Mark Scheme (Results)

Summer 2022

Pearson Edexcel International Advanced Level
In Mechanics 3 (WME03) Paper 01

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

PEARSON EDEXCEL IAL MATHEMATICS

General Instructions for Marking

1. The total number of marks for the paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

<u>'M' marks</u>
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation.
e.g. resolving in a particular direction, taking moments about a point, applying a suvat equation, applying the conservation of momentum principle etc.
The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. in a moments equation, every term must be a 'force x distance' term or 'mass x distance', if we allow them to cancel 'g' s.
For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

M marks are sometimes dependent (DM) on previous M marks having been earned.
e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

<u>'A' marks</u>
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. E.g. M0 A1 is impossible.

<u>'B' marks</u>
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph)

A few of the A and B marks may be f.t. – follow through – marks.

3. General Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol $\sqrt{}$ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- * The answer is printed on the paper
- ⎣ The second mark is dependent on gaining the first mark

4. All A marks are 'correct answer only' (cao.), unless shown, for example, as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks affected are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

General Principles for Mechanics Marking

(But note that specific mark schemes may sometimes override these general principles)

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.

- Omission or extra g in a resolution is an accuracy error not method error.

- Omission of mass from a resolution is a method error.

- Omission of a length from a moments equation is a method error.

- Omission of units or incorrect units is not (usually) counted as an accuracy error.

- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.

- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.

- Use of g = 9.81 should be penalised once per (complete) question.

  N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.

- Marks must be entered in the same order as they appear on the mark scheme.

- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.

- Accept column vectors in all cases.

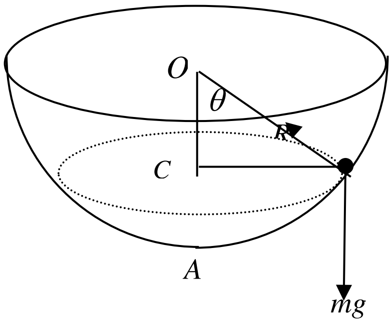
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft

- Mechanics Abbreviations

M(A)	Taking moments about A.
N2L	Newton's Second Law (Equation of Motion)
NEL	Newton's Experimental Law (Newton's Law of Impact)
HL	Hooke's Law
SHM	Simple harmonic motion
PCLM	Principle of conservation of linear momentum
RHS, LHS	Right hand side, left hand side

Question Number	Scheme	Marks
1(a)	$\frac{2\pi}{\omega} = \frac{1}{2} \Rightarrow \omega = ...$	M1
	$\omega = 4\pi$	A1
	$v = "\omega" \times 0.3$	M1
	$v = 1.2\pi$, 3.8 or better (m s^{-1})	A1 (4)
(b)	$x = a\sin\omega t \Rightarrow 0.15 = 0.3\sin 4\pi t \Rightarrow t = ...$	M1
	$t = \frac{1}{4\pi} \times \frac{\pi}{6} = \frac{1}{24}$ (s) $0.04166... = 0.042$ or better	A1 (2) **[6]**

	Notes
(a)	
M1	Use period = 1/frequency to find a value for ω . Must be correct way up.
A1	Correct value for ω
M1	Use of $v = a\omega$ or $v^2 = \omega^2(a^2 - x^2)$ with x=0 .
A1	cao
(b)	
M1	Use $0.15 = a\sin\omega t$ to obtain a value for t . Use *their a* and ω.
A1	Correct value, 0.042 or better
ALT 1(b)	**Using cos** Complete method using $x = a\cos\omega t$ AND $\frac{T}{4}$ to obtain a value for t
MI	$x = a\cos\omega t \Rightarrow 0.15 = 0.3\cos 4\pi t \Rightarrow t = ...$ $\frac{T}{4} - t = \frac{0.5}{4} - t = ...$
A1	Correct value, 0.042 or better

Question Number	Scheme	Marks
2.		
	$R\sin\theta = m \times 6r\sin\theta \times \frac{g}{4r}$	M1A1A1
	$R = \frac{3}{2}mg$	
	$R\cos\theta = mg$	M1A1
	$\frac{3}{2}mg\cos\theta = mg$	DM1
	$\cos\theta = \frac{2}{3}$	A1
	$OC = 6r\cos\theta = 6r \times \frac{2}{3} = 4r$	M1A1
		[9]

	Notes
M1 **A1** **A1**	Attempt NL2 along *CP* with correct number of terms and forces resolved. Either side correct Fully correct equation Note: If R is not resolved then M0 **but** do allow if $\sin\theta$ is cancelled from **both** sides: $R = m \times 6r \times \frac{g}{4r}$ would score M1A1A1 If r is used instead of the radius: $R\sin\theta = m \times r \times \frac{g}{4r}$ would score M1A1A0 (force resolved correctly on LHS but error in radius on RHS)
M1 **A1**	Resolve vertically Correct equation
DM1 **A1** **M1** **A1**	Eliminate *R* between the two equations. Depends on both M marks above Correct value for $\cos\theta$ seen or implied Attempt to obtain *OC* (allow sin/cos confusion) $OC = 4r$
	Note: If θ is the angle with the horizontal then all equations above will appear with $\sin\theta$ and $\cos\theta$ reversed.

Question Number	Scheme	Marks
ALT 1	**Case: using trig ratios where radius, L, and ω2 are never replaced** M1 A1 A1: R sinθ = m L ω2 M1 A1: R cosθ = mg DM1 A1: tan θ = $\frac{L\omega^2}{g} = \frac{L}{4r}$ M1 A1: tan θ = $\frac{L}{OC} \Rightarrow OC = 4r$	
ALT 2	**Case: resolving tangentially where R is never seen** $mg\sin\theta = m \times (6r\sin\theta) \times \frac{g}{4r}\cos\theta$ scores M1A1A1 M1A1 DM1 leads straight to $\cos\theta = \frac{2}{3}$ A1	

Question Number	Scheme	Marks
3(a)	$v=\dfrac{50}{2x+3}$	
	$\dfrac{dv}{dt}=\dfrac{dv}{dx}\times\dfrac{dx}{dt}$	M1
	$=\dfrac{-100}{(2x+3)^2}\times\dfrac{50}{2x+3}\quad\left(=\dfrac{-5000}{(2x+3)^3}\right)$	DM1A1
	$x=12\quad \dfrac{dv}{dt}=-\dfrac{5000}{27^3}=-0.2540...=-0.25\text{ or }-0.254\text{ m s}^{-2}$	M1
	deceleration $=0.25$ (m s $^{-2}$) or better	A1 (5)
(b)	$v=\dfrac{dx}{dt}=\dfrac{50}{2x+3}$	M1
	$\int(2x+3)\,dx=\int 50\,dt$	
	$x^2+3x=50t\ (+c)$	M1A1
	$t=1,\ x=4\Rightarrow 28=50+c,\ c=-22$	A1
	$x=12\Rightarrow 50t=12^2+36+22\quad t=\dfrac{202}{50}=4.04$ (accept 4.0)	A1 (5)
		[10]

Notes

(a)	
M1	Uses chain rule of the form $\dfrac{dv}{dt}=\dfrac{dv}{dx}\times\dfrac{dx}{dt}$ or $\dfrac{d(\frac{1}{2}v^2)}{dx}$ Note, $\dfrac{1}{2}v^2=\dfrac{1250}{(2x+3)^2}\ \Rightarrow\ \text{acc}=\dfrac{d(\frac{1}{2}v^2)}{dx}=-\dfrac{2500}{(2x+3)^3}\times 2$ However, **M0** for acc = $\dfrac{1}{2}v^2$
DM1	Differentiate v wrt x
A1	Correct differentiation.
M1	Sub x = 12 into their expression for acceleration to obtain the deceleration. Must have attempted to differentiate.
A1	Correct deceleration – must be positive
(b)	
M1	Use $v=\dfrac{dx}{dt}$
M1	Attempt at integration
A1	Correct integration but c may be missing
A1	Use $t=1,\ x=4$ to obtain the correct value of c for their correct integration
A1	Sub x = 12 to obtain the correct value of t

ALT 3(b)	Using definite integration: $\int_4^{12}(2x+3)\mathrm{dx} = \int_1^T 50\,\mathrm{dt}$
M1	Integrate $\left[x^2+3x\right]_4^{12} = \left[50t\right]_1^T$
A1	Correct integration
A1	Sub in limits $12^2+3(12)-4^2-3(4)=50T-50$
A1	Obtain correct value

Question Number	Scheme	Marks
4(a)	Energy from *C* to *D*	
	$$mg\frac{l}{4}\sin 30° = \frac{\lambda}{2l}\left(\frac{l}{4}\right)^2$$	M1A1A1
	$$\lambda = 4mg \ *$$	A1* **(4)**
(b)	The greatest speed is when the acceleration of *B* is zero	
	$(\nwarrow)$ $$T = mg\sin 30° = \frac{4mge}{l}$$	M1
	$$e = \frac{l}{8}$$	A1
	Energy: $$\frac{1}{2}mv^2 + \frac{4mg}{2l}\left(\frac{l}{8}\right)^2 = mg\frac{l}{8}\sin 30°$$	M1A1A1
	$$v = \sqrt{\left(\frac{gl}{16}\right)} = \frac{\sqrt{gl}}{4}$$	DM1A1 **(7)**
		[11]
	Notes	

(a)	
M1	Attempt the energy equation from *C* to *D*. Must use a vertical height for PE. EPE must have the form kx^2. Must have 1 PE term and 1 EPE term.
A1	Correct loss of PE
A1	Correct final EPE
A1*	Correct answer correctly obtained
(b)	
M1	Resolve along the plane using HL to find *T*
A1	Correct value for the extension
M1	Form the energy equation with an extension they have found. **M0** if $l/4$ is used for the extension. Must use a vertical height for PE. EPE must have the form kx^2 Must have 1 PE term, 1 KE term and 1 EPE term.
A1	Two correct terms
A1	Completely correct equation
DM1	Solve for *v*. Dependent on previous M.
A1	Correct expression for *v*
4(b) ALT 1	**Using integration**
M1 A1	As above, for finding correct value for *e*. This may be embedded in a complete method.
M1	Uses F=ma to and attempts to integrate. Must have the correct number of terms and weight resolved, $\int g\sin 30 - \frac{4gx}{l}\,\mathrm{d}x = \int v\,\mathrm{d}v$ leading to $\frac{gx}{2} - \frac{2gx^2}{l} = \frac{v^2}{2} + c$
A1	Correct integration with at most one slip/error
A1	Completely correct integration but *c* may be missing
DM1	Find value for *c* (when $x = \frac{l}{4}$, v=0 gives c=0) **and** sub in *e* to find an expression for *v*
A1	Correct expression for *v*

4(b) **ALT 2** M1 A1 M1 A1 A1 M1 A1	**Using SHM** As above, for finding correct value for e. This may be embedded in a complete method. Correctly uses F=ma to show that the motion is SHM Correct proof of SHM Uses $v = aw$ to find an expression for v Correct expression for v

Question Number	Scheme	Marks
5(a)	$(\pi\rho)\int_0^r xy^2\mathrm{d}x$	
	$=(\pi\rho)\int_0^r x\left(r^2-x^2\right)\mathrm{d}x$	M1
	$=(\pi\rho)\left[\frac{1}{2}x^2r^2-\frac{x^4}{4}\right]_0^r$	A1
	$=(\pi\rho)\frac{r^4}{4}$	A1
	$\frac{2\pi\rho r^3}{3}\bar{x}=\pi\rho\int xy^2\mathrm{d}x$	M1
	$\bar{x}=\frac{\pi\rho r^4}{4}\div\frac{2\pi\rho r^3}{3}=\frac{3}{8}r$ *	A1* (5)
(b)	Hemisphere / Cone	
	Mass: $\frac{2}{3}\pi r^3$ / $\frac{1}{3}\pi k r^3$	B1
	Dist of c of m from centre of common plane: $\frac{3}{8}r$ / $\frac{1}{4}kr$	B1
	$\frac{2}{3}\times\frac{3}{8}r=\frac{k}{3}\times\frac{1}{4}kr$	M1A1ft
	$k^2=3 \quad k=\sqrt{3}$	A1 (5) [10]
(a)		
M1	Use of $(\pi\rho)\int_0^r xy^2\mathrm{d}x$ with $y^2=r^2-x^2$ and attempt the integration. Limits not needed.	
A1	Correct integration – limits not needed	
A1	Sub correct (upper) limit. (Sub of 0 not needed)	
M1	Use of $V\rho\bar{x}=\pi\rho\int xy^2\mathrm{d}x$ with their result to obtain $\bar{x}=...$ where V is the volume of the hemisphere or sphere (π , p must be on both sides or neither)	
A1*	$\bar{x}=\frac{3}{8}r$	
(b)		
B1	Correct mass ratio for hemisphere and cone. Total mass not needed for this mark.	
B1	Correct distances of c of m for cone and hemisphere from centre of common plane (or another point). Both can be positive or one can be negative. Distances from vertex of cone (H) $kr+\frac{3}{8}r$ (C) $\frac{3}{4}kr$ Distances from peak of hemisphere (H) $\frac{5}{8}r$ (C) $r+\frac{1}{4}kr$	
M1	Form a dimensionally correct moments equation **with the correct value for $\bar{x}$ depending on where they have taken moments**. (0 from plane face, kr from vertex of cone, r from peak of hemisphere) Allow even if formula for sphere is used. Ignore signs.	

A1ft **A1**	Correct equation, follow through their masses and distances, signs to be correct here. Correct exact result.

Question Number	Scheme	Marks
6(a)	$S - mg\cos\theta = \dfrac{mv^2}{a}$	M1A1
	$\dfrac{1}{2}\times mv^2 - \dfrac{1}{2}\times m\times\dfrac{9ag}{5} = mga\cos\theta$	M1A1
	$mv^2 = 2mga\cos\theta + \dfrac{9}{5}mga$	
	$S = mg\cos\theta + 2mg\cos\theta + \dfrac{9}{5}mg$	DM1
	$S = \dfrac{3}{5}mg\left(5\cos\theta + 3\right)$ *	A1* cso (6)
(b)	$S = 0 \quad \cos\theta = -\dfrac{3}{5}$	B1
	$v^2 = \dfrac{3ag}{5} \qquad v = \sqrt{\dfrac{3ag}{5}}$ *	M1A1*
		(3)
(c)	vert comp = $\sqrt{\dfrac{3ag}{5}}\times\dfrac{4}{5}$	M1
	Vert distance to highest point: $0 = \dfrac{16}{25}\times\dfrac{3ag}{5} - 2gs$	M1
	$s = \dfrac{24}{125}a$	A1
	Total distance above $O = \dfrac{24}{125}a + \dfrac{3}{5}a = \dfrac{99}{125}a$, 0.79$a$ or better	A1ft
		(4)
	Notes	**[13]**

(a) M1	Equation of motion along the radius. Must have 3 terms with weight resolved. Acceleration in either form.
A1	Fully correct equation with acceleration v^2/r
M1	Energy equation from *A* to general position. Difference of 2 KE terms and loss of PE (one or two terms) required. M0 for $v^2 = u^2 + 2as$
A1	Fully correct equation
DM1	Eliminate v^2 between the 2 equations. Depends on both preceding M marks
A1 *cso	Obtain the **given** result from fully correct working.
(b)	
B1	$\cos\theta = -\dfrac{3}{5}$ seen explicitly or used
M1	Use their value of $\cos\theta$ to obtain the value of v^2 or v
A1*	Correct answer from correct working
(c)	
M1	Use their values for θ and v to obtain the vertical comp of velocity (allow sin/cos confusion)
M1	Correct method to find the vertical distance to highest point using their vertical comp of vel
A1	Correct expression for this vertical distance (may be implied)
A1ft	Find the total distance above *O* by adding $\dfrac{3a}{5}$ to their previous answer. Both M marks needed.

ALT 1	**Conservation of Energy from <u>slack</u> to find vertical height**
M1	Uses their value of θ and v to obtain the horizontal component at the highest point $\sqrt{\frac{3ag}{5}}\cos\theta$
M1	Forms an energy equation. **Must** have 2 KE terms and gain in PE $\frac{1}{2}m\frac{3ag}{5}-\frac{1}{2}m\frac{3ag}{5}\left(\frac{3}{5}\right)^2=mgs$
A1	Correct expression for this vertical distance $s=\frac{24}{125}a$
A1ft	Find the total distance above O by adding $\frac{3a}{5}$ to their previous answer. Both M marks needed. $\frac{99}{125}a$, $0.79a$ or better
ALT 2	**Conservation of Energy from <u>initial position</u> (A) to find vertical height**
M1	Uses their value of θ and v to obtain the horizontal component at the highest point $\sqrt{\frac{3ag}{5}}\cos\theta$
M1 A1	Forms an energy equation. **Must** have 2 KE terms and gain in PE $\frac{1}{2}m\frac{9ag}{5}-\frac{1}{2}m\frac{3ag}{5}\left(\frac{3}{5}\right)^2=mgh$
A1	Gives the total distance above O as $h=\frac{99}{125}a$ (do not isw)

Question Number	Scheme	Marks
7(a)	$(T=)\dfrac{20(1)}{2}=\dfrac{\lambda\times 0.8}{1.2}$	M1A1
	$\lambda = 15$ *	A1* (3)
(b)	Either $1.25\ddot{x}=\dfrac{15(0.8-x)}{1.2}-\dfrac{20(1+x)}{2}$ Or $1.25\ddot{x}=\dfrac{20(1-x)}{2}-\dfrac{15(0.8+x)}{1.2}$	M1A1A1
	$\ddot{x}=-18x$	A1* (4)
(c)	$10=a\sqrt{18}\Rightarrow a=\dfrac{10}{\sqrt{18}}$ oe	B1
	When string *PB* becomes slack $v^2=18\left(\left(\dfrac{10}{\sqrt{18}}\right)^2-0.8^2\right)$	M1
	$v=9.4063...$ $v=9.4$ or $9.41\ \text{m s}^{-1}$	A1 (3)
(d)	$0.8=\dfrac{10}{\sqrt{18}}\sin\sqrt{18}t_1$	M1A1
	$t_1=\dfrac{1}{\sqrt{18}}\sin^{-1}\left(0.8\dfrac{\sqrt{18}}{10}\right)$ $(=0.0816...)$	A1
	PA becomes slack when $x=-1$	
	$(\pm1)=\dfrac{10}{\sqrt{18}}\sin\sqrt{18}t_2$	M1
	$t_2=\dfrac{1}{\sqrt{18}}\sin^{-1}\left(\dfrac{\sqrt{18}}{10}\right)$ $(=0.1032...)$	A1
	$T=2(t_1+t_2)=2\left(\dfrac{1}{\sqrt{18}}\sin^{-1}\left(0.8\dfrac{\sqrt{18}}{10}\right)+\dfrac{1}{\sqrt{18}}\sin^{-1}\left(\dfrac{\sqrt{18}}{10}\right)\right)$	A1 (6)
	$=0.3697...=0.37$ or 0.370	
	Notes	**[16]**
(a)		
M1	Form an equation by equating the 2 tensions (found using HL)	
A1	Equation correct	
A1*	Correct answer correctly obtained	
(b)		
M1	Equation of motion for *P*. Acceleration can be *a*	
A1	Correct equation of motion with at most one error, acceleration may be *a*	
A1	Fully correct equation of motion, acceleration may be *a*	
A1*	Correct **given** equation, correctly obtained	

(c) **B1** **M1** **A1**	Correct amplitude, $a = \frac{10}{\sqrt{18}}, \frac{5\sqrt{2}}{3}, \frac{\sqrt{50}}{3}$, 2.4 oe Use $v^2 = \omega^2\left(a^2 - x^2\right)$ with $x = 0.8$ and their a and ω Correct speed when $x = 0.8$
(d) **M1** **A1** **A1** **M1** **A1** **A1**	Use $x = 0.8$ to find the time until *PB* becomes slack using their a and ω Correct equation Correct time (seen or implied) Allow consistent use of degrees. **NB** There are alternative method for finding this time but a complete method for the time until *PB* becomes slack must be used for the M mark to be awarded. Use $x = \pm 1$ to find the time until *PA* becomes slack (as before, alternative methods must be complete) using their a and ω Correct time obtained. Ignore consistent use of degrees. Complete to obtain the **correct** value of T
ALT (c) M1 B1 (treat as A1) A1	**Conservation of Energy, O to slack** Dimensionally correct energy equation with **3 EPE** terms and **2 KE** terms $\frac{20\times 1^2}{2\times 2} + \frac{1.25\times 10^2}{2} + \frac{15\times 0.8^2}{2\times 1.2} = \frac{20\times 1.8^2}{2\times 2} + \frac{1.25\times v^2}{2}$ Correct answer. $v = 9.4063...$ $v = 9.4$ or $9.41\ \mathrm{m\,s^{-1}}$
ALT 7 (d) M1 A1 A1 M1 A1 A1	**Using cos** $0.8 = \frac{10}{\sqrt{18}}\cos\sqrt{18}t_1$ $t_1 = \frac{1}{\sqrt{18}}\cos^{-1}\left(0.8\frac{\sqrt{18}}{10}\right) \quad (= 0.2886...)$ $-1 = \frac{10}{\sqrt{18}}\cos\sqrt{18}t_2$ $t_2 = \frac{1}{\sqrt{18}}\cos^{-1}\left(-\frac{\sqrt{18}}{10}\right) \quad (= 0.4735...)$ $T = 2\left(t_2 - t_1\right) = 2\left(\frac{1}{\sqrt{18}}\cos^{-1}\left(-\frac{\sqrt{18}}{10}\right) - \frac{1}{\sqrt{18}}\cos^{-1}\left(0.8\frac{\sqrt{18}}{10}\right)\right)$ $= 0.3697... = 0.37$ or 0.370

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