Markscheme

November 2018

Physics

Higher level

Paper 3

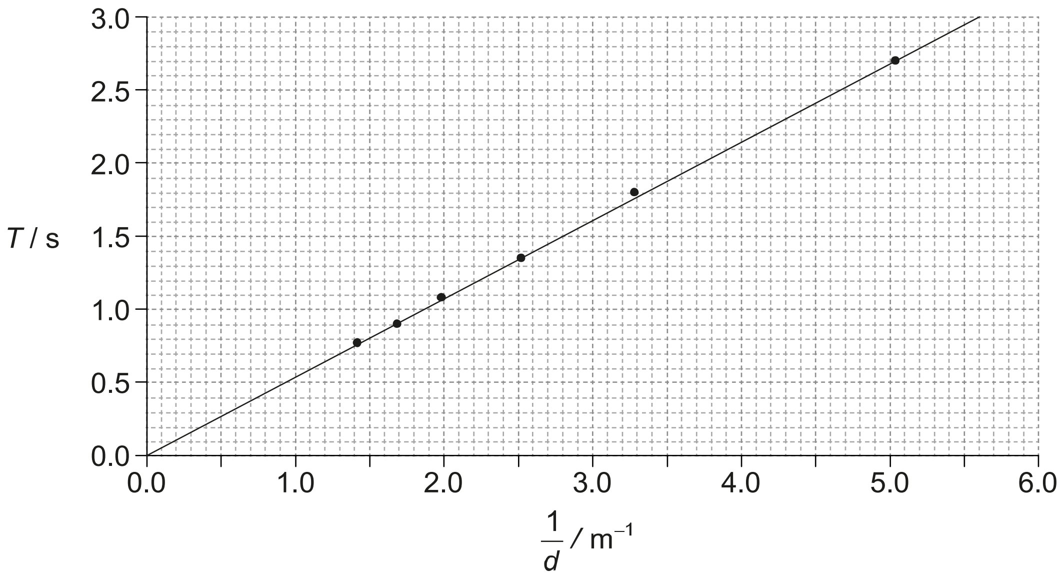
26 pages

Section A

Question			Answers	Notes	Total
1.	**a**		$m^{\frac{3}{2}}$ ✓	*Accept other power of tens multiples of* $m^{\frac{3}{2}}$*, eg:* $cm^{\frac{3}{2}}$.	**1**
1.	**b**		measured uncertainties «for one oscillation and for 20 oscillations» are the same/similar/OWTTE ***OR*** % uncertainty is less for 20 oscillations than for one ✓ dividing «by 20» / finding mean reduces the random error ✓		**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**c**	**i**	Straight line touching at least 3 points drawn across the range ✓ 	*It is not required to extend the line to pass through the origin.*	**1**
1.	**c**	**ii**	theory predicts proportional relation «$T \propto \frac{1}{d}$, slope $= Td = \frac{c}{\sqrt{g}} =$ constant» ✓ the graph is «straight» line through the origin ✓		**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	**d**		correctly determines gradient using points where $\Delta T \geq 1.5s$ ***OR*** correctly selects a single data point with $T \geq 1.5s$ ✓ manipulation with formula, any new and correct expression to enable g to be determined ✓ Calculation of g ✓ With g in range 8.6 and 10.7 «m s^{-2}» ✓	*Allow range 0.51 to 0.57.*	**4**

Question			Answers	Notes	Total
2.	**a**		to provide a constant heating rate / power ***OR*** to have *m* proportional to *t* ✓		**1**
2.	**b**		due to heat losses **«***VIt* is larger than heat into liquid**»** ✓ L_v calculated will be larger ✓		**2**
2.	**c**		heat losses will be similar / the same for both experiments ***OR*** heat loss presents systematic error ✓ taking the difference cancels/eliminates the effect of these losses ***OR*** use a graph to eliminate the effect ✓		**2**

Section B

Option A — Relativity

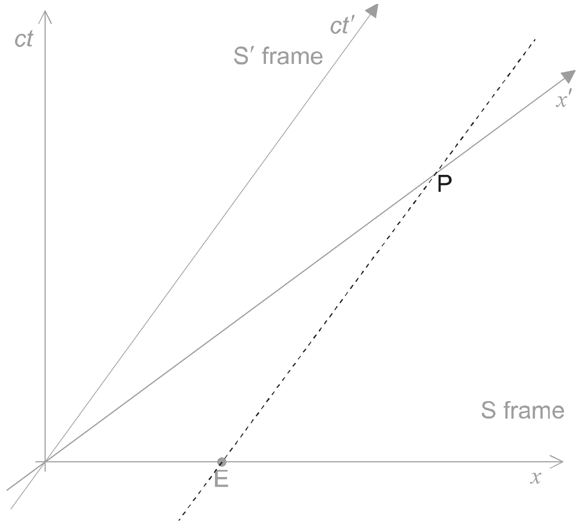
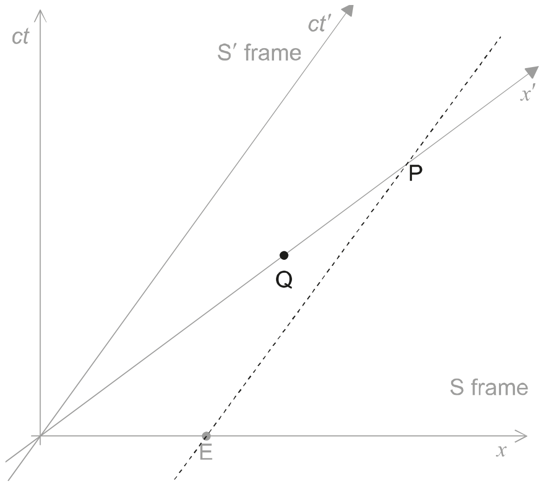
Question			Answers	Notes	Total
3.	**a**		a set of rulers and clocks / set of coordinates to record the position and time of events ✓		**1**
3.	**b**	**i**	***ALTERNATIVE 1:*** the time in frame S′ is $t' = \frac{L}{c}$ ✓ but time is absolute in Galilean relativity so is the same in S ✓ ***ALTERNATIVE 2:*** In frame S, light rays travel at $c + v$ ✓ so $t = \frac{L}{(c+v)-v} = \frac{L}{c}$ ✓	*In Alternative 1, they must refer to S′*	**2**
3.	**b**	**ii**	$x = x' + vt$ and $x' = L$ ✓ «substitution to get answer»		**1**

Question			Answers	Notes	Total
4.	**a**		$\dfrac{0.82c + 0.40c}{1+\dfrac{0.82c \times 0.40c}{c^2}}$ ✓ $0.92c$ ✓		**2**
4.	**b**	**i**	$\Delta t' = \dfrac{120}{0.40c}$ ✓ $\Delta t' = 1.0\times 10^{-6}$ «s» ✓		**2**
4.	**b**	**ii**	$\gamma =$ «$\dfrac{1}{\sqrt{1-0.82^2}} =$» 1.747 ✓ $\Delta t =$ «$\gamma(\Delta t' + \dfrac{v\Delta x'}{c^2})$» $= 1.747 \times \left(1.0\times 10^{-6} + \dfrac{0.82c \times 120}{c^2}\right)$ ***OR*** $\Delta t = \dfrac{120}{1.747\times(0.92-0.82)c}$ ✓ 2.3×10^{-6} «s» ✓		**3**

Question			Answers	Notes	Total
5.	**a**	**i**	$\gamma =$ « $\frac{1}{\sqrt{1-0.745^2}} =$ » 1.499 ✓ $x' =$ « $\gamma(x-vt) =$ » $1.499 \times (1.0-0)$ ✓ « $x' = 1.5\text{ m}$ »		**2**
5.	**a**	**ii**	$t' =$ « $\gamma\left(t-\frac{vx}{c^2}\right) =$ » $1.499 \times \left(0-\frac{0.745c\times 1}{c^2}\right)$ « $= -\frac{1.11}{c}$ » « $ct' = -1.1\text{m}$ » ***OR*** using spacetime interval $0-1^2 = (ct')^2 - 1.5^2 \Rightarrow$ « $ct' = -1.11$ » ✓		**1**

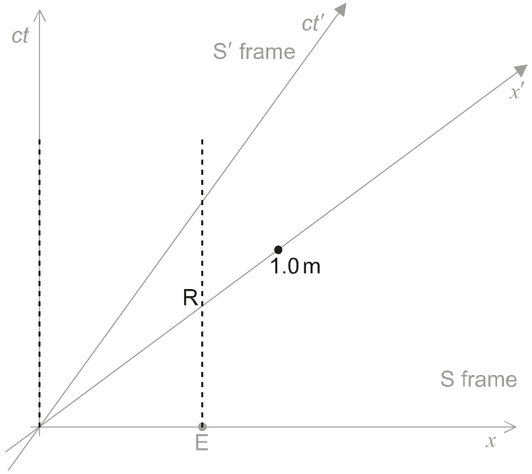
(continued…)

(Question 5 continued)

Question			Answers	Notes	Total
5.	b	i	line through event E parallel to ct' axis meeting x' axis and labelled P ✓		1
5.	b	ii	point on x' axis about $\frac{2}{3}$ of the way to P labelled Q ✓		1

(continued…)

(Question 5 continued)

Question			Answers	Notes	Total
5.	**c**	**i**	ends of rod must be recorded at the same time in frame S′ ✓ any vertical line from E crossing x’, no label required ✓ right-hand end of rod intersects at R «whose co-ordinate is less than 1.0 m» ✓		**3**
5.	**c**	**ii**	0.7 m ✓		**1**

Question			Answers	Notes	Total
6.	a		$pc = \sqrt{E^2 - (mc^2)^2} = \sqrt{1.50^2 - 0.511^2}$ «$= 1.410\text{ MeV}$» ✓		1
6.	b	i	first equation is due to momentum conservation ✓ second equation is due to total energy conservation ✓		2
6.	b	ii	adding $2p_1 = 3.42\text{ MeV c}^{-1} \Rightarrow p_1 = 1.71\text{MeV c}^{-1}$ ✓ $p_2 = 0.30\text{ MeV c}^{-1}$ ✓		2

Question			Answers	Notes	Total
7.	a	i	the distance from the black hole at which the escape speed is the speed of light ✓		1
7.	a	ii	$R_S =$ «$\frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 4.0 \times 10^{36}}{9.0 \times 10^{16}} =$» 5.9×10^9 «m» ✓		1
7.	b		$2 = \frac{1}{\sqrt{1 - \frac{5.9 \times 10^9}{r}}}$ ✓ rearranged to give *r* ***OR*** $r = 1.33 \times 5.9 \times 10^9$ «m» ✓ $r = 7.9 \times 10^9$ «m» ✓		3

Option B — Engineering physics

Question			Answers	Notes	Total
8.	**a**		taking torques about the pivot $R \times 4.00 = 36.0 \times 2.5$ ✓ $R = 22.5$ «N» ✓		**2**
8.	**b**	**i**	$36.0 \times 2.50 = 30.6 \times \alpha$ ✓ $\alpha = 2.94$ «rad s^{-2}» ✓		**2**
8.	**b**	**ii**	the equation can be applied only when the angular acceleration is constant ✓ any reasonable argument that explains torque is not constant, giving non constant acceleration ✓	*eg weight is no longer perpendicular to the rod*	**2**
8.	**c**	**i**	«from conservation of energy» Change in GPE = Change in rotational KE ✓ $W\frac{L}{2} = \frac{1}{2}I\omega^2$ ✓ $\omega = \sqrt{\frac{36.0 \times 5.00}{30.6}}$ ✓ «$\omega = 2.4254$ rad s^{-1}»		**3**
8.	**c**	**ii**	$L = 30.6 \times 2.43 = 74.4$ «J s» ✓		**1**

Question			Answers	Notes	Total
9.	a	i	***ALTERNATIVE 1:*** $P_c = P_B = \frac{P_A V_A}{V_B}$ ✓ $= \frac{2.8\times10^6\times1\times10^{-4}}{2.8\times10^{-4}}$ «$=1.00\times10^6\ Pa$» ✓ ***ALTERNATIVE 2*** $2.80\times10^6\times1.00^{\frac{5}{3}} = P_c\times1.85^{\frac{5}{3}}$ ✓ $P_c = 2.80\times10^6\times\frac{1.00^{\frac{5}{3}}}{1.85^{\frac{5}{3}}}$ «$=1.00\times10^6$ Pa» ✓		**2**
9.	a	ii	***ALTERNATIVE 1:*** Since $T_B = T_A$ then $T_C = \frac{V_C T_B}{V_B}$ ✓ $= \frac{1.85\times385}{2.8}$ «$=254.4\,\text{K}$» ✓ ***ALTERNATIVE 2:*** $\frac{2.80\times1.00}{385} = \frac{1.00\times1.85}{T_c}$ «K» ✓ $T_c = 385\times\frac{1.00\times1.85}{2.80}$ «$=254.4\ \text{K}$» ✓		**2**

(continued…)

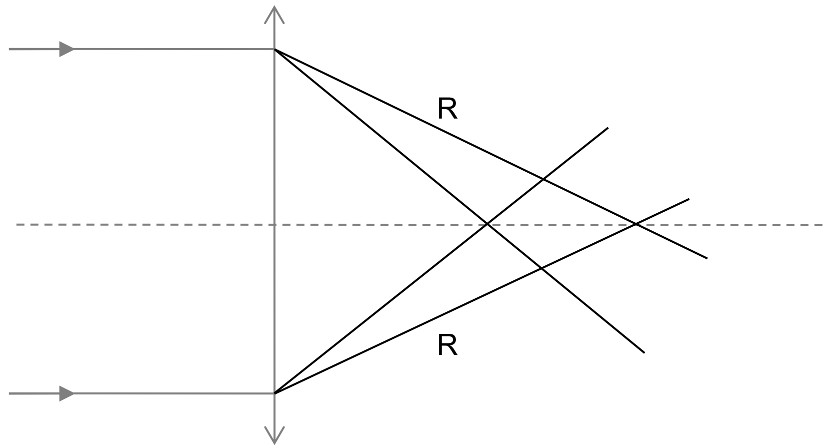
(Question 9 continued)

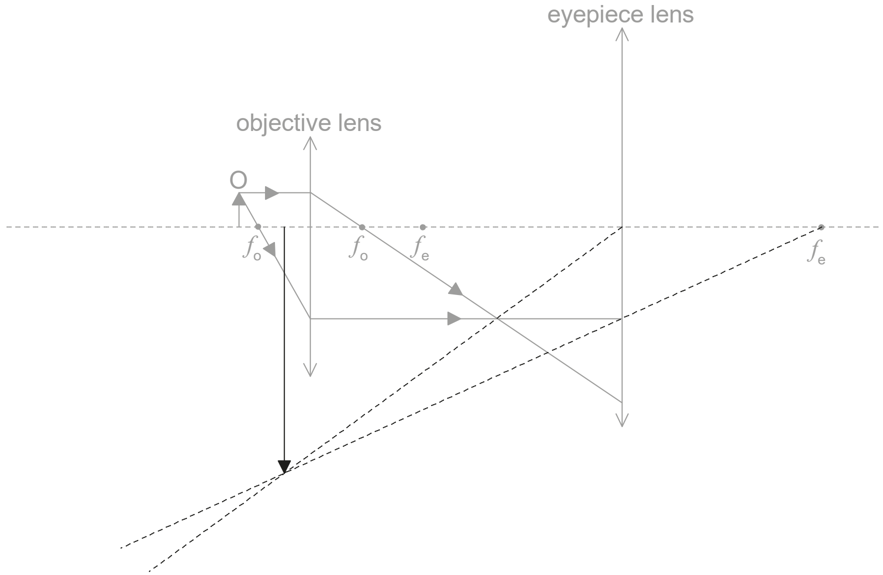
Question			Answers	Notes	Total
9.	b		work done $=$ « $p\Delta V = 1.00\times10^{6}\times(1.85\times10^{-4} - 2.80\times10^{-4}) =$ » -95 « J » ✓ change in internal energy $=$ « $\frac{3}{2}p\Delta V = -\frac{3}{2}\times 95 =$ » -142.5 « J » ✓ $Q = -95 - 142.5$ ✓ « -238 J »	*Allow positive values.*	3
9.	c	i	net work is $288 - 238 = 50$ «J» ✓ efficiency $=$ « $\frac{288-238}{288} =$ » 0.17 ✓		2
9.	c	ii	along $B \rightarrow C$ ✓		1

Question			Answers	Notes	Total
10.	a		ice displaces its own weight of water / OWTTE ***OR*** melted ice volume equals original volume displaced / OWTTE ✓ no change will take place ✓		**2**
10.	b	i	continuity equation says $v \times A_1 = u \times A_2$ ✓ «and» $A_1 = 4A_2$ ✓ «giving result»		**2**
10.	b	ii	*Bernoulli*: «$\frac{1}{2}\rho v^2 + \rho gH + P_{\text{atm}} = \frac{1}{2}\rho u^2 + 0 + P_{\text{atm}}$» gives $\frac{1}{2} \times 1000 \times \frac{u^2}{16} + 1000 \times 9.8 \times 5.0 = \frac{1}{2} \times 1000 \times u^2$ ✓ $u = 10.2$ «m s^{-1}» ✓	*Accept solving directly via conservation of energy.*	**2**

Question			Answers	Notes	Total
11.	a		because the mass and the driver are out of phase «by π» ✓ so upwards ✓	*Justification needed for MP2*	2
11.	b		***ALTERNATIVE 1:*** $«Q = 2\pi\frac{A_0^2}{A_0^2 - A_1^2}» \Rightarrow \frac{A_1^2}{A_0^2} = 1 - \frac{2\pi}{Q}$ ✓ $\frac{A_1}{A_0} = «\sqrt{1-\frac{2\pi}{22}} =» A_1 = 8.5$ «cm» ✓ ***ALTERNATIVE 2:*** driver amplitude is constant ✓ so mass amplitude is unchanged at 10 cm ✓		2

Option C — Imaging

Question			Answers	Notes	Total
12.	**a**		each incident ray shown splitting into two ✓ each pair symmetrically intersecting each other on principal axis ✓ for red, intersection further to the right ✓	 *For MP3, at least one of the rays must be labelled.*	**3**
12.	**b**	**i**	rays diverge after passing through lens ***OR*** the extension of the rays will intersect the principal axis on the side of incident rays/as if they were coming from the focal point/points in the left side/OWTTE ✓		**1**
12.	**b**	**ii**	by placing a diverging lens next to the converging lens ***OR*** make an achromatic doublet ✓	Further details are not required.	**1**

Question			Answers	Notes	Total
13.	**a**		proper construction lines ✓ image at intersection of proper construction lines ✓		**2**

(continued…)

(Question 13 continued)

Question			Answers	Notes	Total
13.	**b**	**i**	distance of intermediate image from objective is $\frac{1}{v}=\frac{1}{20}-\frac{1}{24}$ *ie*: $v=120$ «mm» ✓ distance of intermediate image from eyepiece is $\frac{1}{u}=\frac{1}{60}-\left(-\frac{1}{240}\right)$ *ie*: $u=48$ «mm» ✓ lens separation 168 «mm» ✓		**3**
13.	**b**	**ii**	***ALTERNATIVE 1:*** eyepiece: $m=\frac{-v}{u}=\frac{240}{48}=5$ ***AND*** objective $m=\frac{-v}{u}=\frac{-120}{24}=-5$ ✓ Total $m=-5\times 5=-25$ ✓ ***ALTERNATIVE 2:*** $m=\left(\frac{240}{60}+1\right)\times\left(-\frac{120}{24}\right)$ ✓ $m=-25$ ✓		**2**

Question			Answers	Notes	Total
14.	**a**	**i**	«$\sin\theta_c = \frac{n_1}{n_2}$» $n_1 = 1.52 \times \sin 84.0°$ ✓ $n_1 = 1.51$ ✓		**2**
14.	**a**	**ii**	to have a critical angle close to $90°$ ✓ so only rays parallel to the axis are transmitted ✓ to reduce waveguide/modal dispersion ✓	*Do not accept "so that most rays are reflected".*	**1 max**
14.	**b**	**i**	long path is $\frac{12 \times 10^3}{\sin 84°}$ ✓ $= 12066$ «m» ✓ «so 66 m longer»		**2**
14.	**b**	**ii**	speed of light in core is $\frac{3.0 \times 10^8}{1.52} = 1.97 \times 10^8$ «m s^{-1}» ✓ time delay is $\frac{66}{1.97 \times 10^8} = 3.35 \times 10^{-7}$ «s» ✓		**2**
14.	**b**	**iii**	no, period of signal is 1×10^{-8} «s» which is smaller than the time delay/OWTTE ✓		**1**

Question			Answers	Notes	Total
15.	a		protons spin direction changes ***OR*** proton energy state changes ✓		**1**
15.	b		Relaxation time «of signal/proton spin» ✓ Location/time delay of the emitted RF signal ✓		**2**
15.	c		Relaxation time gives information on tissue type/density/health/OWTTE✓ Location information provides 3D image/OWTTE✓		**2**

Question			Answers	Notes	Total
16.	a		$I_0 e^{-23\times 0.041}$ ✓ $= 0.39\ I_0$ ✓		**2**
16.	b		$R =$ «$\left(\frac{6.3\times10^6 - 1.7\times10^6}{6.3\times10^6 + 1.7\times10^6}\right)^2 =$» 0.33 ✓ so reflected intensity is $0.33\times 0.39 I_0 = 0.13 I_0$ ✓		**2**
16.	c		$0.13 I_0 \times 0.39 = 0.05 I_0$ ✓		**1**

Option D — Astrophysics

Question			Answers	Notes	Total
17.	**a**		In cluster, stars are gravitationally bound ***OR*** constellation not ✓ In cluster, stars are the same/similar age ***OR*** in constellation not ✓ Stars in cluster are close in space/the same distance ***OR*** in constellation not ✓ Cluster stars appear closer in night sky than constellation ✓ Clusters originate from same gas cloud ***OR*** constellation does not ✓		**2 max**
17.	**b**	**i**	$d = 275$ «pc» ✓		**1**
17.	**b**	**ii**	because of the difficulty of measuring very small angles ✓		**1**
17.	**c**		mass of gas cloud $>$ Jeans mass ✓ «magnitude of» gravitational potential energy $> E_k$ of particles ✓ cloud collapses/coalesces «to form a protostar» ✓		**2 max**

Question			Answers	Notes	Total
18.	**a**	**i**	$\lambda =$ «$\frac{2.9\times10^{-3}}{4600} =$» 630 «nm» ✓		**1**
18.	**a**	**ii**	black body curve shape ✓ peaked at a value from range 600 to 660 nm ✓		**2**
18.	**a**	**iii**	$\frac{L}{L_\odot} = \left(\frac{0.73R_\odot}{R_\odot}\right)^2 \times \left(\frac{4600}{5800}\right)^4$ ✓ $L = 0.211L_\odot$ ✓		**2**
18.	**b**		$M =$ «$0.21^{\frac{1}{3.5}}\,M_\odot =$» $0.640\,M_\odot$ ✓	*Accept reverse argument $0.64^{3.5} = 0.21$*	**1**
18.	**c**		$\frac{T_E}{T_\odot} =$ «$\frac{\frac{M_E}{L_E}}{\frac{M_\odot}{L_\odot}} = \frac{0.64}{0.21} =$» 3.0 ✓ $T \approx 27$ billion years ✓		**2**
18.	**d**		red giant ✓ planetary nebula ✓ white dwarf ✓	*do **NOT** accept supernova, red supergiant, neutron star or black hole as stages*	**3**

Question			Answers	Notes	Total
19.	**a**		measured redshift «z» of star ✓ use of Doppler formula ***OR*** z~v/c ***OR*** $v = \frac{c\Delta\lambda}{\lambda}$ to find *v* ✓	*OWTTE*	**2**
19.	**b**		use of gradient or any point on the line to obtain any expression for either $H = \frac{v}{d}$ or $t = \frac{d}{v}$ ✓ correct conversion of *d* to m and v to m/s✓ $= 4.6 \times 10^{17}$ «s» ✓		**3**

Question			Answers	Notes	Total
20.	**a**		energy filling all space ✓ resulting in a repulsive force/force opposing gravity ✓ accounts for the accelerating universe ✓ makes up about 70% of «the energy» of universe✓		**2 max**
20.	**b**		black hole ✓ brown dwarf ✓ massive compact halo object /MACHO✓ neutrinos ✓ weakly interacting massive particle /WIMP ✓		**2 max**

Question			Answers	Notes	Total
21.	**a**		«wavelength of light/CBR» $\lambda \propto R$ ✓ reference to Wien's law showing that $\lambda \propto \frac{1}{T}$ ✓ combine to get result ✓	*OWTTE*	**3**
21.	**b**		$\frac{R_{\text{past}}}{R_{\text{now}}} = \frac{3}{300} = 0.01$ ✓		**1**