}} + F_{\text{B}} = F_{\text{p1}} + F_{\text{p2}} + F_{\text{B}}$$

$$F_{\text{A}} + 351.75278 = 669 + 769 + 621$$

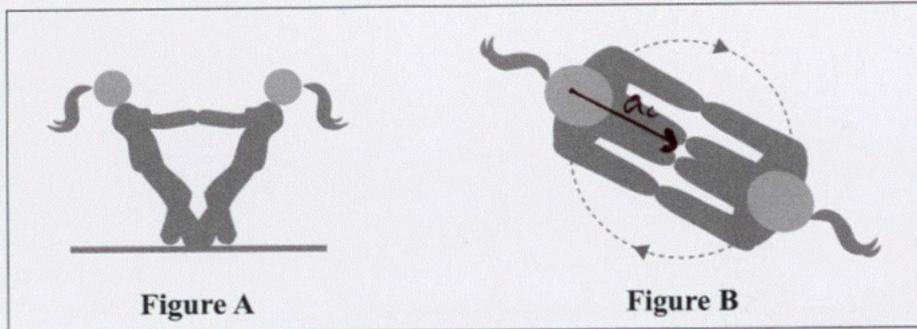
$$F_{\text{A}} = 2059 - 351.75278$$

$$F_{\text{A}} = 1707.247212 \text{ N}$$

$$F_{\text{A}} = 1710 \text{ N (3s.f.)}$$

Question Three continues on the following page.

- (d) Just before the players enter the game, they use one more warm-up activity, where two players hold hands and move around in a circle at constant speed.



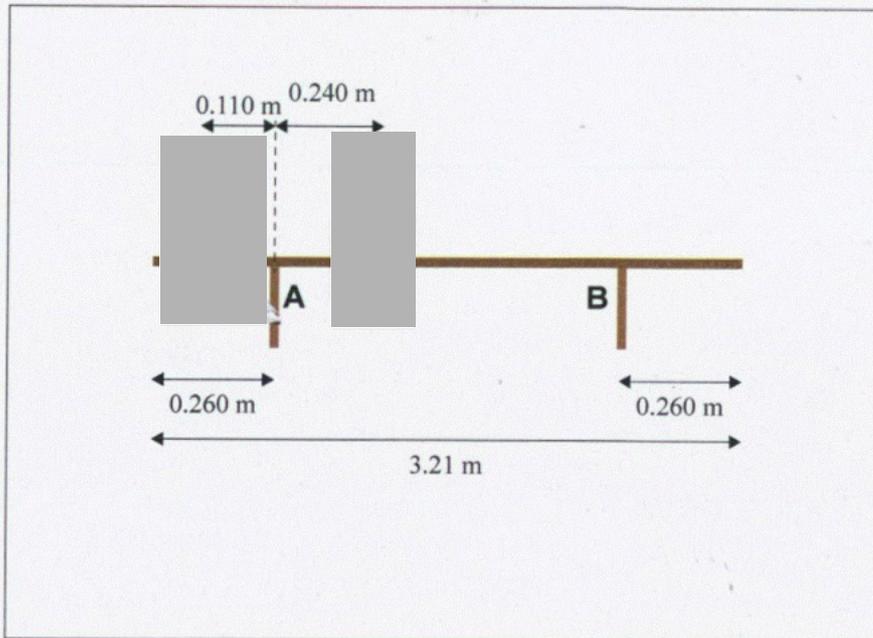
If you need to redraw your response, use the diagram on page 11.

- (i) Add an arrow to the Figure B above to show the direction of acceleration on one of the players.
- (ii) Explain how it is possible for the players to be moving at a constant speed yet accelerating.

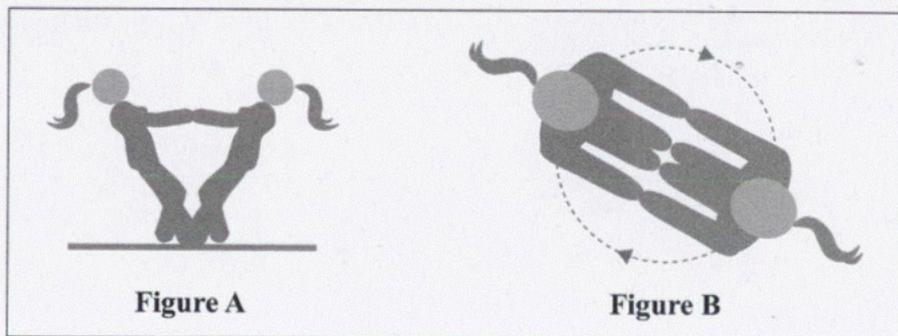
The two players are moving at a constant speed, yet also accelerating. Velocity is a vector quantity, meaning it has both magnitude and direction. The players are moving at a constant speed, but in order to change their direction and move in a circular motion, they must also be accelerating. Acceleration is caused by the centripetal force towards the centre of the circle, and both this force and the acceleration act at right angles to the constant tangential ^{speed} ~~velocity~~, causing the players' direction to change. This is how it is possible that the players are both moving at a constant speed, and also accelerating to change the direction of their motion.

SPARE DIAGRAMS

If you need to redraw your response to Question Three (c), use the diagram below. Make sure it is clear which answer you want marked.



If you need to redraw your response to Question Three (d), use the diagram below. Make sure it is clear which answer you want marked.



Extra space if required.
Write the question number(s) if applicable.

QUESTION
NUMBER

Question 1c continued (Question solved a better way to the right).

Time to 3m:

$$V_i = 13.9798 \text{ ms}^{-1} \quad t = ? \quad a = -9.8 \text{ ms}^{-2} \quad d = -3 \text{ m (on way down)}$$

$$d = v_i t + \frac{1}{2} a t^2$$

$$-3 = 13.9798(t) + \frac{1}{2}(-9.8)t^2$$

Distance at max height:

$$V_i = 13.9798 \quad V_f = 0 \text{ ms}^{-1} \quad a = -9.8 \quad d = ?$$

$$V_f^2 = V_i^2 + 2ad$$

$$0^2 = 13.9798^2 + (2)(-9.8)(d)$$

$$+ 195.435 / 19.6 = d$$

$$d = 9.9711 \text{ m}$$

Finding velocity at 3m

$$V_i = 0 \text{ ms}^{-1} \quad V_f = ? \quad a = 9.8 \quad d = 9.9711 - 3 = 6.971195098 \text{ m}$$

$$V_f^2 = V_i^2 + 2ad$$

$$V_f = \sqrt{0^2 + 2 \times 9.8 \times 6.9711}$$

$$V_f = 11.68911 \text{ ms}^{-1}$$

Finding time at 3m:

$$V_i = 0 \text{ ms}^{-1} \quad V_f = 11.68911 \text{ ms}^{-1} \quad a = 9.8 \quad t = ?$$

$$V_f = V_i + at$$

$$t = \frac{V_f - V_i}{a}$$

$$t = \frac{11.68911 - 0}{9.8}$$

$$t = 1.192766968 \text{ s}$$

Total time of flight = time to max height + time from max height to three metres.

$$t = 1.4265125 + 1.192766928$$

$$t = 2.619279477 \text{ s}$$

$$t = \cancel{2.61927} \quad 2.625 \text{ (3 s.f.)}$$

Extra space if required.
Write the question number(s) if applicable.

QUESTION
NUMBER

Question 1c solved a better way

$$V_h = \cos(34)(25)$$

$$V_h = 20.725 \text{ ms}^{-1}$$

$$V = d/t$$

$$t = d/V$$

$$t = \frac{45}{20.725}$$

$$t = 2.17119 \text{ s}$$

Find the height at $t = 2.17119 \text{ s}$

$$V_v = \sin(34)(25)$$

$$V_v = 13.9798$$

$$V_i = 13.9798, t = 2.17119, a = -9.8,$$

$$d = 3 \text{ (way down)} \quad d = ?$$

$$d = V_i t + \frac{1}{2} a t^2$$

$$d = (13.9798)(2.17119) + \frac{1}{2}(-9.8)(2.17119)^2$$

$$d = 7.2539$$

so the ball goes over the goal ~~post~~, since d is greater than 3 m, when the ball has travelled 45 m (2.17119 s).

Excellence

Subject: L2 Physics

Standard: 91171

Total score: 23

Q	Grade score	Marker commentary
One	E8	Competent, detailed responses. Alternative treatments of (c) illustrated wide-ranging thinking of this candidate.
Two	E8	Response demonstrated clarity of thinking and competence at explaining ideas correctly.
Three	E7	A comprehensively proficient response, marred only by a transcription error.