WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 3

PHYSICS



EXAM QUESTION PACK

OPTION C: THE PHYSICS OF SPORTS

SCORE	PERCENTAGE
/80	%

STEMUP

These questions belong to WJEC Eduqas, not to us.

The examination questions, mark schemes and examiner comments in this pack were written and published by WJEC Eduqas. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with WJEC Eduqas and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. WJEC Eduqas has not endorsed, approved or been involved in the production of it. WJEC Eduqas and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

WJEC Eduqas publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at eduqas.co.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

#1

13. The following photograph shows a cyclist crossing the finish line at the end of a race.



(a) State why the net moment acting on the cyclist is zero. [1]

.....

.....

.....

(b) (i) State what is meant by the moment of inertia of an object. [2]

.....

.....

.....

(ii) A diver of mass 60 kg and height 1.68 m has an angular momentum of 92.1 kg m^2 s^{-1} at the start of her dive. Her moment of inertia, I, at the start of the dive is

$$I = \frac{1}{12} mh^2$$

where m is her mass and h is her height. Calculate her angular velocity. [3]

.....

.....

.....

.....

.....

(iii) During the dive, the diver tucks in her arms and legs and reduces the moment of inertia to 2.7 kg m^2. Calculate the final angular velocity of the diver. [3]

.....

.....

.....

.....

.....

(c) The wheel of a Formula 1 car has a moment of inertia of 1.10 kg m^2. As the car approaches a corner and brakes, its angular velocity decreases from 220 rad s^{-1} to 170 rad s^{-1} in a time of 0.310 s.

(i) Calculate the resultant torque on the wheel of the car during the braking process. [3]

.....

.....

.....

.....

.....

(ii) Determine the total rotational kinetic energy lost by the wheels of the car during the above braking process assuming all the wheels have the same moment of inertia. [3]

.....

.....

.....

.....

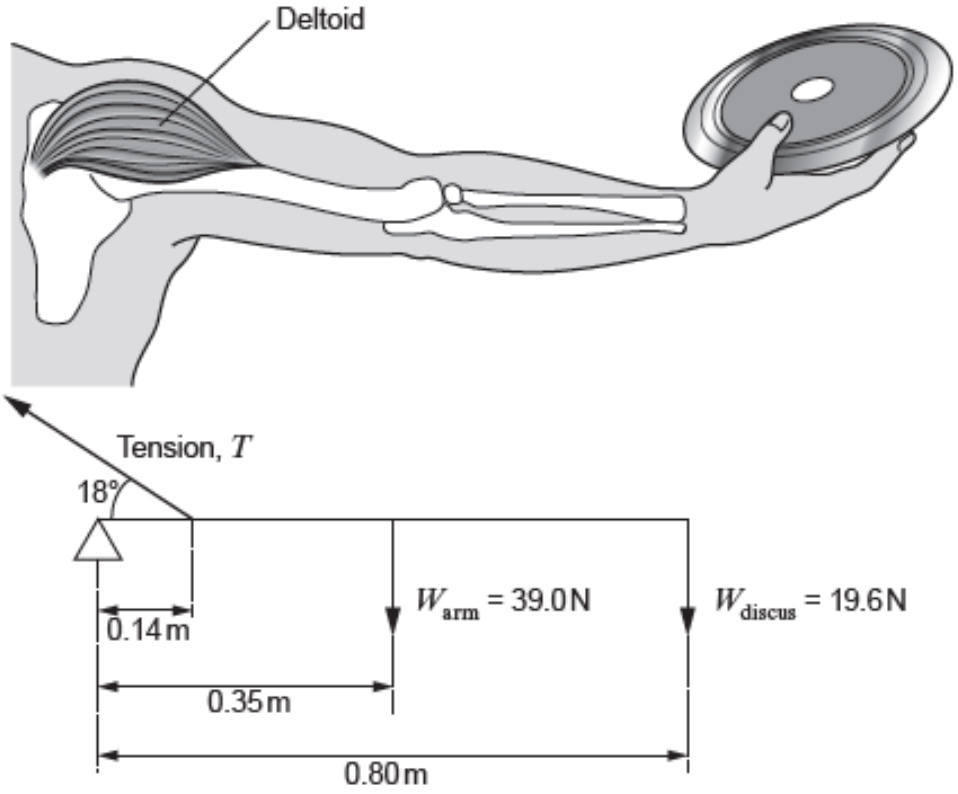
.....

(d) During a Grand Prix a driver loses control of the car when approaching a bend and crashes but escapes with minor injuries. The speed reduces from 213 km hr^{-1} to zero in a time of 0.651 s. The mass of the car is 640 kg and the driver's mass is 70 kg. Use the given data to evaluate why Grand Prix race circuits have large areas of grass or loose stone chippings around certain corners. [5]

Question taken from Eduqas examination paper 842103, June 2018

#2

13. *(a)* The diagram shows the forces acting on an athlete's arm as she holds a discus. Calculate the magnitude of the tension, T, provided by the deltoid muscle. [3]



.....

.....

.....

.....

(b) (i) Define angular acceleration. [1]

.....

.....

.....

(ii) When thrown, the discus experiences an angular acceleration. It accelerates from rest to 2.3 revolutions per second in a time of 0.27 s. Calculate the angular acceleration of the discus. [2]

.....

.....

.....

.....

(iii) Calculate the mean torque applied to the discus of mass 2.0 kg and radius 11 cm.

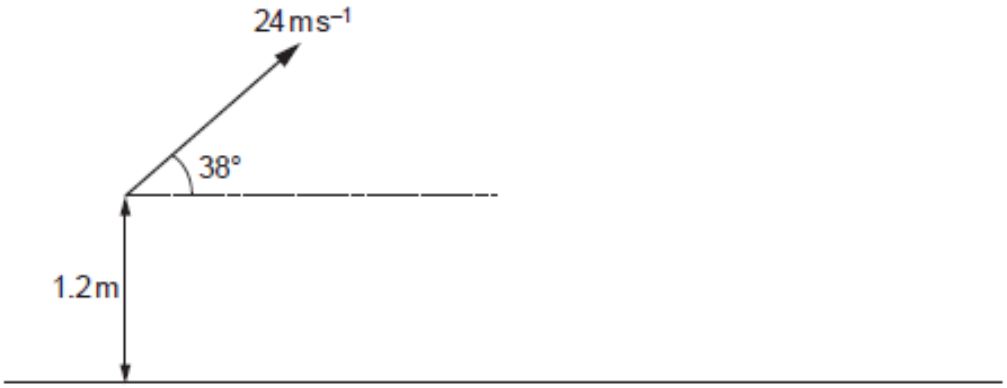
The moment of inertia is given by the equation $I = \frac{mr^2}{2}$. [3]

.....

.....

.....

(c) (i) Calculate the maximum height attained by the discus if it is thrown with a velocity of $24\,m\,s^{-1}$ and an angle of 38° from a height of 1.2 m. *Ignore the effects of air on the motion of the discus.* [4]



.....

.....

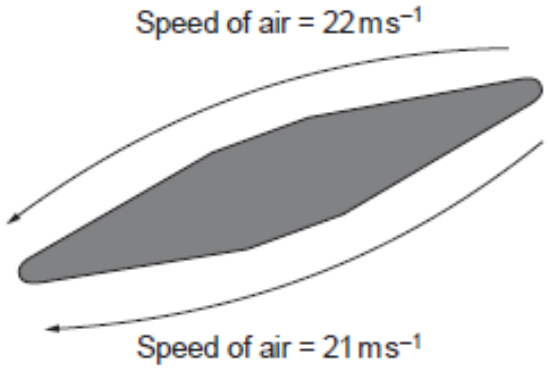
.....

.....

.....

.....

(ii) Taking the effects of air into account, evaluate whether the horizontal distance travelled by the discus will increase, decrease or remain approximately the same. The diagram shows the speed of air relative to the upper and lower surfaces of the discus. The density of air = $1.3\,kg\,m^{-3}$. [5]

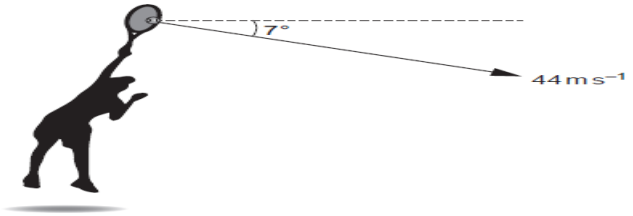


(iii) A wind tunnel is used to examine the motion of the discus in a wind speed of $20\,m\,s^{-1}$. Calculate the factor by which the drag force increases if the speed of the wind is increased to $30\,m\,s^{-1}$ and all other factors are kept constant. [2]

Question taken from Eduqas examination paper 842103, June 2019

#3

(a) (i) At the start of a tennis game, a player serves the ball with an initial velocity of $44\,m\,s^{-1}$ at an angle of 7° to the horizontal as shown below. The maximum horizontal distance for the ball to stay in play is 18.29 m. If the ball remains in the air for a time of 0.41 s, determine if the ball lands in play from the serve. *Ignore the effects of air resistance for this part of the question.* [3]

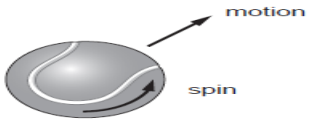


(ii) The tennis ball has a mass of 0.056 kg and is momentarily at rest before being hit by the racquet. Determine the mean force exerted by the racquet on the ball if they remain in contact for a time of 6.0 ms. [2]

(b) (i) The coefficient of restitution between the ball and the floor is 0.74. Explain what this statement means. [2]

(ii) Determine the **second** bounce height of a tennis ball if the ball is dropped from a height of 1.95 m (the coefficient of restitution between the ball and the floor is 0.74). [3]

(c) (i) During the game, the player plays a shot and applies spin to the ball. Explain how the ball will travel through the air by discussing the forces acting on the ball. Label the forces and their directions on the diagram provided. [4]



(ii) The ball is hit with a velocity of $16.4\,m\,s^{-1}$ and spins at a rate of 3500 revolutions per minute. Determine the **total** kinetic energy of the ball if the diameter of the ball is 7.0 cm and its mass is 0.056 kg.
Note: a tennis ball can be considered to be a thin spherical shell. [4]

(iii) Determine the drag force acting on the ball if the drag coefficient for a tennis ball is 0.53 and the density of air is $1.2\,kg\,m^{-3}$. [2]

Question taken from Eduqas examination paper 842103, June 2017

#4

(a) (i) Explain what is meant by the term *moment of inertia* of an object. [2]

(ii) Calculate the moment of inertia of a cricket ball which has a rotational kinetic energy of 1.47 J if it is spinning at a rate of 30 revolutions per second. [3]

(b) (i) The batsman hits the ball with an initial velocity of 25 m s^{-1} at an angle of 30° to the horizontal. A fielder standing 5.6 m away from the batsman can catch a ball 2.4 m above the ground. Evaluate whether the ball can be caught by the fielder. Assume that air resistance can be ignored and that the ball is hit from ground level. [5]



(ii) Explain why a fielder will move his hands in the direction of motion of the cricket ball when catching. [2]

(iii) The coefficient of restitution between the pitch and the ball is 0.37. Determine the bounce height if the ball falls from a height of 2.35 m. [2]

(c) For this part of the question, the interactions between the ball and the air need to be taken into account.

(i) Explain why a spinning cricket ball will change direction when moving through the air. Your answer should include the forces acting on the ball during the flight and a diagram may be included. [3]

(ii) Determine the drag force acting on a cricket ball of radius 3.6 cm during flight if the speed of the ball is 24.3 m s^{-1} and its drag coefficient is 0.76.
Density of air = 1.3 kg m^{-3}. [3]

Question taken from Eduqas examination paper 842103, November 2020

Marking Scheme

#1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
13	(a)		Centre of gravity/Weight of cyclist (and normal reaction) and bicycle acts though the base of the wheel	1			1		
	(b)	(i)	The moment of inertia about an axis is the sum (1) Of mass × radius^2 (distance from the axis) (1) Or $I = \sum mr^2$ (1) and symbols explained – see above (1) accept Moment (1) per unit angular acceleration (1)	2			2		
		(ii)	Calculating M of I = $\frac{1}{12}60 \times 1.68^2 = 14.112$ kg m^2 (1) Rearranging $\omega = \frac{J}{I} = \frac{92.1}{14.112}$ (1) Angular velocity = 6.53 rad s^{-1} (1)		3		3	2	
		(iii)	Applying conservation of angular momentum (1) Substitution of values $\omega = \frac{92.1}{2.7}$ (1) Angular velocity = 34.1 rad s^{-1} (1)	1	1 1		3	2	
	(c)	(i)	Substitution into torque $\tau = I\alpha$ or $\tau = \frac{\Delta(I\omega)}{t}$ or $\tau = \frac{I\Delta\omega}{t}$ (1) Substitute values for $\alpha = \frac{220-170}{0.310}$ or $\Delta(I\omega)=1.10\times(-50)$ [ignore sign] (1) $\tau = 177$ N m (1)	1	1 1		3	2	
		(ii)	Substitution into rotational KE = $\frac{1}{2}I\omega^2$ (1) Factor ×4 (four wheels) (1) Rotational KE lost = 42.9 × 10^3 J (1)	1	1 1		3	2	
	(d)		Converting km hr^{-1} to m s^{-1} correctly (1) Substituting values in $F = \frac{mv-mu}{t}$ or $a = \frac{v-u}{t}$ (1) F = 64.5 kN or 58 kN for car or 6.4 kN for driver or a = 90.9 m s^{-2}(1) Acceleration/Force is large/Need to reduce F or a (1) Grass or gravel area will increase the time or slow down before impact with wall etc.(1)			5	5	2	
			Question 13 total	**6**	**9**	**5**	**20**	**10**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
13	(a)		Anticlockwise moments = $T\sin 18° \times 0.14$ (1) Clockwise moments = $(39 \times 0.35) + (19.6 \times 0.8)$ (1) $T = 678$ [N] (1)	1	1 1		3	2	
	(b)	(i)	Angular acceleration is rate of change of angular velocity	1			1		
		(ii)	$\omega = 2\pi f = 2\pi \times 2.3$ (1) Angular acceleration = 53 [rad s^{-2}] (1)		2		2	1	
		(iii)	Use of torque $\tau = I\alpha$ (1) Moment of inertia = 0.0121 [kg m^2] (1) $\tau = 0.648$ [N m] (1)	1	1 1		3	2	
	(c)	(i)	Using 24 sin 38° (1) Height = $\frac{u^2}{2g}$ sub into equation (1) Height = 11.1 [m] (1) Maximum height = 12.3 [m] [1]	1 1	1 1		4	2	
		(ii)	Using Bernoulli equation $p = p_o - \frac{1}{2}\rho v^2$ (1) Determining difference in pressure = $\frac{1}{2}\rho(v_1^2 - v_2^2)$ (1) Difference in pressure = 28 [Pa] (1) Force = pA = 1.1 [N] [or weight equivalent pressure = 516 Pa] (1) Horizontal distance will remain approximately unchanged because weight is far greater (1) (accept increase slightly and allow ecf)			5	5	2	
		(iii)	$\frac{1}{2}\rho A v^2 C_D$ stated or $F_D \propto v^2$ (1) Factor increase = 2.25 (1)	1	1		2	1	
			Question 13 total	**6**	**9**	**5**	**20**	**10**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Using 44cos7° as horizontal component of velocity (1) Range calculated correctly = 17.9 [m] (1) Conclusion – ball in play (1)			3	3	2	
		(ii)	Use of $F = \frac{mv-mu}{t}$ (1) $F = \frac{0.056 \times 44}{0.006} = 411$ [N] (1)	1	1		2	1	
	(b)	(i)	Relative velocity after a collision = (1) 0.74 × relative velocity before a collision (1) **Alternative:** The ratio of the rebound speed (1) to the impact speed is 0.74 (1)	2			2		
		(ii)	Use of $e = \sqrt{\frac{h}{H}}$ or e used with speed/velocity (1) Height after first bounce = 1.07 [m] (1) Height after second bounce = 0.58 [m] **ecf** on height of first bounce (1)	1	1 1		3	2	
	(c)	(i)	Drag opposing motion and weight shown (1) Lift (Magnus force) shown at 90° to motion (up + left) (1) Lift keeps ball in air longer/gives greater height (1) Lift or drag vary/decrease during flight as speed/spin changes (1)	1	1	1 1	4		
		(ii)	Angular velocity = 367 rad s^{-1} (1) Moment of inertia = 4.6×10^{-5} kg m^2 (1) Total KE = linear + rotational (1) Total KE = 10.60 [J] **ecf** on rotational KE (1)	1	1 1 1		4	3	
		(iii)	$A = 3.8 \times 10^{-3}$ m^2 or $\pi \times (3.5 \times 10^{-2})^2$ (1) $F = 0.33$ [N] (1)		2		2	2	
			Question total	**6**	**9**	**5**	**20**	**10**	**0**

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Moment of inertia of a body about a given axis is defined as $I = \Sigma mr^2$ for all points in the body (1) where m is the mass and r is the distance of each point from the axis (1) accept radius of cricket ball	2			2		
		(ii)	Rotational Kinetic energy = $\frac{1}{2}I\omega^2$ (1) Angular velocity = (30 × 2π) (1) Moment of inertia = 8.3 × 10^{-5} [kg m^2] (1)	1	1 1		3	2	
	(b)	(i)	Vertical component = 12.5 [m s^{-1}] and horizontal component = 21.7 [m s^{-1}] (1) Time taken for ball to travel 5.6 m = 0.25 s ($\frac{5.6}{21.7}$) (1) Correct substitution of values into $x = ut + \frac{1}{2}at^2$ to determine height after 0.25 s (**ecf**) **OR** calculating times at which height is 2.4 m (1) Height = 2.8 [m] **OR** time is around 0.21 [s] (1) So ball cannot be caught by fielder (1)			5	5	4	
		(ii)	Moving hand in direction of ball will <u>increase time</u> of contact **OR** distance of contact (1) According to $F = \frac{mv-mu}{t}$; **OR** $F = \frac{Wd}{x}$ this will reduce force (1)		2		2		
		(iii)	Re-arranging to determine bounce height as e^2H (1) Bounce height = 0.32 [m] (1)		2		2	2	
	(c)	(i)	Forces of drag and weight drawn or discussed (1) Lift or Magnus force shown or discussed (1) Resultant of these forces decides motion (1)	3			3		
		(ii)	Effective area of sphere = πr^2 = 4.07 × 10^{-3} m^2 (1) Substituting values into $F_D = \frac{1}{2}\rho v^2 A C_D$ (1) Drag force = 1.19 [N] (1)		3		3	2	
			Question total	**6**	**9**	**5**	**20**	**10**	**0**