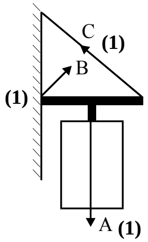
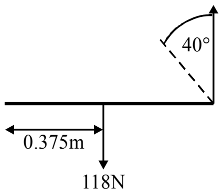
1. (a) (i)



n.b. B must make an appreciable angle with wall and bar

(ii) A weight of sign and bar (accept gravity) **(1)**
B reaction of wall **(1)**
C tension in wire **(1)** max 5

(b)



use of *mg* **(1)**
clockwise moments 118 × 0.375 **(1)**

= anticlockwise moments (Tcos40° **(1)**) × 0.750 **(1)**
T = 77 N **(1)** max 4

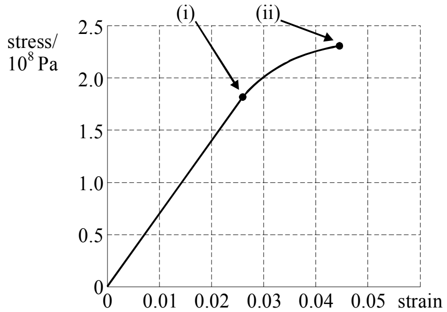
[9]

2. (a) (i) strain = 0.026 **(1)**
$E = 6.92 \times 10^9$ Pa **(1)**

(ii) $A = 1.96 \times 10^{-7}$ (m^2) **(1)**
stress = 230×10^8 Pa **(1)**

(iii) breaking strain = 0.044 **(1)** 5

(b)



shape overall **(1)**

(i) straight line **(1)**
0 to (0.026, 1.8) **(1)**

(ii) curve **(1)**
to (0.044, 2.3) **(1)** Max 4

[9]

3. steel
$A = 4.91 \times 10^{-4}$ (m^2) m = 383kg **(1)**
copper
$A = 3.32 \times 10^{-5}$ (m^2) m = 444 kg **(1)**
one cross-sectional area calculated correctly **(1)**
use of $m = \rho l A$ **(1)**
mass of cable = 827 kg **(1)**

[Max 4]

4. *amplitude*: each point along wave **(1)**
has <u>same</u> amplitude for progressive wave
but varies for stationary wave **(1)**

phase: progressive wave, adjacent points vibrate with different phase **(1)**
stationary wave, between nodes all particles vibrate in phase
[or there are only two phases] **(1)**

energy transfer: progressive wave, energy is transferred through space **(1)**
stationary wave, energy is not transferred through space **(1)** max 5

[5]

5. (a) constant phase relationship **(1)** **(1)**
[or same frequency (wavelength) **(1)** and same phase difference **(1)**] 2

(b) S_1R = 15cm on diagram **(1)** =75cm ∴ 30 waves **(1)**

S_2R = 16cm on diagram **(1)** = 80cm ∴ 32 waves **(1)**
2 whole waves difference so in phase at R **(1)** maximum **(1)** max 5

(c) (falls then rises to) maximum at Q **(1)**
(then falls and rises to) maximum at P **(1)** 2

(d) $f\left(=\frac{c}{\lambda}\right) = \frac{3.0\times10^{8}}{25\times10^{-3}}$ = 1.2×10^{10} Hz (or 12 GHz) **(1)** 1

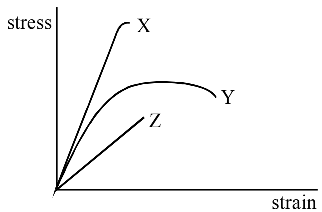
[10]

6. (i) ray straight through at X **(1)**
ray refracted at >30° at Y **(1)**
ray <u>totally internally</u> reflected at Z **(1)**

(ii) $\frac{\sin\theta_{water}}{\sin\theta_{air}} = \frac{c_{water}}{c_{air}}$ [or = $\frac{2.25\times10^{8}}{3.00\times10^{8}}$]
at critical angle $\sin\theta_{air} = 1$ **(1)**
$\sin\theta_{water} = 0.75$, $\theta_{water} = 48.6°$ **(1)**
radius = 1.5tan48.6° **(1)** =1.7m, ∴ diameter = 3.4m **(1)**

[Max 7]

7.



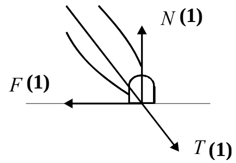
(a) Y **(1)**
significant plastic deformation (or Young modulus less than X) **(1)**

(b) Z **(1)**
no plastic deformation (or smallest value of Young modulus) **(1)**

(c) X **(1)**
small amount of plastic deformation (or Young modulus greater than Y) **(1)**

[6]

8. (a)



lines of action of the three forces pass through single point **(1)** max 3

(b) (i) F = 350N **(1)**
(ii) N = 550N **(1)**
if "sine" used in (i) and "cos" in (ii) allow one mark
allow calculation from drawing scale diagram
if (i) and (ii) not awarded marks, then award
one mark for correct vector diagram 2

[5]

9. (a)

	x/m	$\sin\theta$
1	0.173	0.086
2	0.316	0.156
3	0.499	0.242
4	0.687	0.325
5	0.860	0.395

If angles only calculated 1/2

at least 4 points plotted correctly **(1)**
best straight line **(1)**
gradient calculated from suitable triangle, 50% of each axis **(1)**
correct value from readings **(1)**
appropriate use of $d\sin\theta = n\lambda$ **(1)**
hence N (rulings per metre) = 1.25×10^{5} m^{-1} (1.1 to 1.4 ok) **(1)**
max 2/6 if no graph and more than one data set used <u>correctly</u>,
1/6 only one set
if tan calc but plotted as sin, mark as scheme
tan or distance plotted, 0/6 max 6

(b) (i) maxima wider spaced [or pattern brighter] **(1)**
$\sin\theta$ or θ increases with N [or light more concentrated] **(1)**

(ii) maxima spacing less **(1)**
$\sin\theta$ or θ decreases with λ [or statement] **(1)**

(iii) maxima wider spaced [or pattern less bright] **(1)**
same θ but larger D [or light more spread out] **(1)** 6

(c) (i) waves in phase from **(1)**
any sensible ref to coherence **(1)**
whole number of wavelengths path difference **(1)**

(ii) use of geometry to show that $\sin\theta = \frac{\lambda}{d}$ **(1)** max 3

[15]

10. (a) (i) superposition **(1)**
between waves in phase **(1)**
gives constructive interference **(1)**

(ii) at D or E waves out of phase **(1)**
so destructive interference **(1)** max 4

(b) (i) $\lambda = \frac{330}{2\times10^3} = 0.165\text{m}$ **(1)**

separation between maxima = $\frac{\lambda D}{s}$ **(1)**

$\left(= \frac{0.165\times5}{0.75}\right) = 1.10(\text{m})$ **(1)**

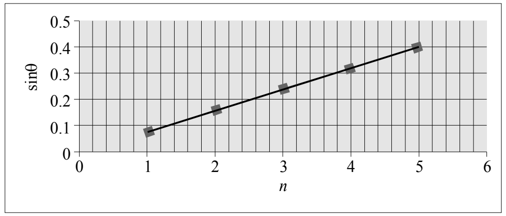
distance CE (= $\frac{1}{2}$ × separation)= 0.55 m **(1)** 4

[8]

11. (a)

	x/m	sin θ
1	0.173	0.086
2	0.316	0.156
3	0.499	0.242
4	0.687	0.325
5	0.860	0.395

If angles only calculated 1/2



at least 4 points plotted correctly **(1)**
best straight line **(1)**
gradient calculated from suitable triangle, 50% of each axis **(1)**
correct value from readings **(1)**
appropriate use of $d\sin\theta = n\lambda$ **(1)**
hence N (rulings per metre) = $1.25\times10^5\ \text{m}^{-1}$ (1.1 to 1.4 ok) **(1)**

max 2/6 if no graph and more than one data set used correctly,
1/6 only one set
if tan calc but plotted as sin, mark as scheme
tan or distance plotted, 0/6 max 6

(b) (i) maxima wider spaced [or pattern brighter] **(1)**
sin θ or θ increases with N [or light more concentrated] **(1)**

(ii) maxima spacing less **(1)**
sin θ or θ decreases with λ [or statement] **(1)**

(iii) maxima wider spaced [or pattern less bright] **(1)**
same θ but larger D [or light more spread out] **(1)** 6

(c) (i) waves in phase from **(1)**
any sensible ref to coherence **(1)**
whole number of wavelengths path difference **(1)**

(ii) use of geometry to show that $\sin\theta = \frac{\lambda}{d}$ — max 3

[15]

12. (a) diagram showing two supported wires and vernier
[or long wire and appropriate scale] **(1)**
one justification of design **(1)**
measurements:
identified length with ruler **(1)**
diameter with micrometer **(1)**
in several places [or in different directions] **(1)**
add load [mass] and read vernier **(1)**
repeat for range of loads **(1)**
within limit of proportionality [allow elastic limit] **(1)**
calculation of at least one value from readings **(1)**
graph or calc and average **(1)**
if apparatus unsuitable, mark to scheme to max 6/8 — max 8

(b) aluminium yields, has smaller yield strength identified from data sheet **(1)**
use of $F(=sA)$ **(1)**
$= 50 \times 10^6 \times \pi \times (0.36 \times 10^{-3})^2$ **(1)**
= 20.3N **(1)** — 4

[12]

13. (a) (i) gradient = $\frac{2.1}{0.7}$ = 3.0 ms^{-2} **(1)**

(ii) distance is area under graph (to t = 0.1 s)
or $\frac{1}{2} \times 0.7 \times 2.1$ $\left(\frac{2.1+2.5}{2}\right)0.3$ **(1)** = 1.4(2) m **(1)** — 3

(b) (i) $T - mg = ma$ [or $T = 1500(9.8+3.0)$] **(1)**
$= 1.9 \times 10^4$ N **(1)**
$T = mg = 1.5 \times 10^4$ N **(1)**

(ii) EF **(1)** — 4

(c) power = $F\upsilon$ or $1.5 \times 10^4 \times 2.5$ **(1)**
$= 3.7[3.8] \times 10^4$ W **(1)** — 2

[9]

14. (a) (i) F = W sin θ $= W \times \frac{1}{15}$ **(1)** correct angle **(1)**
= 46N **(1)**
[2 out of 3 if no working shown]

(ii) $P(= F\upsilon)$ = 410W **(1)** — 4

(b) (i) kinetic energy of bicycle + rider $\Rightarrow$ gravitational potential energy **(1)**

(ii) initial E_k = gain in gravitational Ep = 2.8×10^3 (J) **(1)**
h = 4.1m **(1)**
distance = 62m **(1)**
alternative:
(F = ma) $a = \frac{46}{70}$ = 0.657 (ms^{-2}) **(1)**
$v^2 = u^2 = 2as$ **(1)**
$s = \frac{9^2}{2 \times 0.657}$ = 62m **(1)** — max 3

[7]

15. (i) $a = \frac{44}{4.0}$ = 11 ms^{-2} **(1)**
$F = ma$ = 1.1×10^5 N **(1)**

(ii) $\Delta\upsilon$ = 236 m s^{-1}
$a = \frac{236}{8.0}$ = 29.5 ms^{-2} **(1)**

(iii) $s_{one} = \upsilon_{av} \times t = \left(\frac{44+0}{2}\right) \times 4.0 = 88\text{m}$ **(1)**

$s_{two} = \upsilon_{av} \times t = \left(\frac{280+44}{2}\right) \times 8.0$ **(1)** $= 1296(\text{m})$ **(1)**

total distance = 1384 m **(1)**

[6]

16. (a) for equilibrium**(1)**
clockwise moment = counterclockwise moment **(1)** 2

(b) (i) right hand support

$W_p = 88(\text{N})$ and $W_x = 29(\text{N})$ **(1)**

$F = 44 + 29 = 73$ N **(1)**

left hand support

$F = 44\text{N}$ **(1)**

(ii) right hand support, moments about left hand support

$88 \times 0.75 + 29 \times 0.5 = F \times 1.5$ gives $F = 54$ N **(1)**

left hand support

$F_L + F_R = 118$ *(N)* **(1)** so $F_L = 64\text{N}$ **(1)** 6

[8]

17. (a) (i) displacement is distance of particle **(1)**

from mean [or equilibrium] position **(1)**

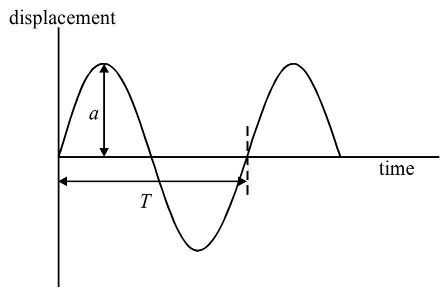
in direction of wave (energy) **(1)**

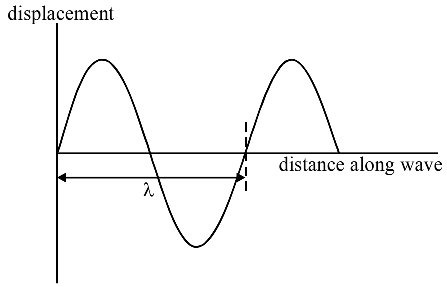
amplitude is maximum displacement **(1)**

wavelength is shortest distance **(1)**

between two points in phase **(1)** max 4

(b)





any two points $\frac{\lambda}{4}$ apart **(1)** 4

[8]

18. (a) (i) (since $d \sin \theta = n\lambda$) $d \sin 18.5^\circ = 632.8 \times 10^{-9}$ **(1)**

$d = 1.99 \times 10^{-6}$ **(1)**

number of lines per metre = $\frac{1}{d} = 5.01 \times 10^5$ **(1)**

(ii) $n\lambda = 1.99 \times 10^{-6} \sin 90^\circ$ **(1)**

$n = \frac{1.99}{0.6328} = 3.1(5)$ **(1)**

hence highest order is third **(1)** 6

(b) $\lambda_{new} = \frac{632.8\times10^{-9}\times\sin 17.2^\circ}{\sin 18.5^\circ}$ [or $1.994\times10^{-6}\times\sin 17.2^\circ$] **(1)**

= 590nm **(1)** 2

[8]

19. (a) for ray going from more dense to less dense substance **(1)**

for one incident angle, *(i)*, called critical angle (θ_c)

refracted ray is at 90° **(1)**

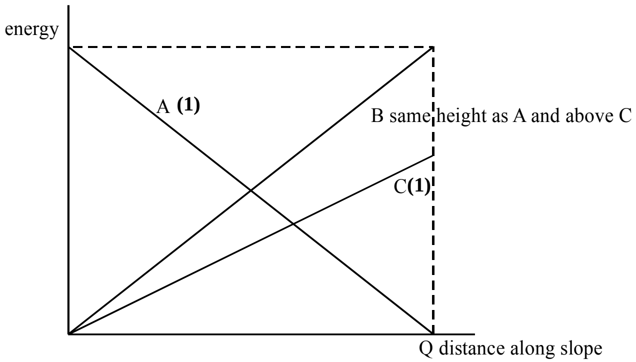
all incident light is reflected for $i > \theta_c$ **(1)** 3

(b) θ marked correctly on diagram **(1)**

correct use of triangle showing R and $(R + r)$ **(1)** 2

[5]

20. (a) (i) and (ii)



(iii) A + B = constant **(1)**
loss in potential energy = gain in kinetic energy <u>for A and B</u>
[or potential energy at P = kinetic energy at Q <u>for A and B</u>] **(1)**
reason for C being below B e.g. transfer to heat
[or work done against friction] **(1)** 6

(b) (i) clear reference to energy $\upsilon_c (= \sqrt{2gh}) = \sqrt{2\times9.8\times50}$ **(1)**
$= 31(.3)\text{m s}^{-1}$ **(1)**

(ii) $F\left(= \frac{m\upsilon_c^2}{r}\right) = \frac{80\times(31.3)^2}{20}$ **(1)**

$= 3.9(2)\times10^3$ N
towards centre of circle **(1)**

(iii) gain in gravitational potential energy
$(= mgh \sin\theta) = 620\times9.8\times60\times\sin 20^\circ$ **(1)**
$= 1.25\times10^5$ J

(iv) $620\times9.8\times50 = (F\times60)$ **(1)** $+1.25\times10^5$ **(1)**
F = 3000N **(1)**
alternative (iv)
calculation of acceleration = (–)8.0 m s^{-2} **(1)**
use of $F + mg \sin\theta = ma$ **(1)**
F = 3000N **(1)** max 9

[15]

21. (i) appropriate discussion of energy conservation **(1)**
Δ p.e. $= 2.5\times10^{-2}\times9.8\times1.2$ **(1)** (= 0.29 J)

(ii) $F = \frac{2E_p}{e}$ **(1)** = 590N **(1)**

(iii) $A = 3.1\times10^{-6}$ (m^2) **(1)**
stress $= 1.9\times10^8$ Pa **(1)**

(iv) strain $= \frac{e}{L} = \frac{0.001}{1.2} = 8.3\times10^{-4}$ **(1)**

(v) $E = \frac{\text{stress}}{\text{strain}} = \frac{1.9\times10^8}{8.3\times10^{-4}}$ **(1)** $= 2.3\times10^{11}$ Pa **(1)**

[9]

22. (a) (i) vertical or parallel **(1)**
equally spaced **(1)**
black and yellow [or dark and light] bands **(1)**

(ii) $w\left(=\frac{\lambda D}{s}\right)=\frac{5.86\times10^{-7}\times1.8}{0.36\times10^{-3}}$ **(1)**

$= 2.9 \times 10^{-3}$ m **(1)**

$\tan\theta = \frac{2\times2.9\times10^{-3}}{1.8}$ **(1)** gives $\theta = 0.18°$ **(1)**

(iii) narrower slits give more diffraction **(1)**
more overlap (so more fringes) **(1)**
fringes same width **(1)** max 8

(b) (i) $d = \frac{1}{400\times10^{3}}$ **(1)**

$\frac{1}{400\times10^{3}}\times\sin\theta = 5.86\times10^{-7}$ **(1)**

$\theta = 13.6°$ **(1)**

(ii) $\theta = 90°$ and correctly used **(1)**

$n = \frac{1}{400\times10^{3}\times5.86\times10^{-7}} = 4.3 \therefore$ 4th order **(1)** 5

(c) brighter images **(1)**
large angles **(1)**
sharper (or narrower) lines **(1)** max 2

[15]

23. (a) (i) $\lambda\left(=\frac{0.270}{3}\times2\right) = 0.18$m **(1)**

(ii) $f\left(=\frac{c}{\lambda}\right) = \frac{340}{0.18} = 1.89\times10^{3}$ Hz **(1)** 2

(b) *transverse*
direction of vibration perpendicular to propagation
[or can be polarised] **(1)**
longitudinal
direction of vibration parallel to propagation
[or cannot be polarised] **(1)**

longitudinal **(1)** 3

(c) (i) frequency same **(1)**

(ii) $a_p \rangle a_q$

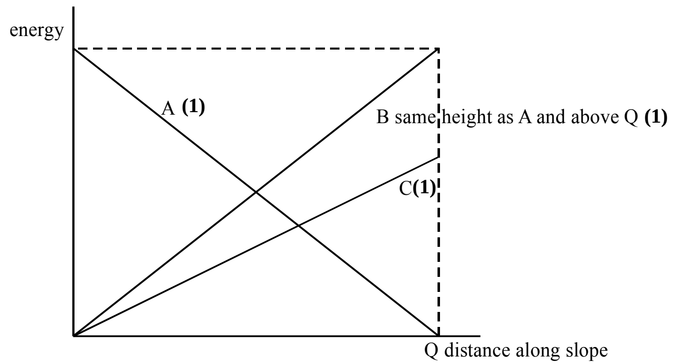
(iii) phase difference = π **(1)** 3

[8]

24. uses slope of straight line region **(1)**
slope = 1.54×10^{5} (Nm^{-1}) **(1)**
E = slope × $\frac{l}{A}$ **(1)**
$A = 5.03 \times 10^{-7}$ (m^2) **(1)**
$E = 1.5 \times 10^{11}$ Pa **(1)**
$F_y = 87$ (N) **(1)**
yield stress = 1.7×10^{8} Pa **(1)**

[6]

25. (a) (i) and (ii)



(iii) A + B = constant **(1)**
loss in potential energy = gain in kinetic energy for A and B
[or potential energy at P = kinetic energy at Q for A and B] **(1)**
reason for C being below B e.g. transfer to heat
[or work done against friction] **(1)** 6

(b) (i) clear reference to energy $\upsilon_C (= \sqrt{2gh}\,) = \sqrt{2 \times 9.8 \times 50}$ **(1)**

$= 31(.3)\ \text{m s}^{-1}$ **(1)**

(ii) $F\left(= \frac{m\upsilon_C^2}{r}\right) = \frac{80 \times (31.3)^2}{20}$ **(1)**

$= 3.9(2) \times 10^3$ N **(1)**

towards centre of circle **(1)**

(iii) gain in gravitational potential energy

(= *mgh* sin θ)= 620 × 9.8 × 60 × sin 20° **(1)**

$= 1.25 \times 10^5$ J **(1)**

(iv) $620 \times 9.8 \times 50 = (F \times 60)$ **(1)** $+1.25 \times 10^5$ **(1)**

F = 3000N **(1)**

alternative (iv)

calculation of acceleration = (–)8.0 m s^{-2} **(1)**

use of *F* + *mg* sin θ = *ma* **(1)**

F = 3000N **(1)** max 9

[15]

26. (a) (i) vertical or parallel **(1)**

equally spaced **(1)**

black and yellow [or dark and light] bands **(1)**

(ii) $w\left(= \frac{\lambda D}{s}\right) = \frac{5.86 \times 10^{-7} \times 1.8}{0.36 \times 10^{-3}}$ **(1)**

$= 2.9 \times 10^{-3}$ m **(1)**

$\tan\theta = \frac{2 \times 2.9 \times 10^{-3}}{1.8}$ **(1)** gives $\theta = 0.18°$ **(1)**

(iii) narrower slits give more diffraction **(1)**

more overlap (so more fringes) **(1)**

fringes same width **(1)** max 8

(b) (i) $d = \frac{1}{400 \times 10^3}$ **(1)**

$\frac{1}{400 \times 10^3} \times \sin\theta = 5.86 \times 10^{-7}$ **(1)**

θ = 13.6° **(1)**

(ii) θ = 90° and correctly used **(1)**

$n = \frac{1}{400 \times 10^3 \times 5.86 \times 10^{-7}} = 4.3 \therefore$ 4th order **(1)** 5

(c) brighter images **(1)**

large angles **(1)**

sharper (or narrower) lines **(1)** max 2

[15]

27. (a) (i) B line along distance axis **(1)**

(ii) C negative sine wave starting at O **(1)**

(iii) A, N **(1)** 3

(b) (i) s.h.m. [or particle stationary] **(1)**

amplitude = 20 mm **(1)**

$f = \frac{1}{T} = 25$ Hz or s^{-1} **(1)**

(ii) 10 mm **(1)**

W,V phase difference π [or antiphase or 180°] **(1)**

W,Z in phase **(1)** 6

[9]

28. (a) (i) component velocity North = 20 cos68° **(1)**

= 7.5 m s^{-1}

which is supplied by wind **(1)**

by triangle of velocities [or by components] (aircraft must point East) **(1)**

alternative (a)(i)

triangle or parallelogram of velocities **(1)**

find angle between aircraft component and wind using sine and cosine formulae – prove 90° **(1)** **(1)**

(ii) work done = $Fs\cos\theta$ [or force × distance moved in direction of force or $2.0 \times 10^3 \times 10 \times 10^3 \cos 22°$] **(1)**
$= 1.8(5) \times 10^7$ J **(1)**

(iii) power = $\dfrac{\text{work done}}{\text{time taken}} = 1.8(5) \times 10^7 \div \left(\dfrac{10000}{20}\right)$ **(1)**
$= 3.6 \times 10^4$ W **(1)**

alternative (iii)
power = force × vel. component East = $2.0 \times 10^3 \times 20 \cos 22°$ **(1)**
$= 3.6 \times 10^4$ W **(1)** max 6

(b) return time = $\dfrac{10000}{14} = 714$ s $\therefore$ total time = 1214 s **(1)**
average speed = $\dfrac{20000}{1214} = 16[16.5]$ m s^{-1} **(1)** 2

[8]

29. (a) (i) $T = 2.0 \times 9.8 = 19.6$N **(1)**

(ii) moments about B
$19.6\cos 30° \times 1.6$ **(1)** $= mg \times 0.8$ **(1)**
mass = $\dfrac{33.9}{9.8}$ **(1)** (= 3.46 kg) 4

(b) maximum support when wire vertical **(1)**
moments about B
$2.0 \times 9.8 \times 1.6 = (M \times 9.8 \times 1 .2)$ **(1)** $+ 33.9 \times 0.8$ **(1)**
$\therefore M = 0.36$ kg **(1)**
[n.b. 0.33 kg if 3.5 used] 4

[8]

30. (a) (i) diagram to show: **(1)**

ray refracted towards normal **(1)**
total internal reflection at core-cladding interface **(1)**
$i = r$ indicated **(1)**
ray continues whole length of fibre and emerges, without errors**(1)**

(ii) refraction **(1)**

(iii) use of ${}_1n_2 = \dfrac{\sin\theta_1}{\sin\theta_2}$ gives $\dfrac{n_2}{n_1} = \dfrac{\sin\theta_1}{\sin\theta_2}$ **(1)**

$\dfrac{1.50}{1.45} = \dfrac{1}{\sin\theta_2}$ **(1)**

$\theta_C (= \theta_2) = 75.2°$ **(1)**

[**or** $\sin\theta_C = 1/n$ gives $\sin\theta_c = n_{clad}/n_{core}$ **(1)**
$\sin\theta_C = 1.45/1.50$ **(1)**
$\theta_C = 7\,5.2°$**(1)**] max 7

(b) (i) to protect outer surface of the core **(1)**

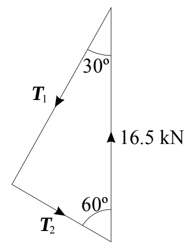
(ii) greater acceptance angle **(1)**
enables more light to be collected
(or smaller critical angle makes escape less likely) **(1)** 3

(c) endoscopy or communications **(1)** 1

[11]

31. (a) resultant force = zero
(or the forces can be represented in magnitude and direction by the three sides of a triangle taken in order) **(1)** 1

(b)



scale drawing:
sensible scale used and stated **(1)**
arrows shown correctly **(1)**
one length measurement correctly stated **(1)**
both scale conversions correct to give T_1, = 14 kN, T_2= 8 kN **(1)**
[**or** by calculation: T_1 = 16.5 sin 60 **(1)**   14.3 kN **(1)**

T_2 16.5 cos 60 **(1)**   8.3 kN **(1)**

[**or** by resolving forces vertically and horizontally:

T_1 sin 30 = T_2 sin 60 **(1)**
T_1 cos 30 + T_2 cos 60 = 16.5 (kN) **(1)**
gives T_1 = 14.3 kN **(1)** and T_2 = 8.3 kN **(1)**   4

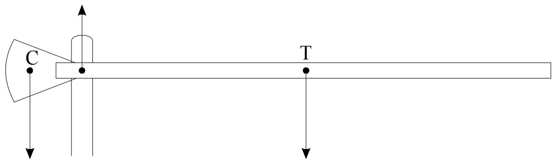
[5]

32. (a) (i) a force multiplied by a distance
perpendicular distance from line of action of the force to the point P **(1)**
(stated or from diagram)

(ii) N m **(1)**   3

(b) (i) force up at pivot **(1)**

two downward forces at correct points **(1)**



(ii) weight of tube (= mg) = 12.0 × 9.81 = 118 N **(1)**

(iii) moments about pivot equated **(1)**
118 × 1.6 = W × 0.3 gives W = 629 (N) **(1)**
(allow e.c.f. for weight in (ii))

mass = $\frac{629}{9.81}$ = 64.1 kg **(1)**   (allow e c f for W)   5

[8]

33. (a) (i) **region A**: uniform acceleration

(or (free-fall) acceleration = g(= 9.8(i) m s^{-2}))

force acting on parachutist is entirely his weight

(or other forces are very small) **(1)**

(ii) **region B**: speed is still increasing

acceleration is decreasing **(2)**   (any two)

because frictional (drag) forces become significant
(at higher speeds)

(iii) **region C**: uniform speed (50 m s^{-1})

because resultant force on parachutist is zero **(2)** (any two)

weight balanced exactly by resistive force upwards   6
QWC

(b) deceleration is gradient of the graph (at t = 13s) **(1)**

(e.g. 20/1 or 40/2) = 20 m s^{-2} **(1)**   2

(c) distance = area under graph **(1)**
suitable method used to determine area (e.g. counting squares) **(1)**
with a suitable scaling factor (e.g. area of each square = 5 m^2) **(1)**
distance=335m (±15m) **(1)**   4

(d) (i) speed = $\sqrt{(5.0^2 + 3.0^2)}$ = 5.8 m s^{-1} **(1)**

(ii) tan $\theta = \frac{3}{5}$ gives θ = 31°**(1)**   2

[14]

34. (a) F cos 20 = 300 gives F = 319 N**(1)**   1

(b) (i) work done = force × distance moved in direction of force **(1)**
F is not in the direction of motion **(1)**

(ii) work done = force × distance = 300 × 8000 = 2.4 × 10^6 J

(iii) power = $\frac{\text{work done}}{\text{time taken}}$ **(1)**

$= \frac{2.4}{5.0 \times (60 \times 60)} \times 10^6$ **(1)** (allow e.c.f. for work done in (ii))

= 133 W **(1)**   (allow e.c.f. for incorrect time conversion)   6

(c) on the level, work is done only against friction **(1)**
uphill, more work must be done to increase in potential energy **(1)**
sensible conclusion drawn
(e.g. increased work at constant power requires longer time) **(1)** 3

[10]

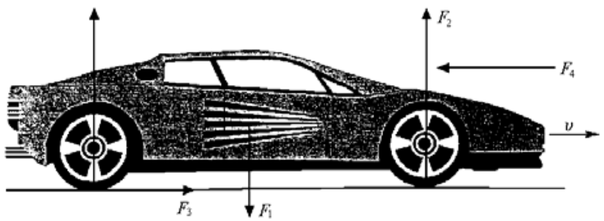
35. (a) $\left({}_1n_2 = \dfrac{\sin\theta_1}{\sin\theta_2}\right.$ gives$\left.\right)$ $1.5 = \dfrac{\sin 35°}{\sin\theta}$ **(1)**
$\theta = 22°$ **(1)** (22.48°) 2

(b) (i) ($\sin\theta_c = 1/n$ gives) $\sin\theta_c = \dfrac{1}{1.5}$ **(1)**
$\theta_c = 42°$ **(1)** (41.8°)

(ii) ray diagram to show:
one total internal reflection **(1)**
with one angle of reflection marked as 68° **(1)**
correct refraction of ray on exit from top surface with 35° marked **(1)**
angle of incidence of 22° marked at point of exit **(1)** 6

[8]

36. (a) (i)



F_1 weight / mg **(1)**
F_2 reaction or normal contact force **(1)**
F_3 driving force **(1)**
F_4 friction or air resistance **(1)**

(ii) zero acceleration **(1)**
zero resultant force **(1)** max 5
QWC

(b) ($P = Fv$ gives) $18 \times 10^3 = F \times 10$ **(1)** (and $F = 1.8 \times 10^3$ N) 1

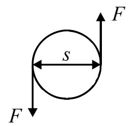
(c) (i) $1800 - 250 = 1.6 \times 10^3$ N **(1)** (1.55×10^3 N)

(ii) force $= 4 \times 1.55 \times 10^3 = 6.2 \times 10^3$ N **(1)**
(allow e.c.f. from(i))

(iii) total force = 6200 + 250(N) **(1)** (= 6.45×10^3(N))
($P = Fv$ gives) $P = 6.45 \times 10^3 \times 20 = 1.3 \times 10^5$ W **(1)** (1.29×10^5 W)
(allow e.c.f. for value of total force) 4

[10]

37. (a) (i)



two forces opposing **(1)**
forces parallel **(1)**
s correct **(1)**

(ii) N m **(1)** 4

(b) (i) anticlockwise moments = clockwise moments **(1)**

(ii) weight of beam acts at centre **(1)**
this is through the pivot **(1)** 3

(c) (equating moments gives) $400 \times 1.0 = 200 \times 0.50 + 250 \times d$ **(1)**
$\therefore 400 - 100 = 250 \times d$ and $d = 1.2$ m **(1)** 2

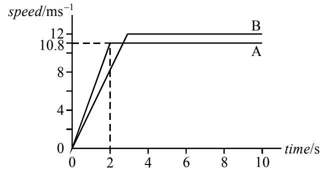
[9]

38. (a) (i) $\left(v = \dfrac{s}{t}\right.$ gives$\left.\right)$ $v = \dfrac{100}{10.2} = 9.8$ m s^{-1} **(1)**

(ii) ($v = at$ gives) $v = 5.4 \times 2 = 11$ m s^{-1} (10.8 m s^{-1})

(iii) ($s = ut + ½at^2$ gives) $s = ½ \times 5.4 \times 2^2$ **(1)**
$= 11$ m **(1)** (10.8 m) 4

(b)



positive slope and then horizontal **(1)**
initial slope correct **(1)**
horizontal line with correct value from (a)(ii) **(1)**

3

(c) (i) t = 2.8 s **(1)**

(ii) (area under graph gives)
athlete B : 15 m **(1)**
athlete A : 11 **(1)** + 8.6(4) = 20 m **(1)** (10.8 + 8.64 = 19.4 m)

(iii) 20 – 15 = 5.0 m **(1)** (19 – 15 = 4.0 m)
(allow e.c.f. from(c)(ii)) max 4

[11]

39. (a) (i) tensile stress: the force per unit cross-sectional area **(1)**
tensile strain: extension per unit length **(1)**

(ii) the Young modulus = tensile stress/tensile strain **(1)** 3

(b) (i) brittle: material A **(1)**

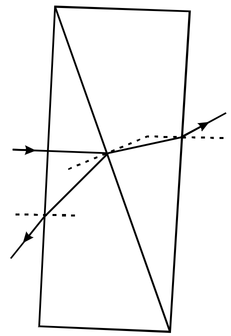
(ii) A, (brittle) obeys Hooke's law (until it fractures without warning) **(1)**
B, (ductile) obeys Hooke's law up to the limit of proportionality **(1)**
beyond this point wire is permanently stretched (or behaves plastically) **(1)**

(iii) A has greatest value of the Young modulus
because of steeper gradient **(1)** max 5

(c) ($Y = \frac{F}{A} \times \frac{l}{e}$ gives) $2.10 \times 10^{11} = \frac{80}{1.3 \times 10^{-6}} \times \frac{1.5}{e}$ **(1)**
$e = 0.44 \times 10^{-3}$ m **(1)** 2

[10]

40. (a)



Ray diagram to show:

(i) refraction towards normal at boundary **(1)**
emerging ray refracted away from normal **(1)**

(ii) reflection at boundary with i ≈ r
emerging ray refracted away from normal **(1)** 4

(b) (i) 20° **(1)**

(ii) ${}_1n_2 = \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\vartheta_2}$ **(1)**

$\frac{1.60}{1.40} = \frac{\sin 20^\circ}{\sin\theta}$ **(1)**

θ_2 = 17 (.4)° **(1)** 4

(c) ($\sin\theta_c = 1/n$ gives) $\sin\theta c = 1/1.60$ **(1)**
$= \theta_c = 38.7°$ **(1)** 2

[10]

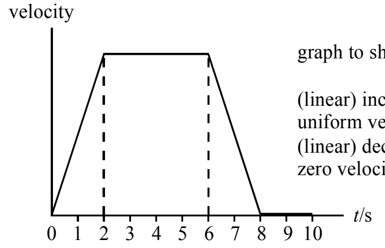
41. (a) (i) rate of change of velocity
[or $a = \frac{\Delta v}{t}$] **(1)**

(ii) (acceleration) has (magnitude and) direction **(1)** 2

(b) (i) (acceleration) is the gradient (or slope) of the graph **(1)**

(ii) (displacement) is the area (under the graph) 2

(c)



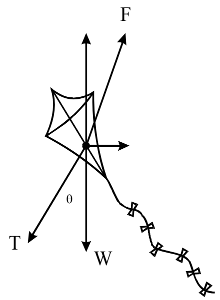
graph to show:

(linear) increase to t = 2.0 ± 0.2 s ✓
uniform velocity between 2.0 s and 6.0 s ✓
(linear) decrease from 6.0 ± 0.2 s to 8.0 s ✓
zero velocity after t = 8.0 s ✓

4

[8]

42. (a)



2

components at right angles **(1)**
vertical component in line with the weight **(1)**
vertical components to start from the •)

(b) (i) (horizontal component) = 25 sin θ = 12 (or 13) N (12.5) **(1)**
(± 0.5N if scale drawing)

(ii) (vertical component) = 25 cos θ = 22 N (21.7) **(1)**
(± 0.5 N if scale drawing) 2

(c) (i) vertical component of F = 21.7 + 2.5 = 24 N (24.2)
[or 25 (24.5)] **(1)**
(allow C.E. from (b))

(ii) horizontal component of F.= 12 (or 13) N **(1)** (12.5)
(allow C.E. from (b))

(iii) F = $\sqrt{(12.5^2 + 24.2^2)}$ **(1)** (allow C.E. from parts (i) and (ii))
= 27 N (27.2) [or 28 (28.2)] **(1)** (26 N to 29 N if scale drawing)
[if θ measured on diagram and F cosθ used, **(1) (1)**
(same tolerance)] 4

[8]

43. (a) sum of clockwise moments equals sum of anticlockwise moments **(1)**
for a body in equilibrium **(1)** 2

(b) point in the body through which the weight/mass (appears to) acts
[or point where resultant torque/moment is zero]
[or point where body would balance] **(1)** 1

(c) (i) towards A **(1)**
so that weight of ruler **(1)**
provides balancing moment **(1)**

(ii) (moments about pivot give) 1.0 × (0.30 – d) = 0.50 × d **(1)**
1.5 d = 0.30 and d = 0.20 m **(1)** 5

[8]

44. (a) decreases for the first four seconds **(1)**
zero for the remaining six seconds **(1)** 2

(b) $E_k = \frac{1}{2} \times 1.4 \times 10^3 \times 16^2$ **(1)**
$= 1.8 \times 10^5$ J **(1)**
(accept v = 15 m s^{-1} from misleading graph and $E_k = 1.6 \times 10^5$ J) 2

(c) (use of $P = Fv$ gives) $20 \times 10^3 = F \times 30$ **(1)**
F = 670 N **(1)** 2

[6]

45. (a) loss of potential energy = $m \times 9.81 \times 6.0$ **(1)**
gain in kinetic energy = loss of potential energy **(1)**
$\frac{1}{2} mv^2 = 58.9\, m$ gives $v = 10.8$ (m s^{-1}) (≈ 11m s^{-1}) 3

(b) loses potential energy (as it moves to B) **(1)**
gains kinetic energy (as it moves to B) **(1)**
regains some potential energy at the expense of kinetic energy
as it moves from B to C **(1)**

some energy lost as heat (due to friction) **(1)** 4 QWC

[7]

46. (a) (i) (use of $v^2 = u^2 + 2as$ gives) $0 = 25^2 - 2 \times 9.81 \times s$ **(1)**
$19.6\ s = 625$ and $s = 32$ m **(1)**

(ii) $t = \frac{25}{9.81} = 2.5$ s **(1)**

(iii) (use of $v^2 = u^2 + 2as$ gives) $v^2 = 25^2 - 2 \times 9.81 \times 16$ **(1)**
(allow C.E. from (a)(i))
and $v = 18$ m s^{-1} **(1)** max 4

(b) time to stop the ball is greater **(1)**
∴ rate of change of momentum is less **(1)**
[or work done on ball is the same but greater distance **(1)** ∴ less force **(1)**] 2

[6]

47. (a) (i) diagram to show:
(long) wire fixed at one end **(1)**
mass/weight at other end **(1)**
measuring scale **(1)**
mark on wire, or means to measure extension **(1)** max 3

[alternative for two vertical wires:
two wires fixed to rigid support **(1)**
mass/weight at end of one wire **(1)**
other wire kept taut **(1)**
spirit level and micrometer or sliding vernier scale **(1)**]

(ii) measurements:
length of the wire between clamp and mark **(1)**
diameter of the wire **(1)**
extension of the wire **(1)**
for a known mass **(1)** max 3

(iii) length measured by metre rule **(1)**
diameter measured by micrometer **(1)**
at several positions and mean taken **(1)**
(known) mass added and extension measured
by noting movement of fixed mark against vernier scale
(or any suitable alternative) **(1)**
repeat readings for increasing (or decreasing) load **(1)** max 5

(iv) graph of mass added/force against extension **(1)**
gradient gives $\frac{F}{e}$ or $\frac{m}{e}$ **(1)**
correct use of data in $E = \frac{Fl}{eA}$ where A is cross-sectional area **(1)**
[if no graph drawn, then <u>mean</u> of readings
and correct use of data to give 2_{max}) **(1)** max 2 QWC

(b) (i) for steel (use of $E = \frac{Fl}{eA}$ gives) $e = \frac{Fl}{EA}$ **(1)**

$e = \frac{125 \times 2}{2.0 \times 10^{11} \times 2.5 \times 10^{-7}}$ **(1)**

$= 5.0 \times 10^{-3}$ m **(1)**

(ii) extension for brass would be 10×10^{-3}(m) (or twice that of steel) **(1)**
end A is lower by 5 mm √ (allow C.E. from (b)(i)) max 3

[16]

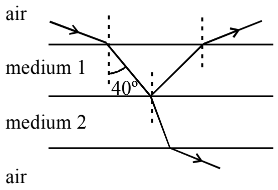
48. (a) graph to show:
maxima of successively smaller intensity **(1)**
subsidiary maxima/minima equally spaced **(1)**
(at least two each side of central axis)
width of subsidiary sections half width of central section **(1)**
symmetrical pattern each side of central axis **(1)** 4

(b) (i) broader maxima or pattern **(1)** [or fringes wider apart]
dimmer pattern **(1)**

(ii) maxima are closer **(1)** [or narrower fringes]
green and dark regions **(1)** max 3

[7]

49. (a)



(i) incident angle > 40° **(1)**
angle of refraction into medium 2 < 40° **(1)**
emergent ray with correct refraction **(1)**

(ii) reflection at boundary between media with $i \approx r$ **(1)**
(hence) emergent ray at approximately same angle as incident ray
and showing correct refraction **(1)** max 4

(b) (i) (use of $_1n_2 = \frac{\sin\theta_1}{\sin\theta_2}$ gives) $1.35 = \frac{\sin\theta_1}{\sin 40}$ **(1)**
$\theta_1 = 60(\ 2)°$ **(1)**

(ii) $\left(\text{use of } {}_1n_2 = \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2} \text{ gives}\right)$ $\frac{1.65}{1.35} = \frac{\sin 40}{\sin\theta_2}$ **(1)** **(1)**
$\theta = 31.7°$ **(1)** 5

(c) (total internal reflection) only occurs when light goes
from a higher to a lower refractive index
[or goes from a more dense to a less dense medium/material] **(1)** 1

[10]

50. (a) AB: (uniform) acceleration **(1)**
BC: constant velocity/speed or zero acceleration **(1)**
CD: negative acceleration or deceleration or decreasing speed/velocity **(1)**
DE: stationary or zero velocity **(1)**
EF ; (uniform) acceleration in opposite direction **(1)** 5

(b) area under the graph **(1)** 1

(c) distance is a scalar and thus is the total area under the graph
[or the idea that the train travels in the opposite direction] **(1)**
displacement is a vector and therefore the areas cancel **(1)** 2

[8]

51. (a) (use of $F = ma$ gives) $F = 1.3 \times 10^3 \times 2.5$ **(1)**
$= 3250$ N **(1)**(3.25×10^3) 2

(b) (i) driving force = 3250 + 410 = 3660 N **(1)**
(allow C.E. from (a))

(ii) (use of $P = Fv$ gives) $P = 3660 \times 2.2$ **(1)**
(allow C.E. from(i))
$= 8100$ W **(1)** (8.1×10^3) 3

(c) (component of) car's weight opposes motion
[or overcomes gravity
or more work is done as car gains potential energy] **(1)** 1

[6]

52. (a) (rate of change of horizontal) displacement is constant **(1)**
hence (horizontal) velocity is constant **(1)**
thus no (horizontal) force acting **(1)** max 2

(b) there is a vertical force
[or weight/force of gravity acting on ball] **(1)**
ball therefore accelerates (in vertical direction) **(1)**
acceleration is constant **(1)** max 2

(c) (i) (horizontal) displacement would be less **(1)**

(ii) (vertical) displacement or acceleration would be less **(1)**
effect would increase with time **(1)**
[or air resistance increases with speed until equals weight **(1)**
hence reaches terminal velocity/speed **(1)**] 3

[7]

53. (a) (i) the Young modulus: tensile stress/tensile strain **(1)**

(ii) maximum force or load which can be applied without wire being permanently deformed
[or point beyond which (when stress removed,) material does not regain original length] **(1)** 2

(b) (i) graph: suitable scale **(1)**
correct points **(1)** **(1)**
best straight line followed by curve **(1)**

(ii) indication of region or range of Hooke's law **(1)**

(iii) (use of $E = \frac{Fl}{Ae}$)
values of F and e within range or correct gradient **(1)**
to give $E = \frac{6.7}{4\times10^{-3}} \times \frac{1.6}{8.0\times10^{-8}}$ **(1)**
$= 3.3(5) \times 10^{10}$ Pa **(1)** 8

(c) (i) work done = force × distance **(1)**
= average force × extension (= ½Fe) **(1)**
[or use work done = area under graph
area = ½ base × height]

(ii) energy stored = $\frac{6.7\times4\times10^{-3}}{2}$ **(1)**
$= 13.(4) \times 10^{-3}$ J **(1)** 4

[14]

54. (a) (i) fringes formed when light from the two slits overlap (or diffracts) **(1)**
slits emit waves with a constant phase difference (or coherent) **(1)**
bright fringe formed where waves reinforce **(1)**
dark fringe formed where waves cancel **(1)**
[or if 3rd and 4th not scored, waves interfere **(1)**]
path difference from slits to fringe =
whole number of wavelengths for a bright fringe **(1)**
whole number + half a wavelength for a dark fringe **(1)**
[or phase difference is zero (in phase) for a bright fringe **(1)**
and 180° for a dark fringe **(1)**]

(ii) (interference) fringes disappear **(1)**
single slit diffraction pattern observed
[or single slit interference observed] **(1)**
central fringe (of single slit pattern) **(1)**
side fringes narrower than central fringe **(1)** max 8

(b) (i) fringes closer **(1)**
(because) each fringe must be closer to the centre for the same path difference
[or correct use of formula as explanation] **(1)**

(ii) $\sin\theta_c$ (= $\frac{n_2}{n_1}$) = $\frac{1.32}{1.50}$ **(1)** (= 0.88)
$\theta_c = 61.6°$ **(1)**

(iii) for second light ray, diagram to show:
smaller angle of incidence at P than first ray **(1)**
point of incidence at core/cladding boundary to right of first ray **(1)**
total internal reflection drawn correctly or indicated at point of incidence to right of right angle **(1)**

[alternative if ray enters at P from above:
correct refraction at P **(1)**
TIR at boundary if refraction at P is correct **(1)**
angle of incidence visibly ≥ critical angle **(1)**] 7

[15]

55. (a) vt_b: distance moved (at speed v) before brakes are applied
[or thinking/reaction distance] **(1)**
$\frac{v^2}{2a}$: distance moved while braking [or after applying brakes] **(1)** 2

(b) (i) column B: (8.9) 13.3(5) 17.8 22.2(5) 26.7 31.1(5)
(all values correct to 2 or 3 sig. figs ± 0.2) **(1)**

(ii) column D: 1.3(5) 1.72 2.02 2.39 2.73 3.08
(all values correct to 2 or 3 sig figs ± 0.1) **(1)** 2

(c) graph of $\frac{s}{v}$ against v [or v against $\frac{s}{v}$] **(1)**
axes labelled correctly **(1)** (column D vs column B or A)
appropriate scales **(1)**
at least four points plotted correctly to 1 square **(1)**
acceptable straight line **(1)**
[note: if chosen graph gives a curve (e.g. s against v) then candidate can only score 2nd, 3rd and 4th marks] 5

(d) (i) (intercept) t_b = 0.66 s **(1)** (values in range 0.6 to 0.7 accepted)

(ii) gradient = (any triangle e.g. (3 – 1)/(30 – 4.5))
= 7.8×10^{-2} ($s^2\ m^{-1}$) **(1)**
[other answers, if consistent with graph, acceptable]
gradient = $(1/2a)$ **(1)**
gives $a = 6.4\ m\ s^{-2}$ **(1)** (values in range 6.1 to 6.7 accepted)
(allow C.E. for value of gradient)
[if column D vs column A used, gradient = 0.022
use of conversion factor gives gradient = 0.078 ($s^2\ m^{-1}$)]

[if graph of v against $\frac{s}{v}$, gradient = 12.8 m s^{-2}
= $2a$ for first two marks] 4

[13]

56. (a) (i) θ_c marked **(1)**

(ii) $\sin\theta_c = \frac{1}{n}$ **(1)** $\left(= \frac{1}{1.55}\right)$
$\theta_c = 40.2°$ **(1)** 3

(b) $n = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)**
(θ_2 = 90 – 75.2 = 14.8°)
θ_1 (= $\sin^{-1}${1.55 sin 14.8}) = 23.3° **(1)** 2

(c) Mark scheme not available. 3

[8]

57. (a) (i) resultant force acting on tray is zero [or $P + W = Q$] **(1)**
resultant torque is zero
[or correct moments equation
or anticlockwise moments = clockwise moments] **(1)**

(ii) W= 0.12 × 9.81 = 1.2N **(1)** (1.18N)

(iii) (taking moments about P gives)
Q × 0.1 = 0.12 × 9.81 × 0.25 **(1)**
Q = 2.9 N (2.94 N) **(1)**
P = 2.9 – 1.2 = 1.7 N **(1)** (or 2.94 – 1.18 = 1.76 N)
(allow C.E. for values of W and Q) 6

(b) placed at Q **(1)**
no additional turning moment about Q **(1)** 2

[8]

58. (a) (i) 70 m s^{-1} **(1)**

(ii) v = 9.81 × 2.0 **(1)**
= 20 m s^{-1} **(1)** (19.6 m s^{-1})

(iii) $v = \sqrt{(70^2 + 19.62^2)}$ = 73 m s^{-1} **(1)**
direction: $\tan\theta = \frac{19.6}{70} = 0.28$
θ = 15.6° **(1)** (±0. 10) (to horizontal) **(1)**
(allow C.E. for values of v from (i) and (ii))
[or use of correct scale drawing] 5

(b) (i) air resistance is greater than weight **(1)**
(hence) resultant force is upwards **(1)**
hence deceleration (Newton's second law) **(1)**

(ii) air resistance decreases as speed decreases **(1)**
weight equals air resistance (hence constant speed)
(hence) resultant force is zero (Newton's first law) **(1)** max 4
QWC 2

[9]

59. (a) correct plotting of points **(1) (1)**
increasing load graph **(1)**
decreasing load graph **(1)** 4

(b) (initially) the material/wire obeys Hooke's law
[or behaves elastically] **(1)**
up to the limit of proportionality **(1)**
(beyond this), elastic limit is reached **(1)**
undergoes plastic deformation **(1)**
undergoes permanent change **(1)**
reference to Hooke's law obeyed as load decreases **(1)** max 4
QWC 2

(c) ($E = \frac{Fl}{Ae}$ gives $E = \frac{F}{e} \times \frac{l}{A}$)

gradient = (e.g.) $\frac{46}{4.2 \times 10^{-3}}$ **(1)** (= 1.095×10^4)

$E = 1.095 \times 10^4 \times \frac{3}{2.8 \times 10^{-7}} = 1.2 \times 10^{11}$ **(1)** Pa **(1)** (1.17×10^{11} Pa) 3

(d) area under the graph at any given point 1

[12]

60. (a) (i) (35×9.81) = 343 N

(ii) tension in each cable (= $\frac{mg}{2}$) = 172 N **(1)** 2

(b) area of cross-section (= $\frac{\pi d^2}{4}$) = $\frac{\pi (8.26 \times 10^{-3})^2}{4}$ = 5.36×10^{-5} (m^2) 4

(c) (i) moments about T_2, (cable B) gives
$5.52\ T_1$ **(1)** = 343×2.76 **(1)** + 196×4.52 **(1)**
$T_1 = \left(\frac{1833}{5.52}\right)$ **(1)** (= 332 N)

(ii) $T_1 + T_2 = 343 + 196 = 539$ (N) **(1)**
$T_2 = 539 - 332 = 207$ N **(1)**
(allow C.E. for. value of T_1, from (i))

[or moments about T_1 gives $5.52\ T_2 = (343 \times 2.76) + (196 \times 1.)$ **(1)**
$T_2 = 1143/5.52 = 207$ N **(1)** 6

[12]

61. (a) (i) (use of $n = \frac{c_1}{c_2}$ gives) $c_{glass} = \times \left(= \frac{3.00 \times 10^8}{1.45} \right)$
$= 2.07 \times 10^8$ m s^{-1} **(1)**

(ii) use of $\frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$ **(1)**

$c_{liquid} = \frac{2.07 \times 10^8 \times \sin 29.2°}{\sin 26.6°} = 2.26 \times 10^8$ m s^{-1} **(1)**

(allow C.E. for values of c_{glass} from (i)) 3

(b) use of ${}_1n_2 = \frac{c_1}{c_2}$ and ${}_1n_2 = \frac{n_2}{n_1}$

to give $n_{liquid} = \frac{1.45 \times 2.07 \times 10^8}{2.26 \times 10^8} = 1.33$ **(1)**

$\left[\text{or } n_1 = \frac{c_1}{c_{liquid}} = \frac{3 \times 10^8}{2.26 \times 10^8} = 1.33 \right]$ (allow C.E. for value of c_{liquid})

[or use ${}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2}$ and ${}_1n_2 = \frac{n_2}{n_1}$ = to give correct answer] 2

(c) diagram to show :
total internal reflection on the vertical surface **(1)**
refraction at bottom surface with angle in air greater than that in the liquid (29.2°) **(1)** 2

[7]

62. (a) (i) (gravitational) potential energy to kinetic energy **(1)**

(ii) kinetic energy to heat energy
[or work done against friction] **(1)** 2

(b) e.g. when using light gates
place piece of card on trolley of measured length **(1)**
card obscures light gate just before trolley strikes block **(1)**
calculate speed from length of card/time obscured **(1)**

alternative 1: measured horizontal distance **(1)**
speed = distance/time **(1)**
time **(1)**

alternative 2: measure h **(1)**
equate potential and kinetic energy **(1)**
$v^2 = gh$ **(1)**

alternative 3: data logger + sensor **(1)**
how data processed **(1)**
how speed found **(1)** 3
QWC 2

(c) vary starting height of trolley
[or change angle] **(1)**
the greater the height the greater the speed of impact **(1)**

[or alter friction of surface **(1)**
greater friction, lower speed] **(1)** 2

[7]

63. (i) weight greater than air resistance
[or (initially only) weight/gravity acting] **(1)**
hence resultant force downwards or therefore acceleration (2nd law) **(1)**
air resistance or upward force increases with speed **(1)**
until air resistance equals weight or resultant force is zero **(1)**
leaf moves at constant velocity (1st law)
[or 1st law applied correctly] **(1)**

(ii) air resistance depends on shape
[or other correct statement about air resistance] **(1)**
air resistance less significant **(1)**
air resistance less, therefore greater velocity
[or average velocity greater or accelerates for longer] **(1)** max 5
QWC 2

[5]

64. (a) (i) horizontal component of the tension in the cable **(1)**

(ii) vertical component of the tension in the cable **(1)** 2

(b) (i) $T_{vert} = 250 \times 9.81 = 2500$ N **(1)** (2452 N)

(ii) $T_{horiz} = 1200$ N

(iii) $T^2 = (1200)^2 + (2500)^2$ **(1)**
$T = (1.44 \times 10^6 + 6.25 \times 10^6)^{1/2} = 2800$ N **(1)** (2773 N)
(if use of $T_{vert} = 2450$ N then $T = 2730$ N)
(allow C.E. for values from (b) (i) and (b)(ii))

(iv) $\tan\theta = \frac{1200}{2500}$ **(1)**
$\theta = 26°$ **(1)**
(allow C.E. for values from (b) (i) and (b)(ii)) 6

[8]

65. (a) (i) X **(1)**
stress (force) $\propto$ strain (extension) for the whole length **(1)**

(ii) Y **(1)**
has lower breaking stress (or force/unit area is less) **(1)**

(iii) Y **(1)**
exhibits plastic behaviour **(1)**

(iv) Y **(1)**
for given stress, Y has greater extension
[or greater area under graph] **(1)** 8
QWC 2

(b) (i) (use of $E = \frac{F}{A} \times \frac{l}{e}$ gives)

$$F\left(=\frac{EAe}{l}\right) = \frac{2.0 \times 10^7 \times 0.64 \times 10^{-6} \times 30 \times 10^{-3}}{160 \times 10^{-3}}$$ **(1)**

(1) for data into correct equation, **(1)** for correct area
= 2.4 N **(1)**
(allow C.E. for incorrect area conversion)

(ii) (use of energy stored = ½Fe gives) energy = $\frac{2.4 \times 30 \times 10^{-3}}{2}$ **(1)**
$= 36 \times 10^{-3}$ J **(1)**
(allow C.E. for value of F from (i)) 5

[13]

66. (a) interference or superposition **(1)**
reflection from metal plate **(1)**
two waves of the same frequency/wavelength **(1)**
travelling in opposite directions (or forward/reflected waves) **(1)**
maxima where waves are in phase or interfere constructively **(1)**
minima where waves are out of phase/antiphase or interfere destructively **(1)**
nodes and antinodes or stationary waves identified **(1)** max 4
QWC 2

(b) (i) (distance between minima $= \frac{\lambda}{2}$) **(1)**

$\left(\frac{\lambda}{2} = \frac{144}{9} \text{ gives}\right)$ $\lambda = 32.0$ mm **(1)**

(ii) $c = f\lambda$ and $c = 3 \times 10^8$ (m s^{-1}) **(1)**
$f = \frac{3 \times 10^8}{32 \times 10^{-3}} = 9.38 \times 10^9$ Hz **(1)**
(allow C.E. for value of λ from (i)) 3

[7]

67. (a) (i) initial acceleration/increase of speed **(1)**
reaches a constant speed/velocity **(1)**
acceleration decreases to become zero (at this speed) **(1)**

(ii) drag/frictional forces increases with speed **(1)**
drag equal to weight (– upthrust) **(1)**
no resultant force at terminal speed
[or balanced forces or forces cancel] **(1)** max 5

(b) column C
26.6
39.7 four values correct **(1)**
49.4 all values correct and to 3 or 4 s.f. **(1)**
75.2
118
173.5 2

(c) (i) column E
1.42
1.60
1.69 all values correct and to 3 or 4 s.f. **(1)**
1.88
2.07
2.24

(ii) axes labelled and suitable scales chosen **(1)**
at least 5 points plotted correctly **(1)**
acceptable line **(1)** 4

(d) (i) gradient $= \left((\text{e.g})\ \frac{2.40 - 1.00}{0.7}\right) = 2.0$ **(1)**
$= n$ gradient (= 2) **(1)**

(ii) intercept on y-axis = log k **(1)**
intercept = 1.0 **(1)**
k (= $10^{1.0}$) = 10 **(1)**
units of k: for $n = 2$, mm^{-1} s^{-1} **(1)** max 5

[16]

68. (a) (i) diagram to show: refraction towards normal on entry **(1)**
total internal reflection shown along fibre **(1)**
refraction away from normal on leaving glass **(1)**

(ii) speed of light decreases on entry into glass <u>and</u> increases on leaving **(1)** 4

(b) (i) (use of $\sin \theta_c = \frac{1}{n}$ gives) $\sin \theta_c = \frac{1}{1.57}$) **(1)**

$\theta_c = 39.6°$ **(1)**

(ii) ${}_1n_2 \left(\frac{n_2}{n_1}\right) = \frac{1.57}{1.47}$ **(1)** (=1.07)

$\sin \theta_c = \frac{1}{1.07}$ **(1)**

$\theta_c = 69.4°$ **(1)**

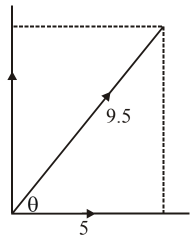
(iii) to protect the core surface
[or to prevent cross-over] 6

[10]

69. (a) (i) a quantity that has magnitude only
[or has no direction] **(1)**

(ii) any two: e.g. energy **(1)**
temperature **(1)** 3

(b) (i)



scale **(1)**
5 N and 9.5 N **(1)**
correct answer (8.1 N ± 0.2 N) **(1)**

[or $9.5^2 = 5.0^2 + F^2$ **(1)**
$F^2 = 90.3 - 25$ **(1)**
$F = 8.1$ N **(1)** (8.07 N)]

(ii) $\cos\theta = \frac{5.0}{9.5}$
gives $\theta = 58°$ **(1)** (± 2° if taken from scale diagram) 4

[7]

70. (a) (i) (use of F = ma gives) $1.8 \times 10^3 = 900\,a$ **(1)**
$a = 2.0$ m s^{-2} **(1)**

(ii) (use of $v = u + at$ gives) $v = 2.0 \times 8.0 = 16$ m s^{-1} **(1)**
(allow C.E. for a from (i))

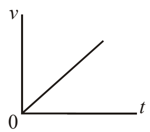
(iii) (use of $p = mv$ gives) $p = 900 \times 16$
$= 14 \times 10^3$ kg m s^{-1} (or N s) **(1)** (14.4×10^3 kg m s^{-1})
(allow C.E. for v from(ii))

(iv) (use of $s = ut + ½at^2$ gives) $s = \frac{1}{2} \times 2.0 \times 8^2$ **(1)**
$= 64$ m **(1)**
(allow C.E. for a from (i))

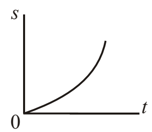
(v) use of $W = Fs$ gives) $W = 1.8 \times 10^3 \times 64$ **(1)**
$= 1.2 \times 10^5$ J **(1)** (1.15×10^5 J)
(allow C.E. for s from (iv))

[or $E_k = ½mv^2 = ½ \times 900 \times 16^2$ **(1)**
$= 1.2 \times 10^5$ J **(1)**
(allow C.E. for v from (ii))] 9

(b)



(1)



(1) 2

(c) (i) decreases **(1)**
air resistance increases (with speed) **(1)**

(ii) eventually two forces are equal (in magnitude) **(1)**
resultant force is zero **(1)**

hence constant/terminal velocity (zero acceleration)
in accordance with Newton's first law **(1)**

correct statement and application of Newton's first
or second law **(1)** max 5
QWC 2

[16]

71. (a) for a body in equilibrium **(1)**
the (sum of the) clockwise moments <u>about a point</u> **(1)**
are equal to (the sum of) the anticlockwise moments **(1)**
[or resultant torque <u>about a point</u> **(1)** is zero **(1)**] 3

(b) (i) diagram to show: pivot/fulcrum/balance point **(1)**
masses or appropriate objects **(1)**

(ii) known masses on either side of pivot **(1)**
move this mass until ruler is in equilibrium/balanced **(1)**
measure distances **(1)**
repeat with other masses **(1)**

(iii) (calculate) weights of masses (on left and right of pivot) **(1)**
product of weight and distance to pivot on either side of pivot **(1)**
hence should be equal **(1)** max 7
QWC 2

[10]

72. (a) tensile stress: (stretching) force (applied) per unit <u>cross-sectional</u> area **(1)**
tensile strain: extension (produced) per unit length **(1)** 2

(b) Hooke's law (or stress ∝ strain) obeyed up to point A **(1)**
A is limit of proportionality **(1)**
elastic limit between A and region B **(1)**
region C shows plastic behaviour or wire is ductile **(1)**
region B to C wire will not regain original length **(1)**
beyond region C necking occurs (and wire breaks) **(1)** max 5
QWC

[7]

73. (a) density = $\frac{\text{mass}}{\text{volume}}$ **(1)** 1

(b) (i) volume of copper = $\frac{70}{100} \times 0.8 \times 10^{-3}$ $(= 0.56 \times 10^{-3}\ \text{m}^3)$

(volume of zinc = $0.24 \times 10^{-3}\ \text{m}^3$)

$m_c\ (= \rho_c V_c) = 8.9 \times 10^3 \times 0.56 \times 10^{-3} = 5.0$ kg **(1)** (4.98 kg)

$m_z = \frac{30}{100} \times 0.8 \times 10^{-3} \times 7.1 \times 10^3 = 1.7$ (kg) **(1)**

(allow C.E. for incorrect volumes)

(ii) $m_b\ (= 5.0 + 1.7) = 6.7$ (kg) **(1)**

(allow C.E. for values of m_c and m_z)

$\rho_b = \frac{6.7}{0.8 \times 10^{-3}} = 8.4 \times 10^3\ \text{kg m}^{-3}$ **(1)**

(allow C.E. for value of m_b)

[or $\rho_b = (0.7 \times 8900) + (0.3 \times 7100)$ **(1)** $= 8.4 \times 10^3\ \text{kg m}^{-3}$ **(1)**] max 4

[5]

74. (a) two waves that overlap/meet/superpose **(1)**
same wavelength or frequency **(1)**
equal and opposite velocities **(1)**
same or similar amplitudes **(1)** max 2

QWC 2

(b) (i) 0.8(0) m **(1)**

(ii) (use of $f = \frac{c}{\lambda}$ gives) $f\left(= \frac{200}{0.8}\right) = 250$ Hz **(1)**

(allow C.E. for value of λ from (i))

(iii) (use of $T = \frac{1}{f}$ gives) $T = \frac{1}{250} = 4.0$ ms **(1)**

3.0 ms = $\frac{3T}{4}$ [or $\frac{3}{4}$ of one cycle or vibration **(1)**

(to be drawn on the diagram)

 **(1)** 5

(allow C.E. for value of T from (ii) if diagram still shows a stationary wave)

[7]

75. (a) (i) $\sin c = \frac{1}{1.5}$ **(1)**

$c = 42°$ **(1)** (41.8°)

(ii) $1.5 \sin i = \sin 40$ **(1)**

$i = 25°$ **(1)** (25.4°) (use of $c = 41.8°$ gives $i = 26.4°$)

(iii) total internal reflection at R **(1)**
further total internal reflection below Q **(1)**
further total internal reflection **(1)** 7

(b) (i) light ray enters fibre without refraction **(1)**
total internal reflection at fibre/air surface **(1)**

(ii) pulse in fibre 1 takes longer because it travels across the fibre as well as along it **(1)** 3

[10]

76. (a) suitable calculation using a pair of values of x and corresponding t to give an average of 2.2 m s^{-1} (± 0.05 m s^{-1}) **(1)**
valid reason given **(1)**
(e.g. larger values are more reliable/accurate
or use of differences eliminates zero errors) 2

(b) (i) column D (y/t (cm s^{-1})
186
210
233
259
284
307 all values correct to 3 s.f. **(1)**

(ii) graph: chosen graph gives a straight line (e.g. y/t against t) **(1)**
axes labelled correctly **(1)**
suitable scale chosen **(1)**
minimum of four points correctly plotted **(1)**
best straight line **(1)**

(iii) u (= y - intercept) = 162 cm s^{-1} (± 4 cm s^{-1}) **(1)**
gradient = 495 (cm s^{-2}) (± 25 cm s^{-2}) **(1)**
k = gradient (= 495 cm s^{-2}) **(1)** 9

(c) (i) u : initial vertical component of velocity **(1)**
(ii) k : = ½ g **(1)** 2

(d) $v^2 = u^2 + 2.2^2$ **(1)**
gives $v = (1.62^2 + 2.2^2)^{1/2}$ = 2.7 m s^{-1} (± 0.1 m s^{-1}) **(1)** 2

[15]

77. (a) microwaves from transmitter are polarised
[or vibrate in certain plane or direction] **(1)**
rotating transmitter through 90° rotates plane of vibration/polarisation of the microwaves **(1)**
receiver signal becomes zero when receiver is perpendicular to plane/direction of vibration/polarisation of the microwaves **(1)** 3
QWC 2

(b) (i) (use of $c = f\lambda$ gives) $f\left(=\frac{3.0\times10^8}{0.12}\right) = 2.5\times10^9$ Hz **(1)**

(ii) no energy/amplitude/intensity/vibrations at nodes **(1)**
food at nodes would not be heated **(1)** 3

[6]

78. (a) (i) (angle) F **(1)**
(ii) angle D is greater than angle B
[or at the glass-water boundary, ray R_1 refracts away from the normal] **(1)** 2

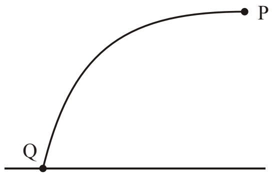
(b) (i) (use of $\sin\theta_c = \frac{1}{n}$ gives) $\sin 48.8 = \frac{1}{n}$ **(1)**
n = 1.3 **(1)** (1.33)

(ii) use of $\frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$ **(1)**
$\frac{\sin 48.8}{\sin 42.9} = \frac{c_{water}}{c_{glass}}$ **(1)**
$\frac{c_{water}}{c_{glass}}$ = 1.1 **(1)** (1.11) 5

(c) ray R_2 to have greater angle of refraction in water than ray R_1 **(1)**
total internal reflection at water-air boundary **(1)** 2

[9]

79. (a) (i)



(1)

(ii) no **horizontal** force acting **(1)**
(hence) no (horizontal) acceleration **(1)**
[or correct application of Newton's First law] 3

(b) (i) (use of $v^2 = u^2 + 2as$ gives) $32^2 = (0) + 2 \times 9.81 \times s$ **(1)**
$s = \frac{1024}{19.62}$ **(1)** (= 52.2 m)

(ii) (use of $s = ½ at^2$ gives) $52 = ½\, 9.81 \times t^2$ **(1)**
$t = \sqrt{\left(\frac{104}{9.81}\right)}$ = 3.3 s **(1)** (3.26 s)

[or use of $v = u + at$ gives $32 = (0) + 9.81 \times t$ **(1)**
$t = \frac{32}{9.81}$ = 3.3 s **(1)** (3.26 s)]

(iii) (use of $x = vt$ gives) x (= QR) = 95 × 3.26 **(1)**
= 310 m **(1)**

(use of t = 3.3 gives x = 313.5 m)
(allow C.E. for value of t from (ii) 6

(c) maximum height is greater **(1)**
because vertical acceleration is less **(1)**
[or longer to accelerate] 2

[11]

80. (a) product of the force and the **perpendicular distance** **(1)**
reference to a point/pivot **(1)** 2

(b) (i) since W is at a greater distance from A **(1)**
then W must be less than P if moments are to be equal **(1)**

(ii) P must increase **(1)**
since moment of girl's weight increases as she moves from A to B **(1)**
correct statement about how P changes
(e.g. P minimum at A, maximum at B, or P increases in a linear fashion) **(1)** max 4

[6]

81. (a) (i) (use of $E_p = mgh$ gives) $E_p = 70 \times 9.81 \times 150$ **(1)**
$= 1.0(3) \times 10^5$ J **(1)**

(ii) (use of $E_k = ½mv^2$ gives) $E_k = ½ \times 70 \times 45^2$ **(1)**
$= 7.1 \times 10^4$ J **(1)** (7.09×10^4 J) 4

(b) (i) work done ($= 1.03 \times 10^5 – 7.09 \times 10^4$) $= 3.2(1) \times 10^4$ J **(1)**
(allow C.E. for values of E_p and E_k from (a))

(ii) (use of *work done* = *Fs* gives) $3.21 \times 10^4 = F \times 150$ **(1)**
(allow C.E. for value of *work done* from (i)
$F = 210$ N **(1)** (213 N) 3

[7]

82. (a) extension proportional to the applied force **(1)**
up to the limit of proportionality
[or provided the extension is small] **(1)** 2

(b) (i) $8 \times 9.81 = 78$ (5) N **(1)**

(allow C.E. in (ii), (iii) and (iv) for incorrect value)

(ii) (use of $E = \frac{F}{A}\frac{l}{e}$ gives) $2.0 \times 10^{11} = \frac{78.5}{2.8\times10^{-7}} \times \frac{2.5}{e}$ **(1)**

$e = 3.5 \times 10^{-3}$ m **(1)**

(iii) similar calculation **(1)**
to give $A_S = 5.6 \times 10^{-7}$ m^2 **(1)**
[or $A_B = 2A_S$ **(1)** and correct answer **(1)**]

(iv) (use of energy stored = ½*Fe* gives) energy stored
$= ½ \times 78.5 \times 3.5 \times 10^{-3}$ **(1)**
$= 0.14$ J **(1)** 7

(c) (i) end A is lower **(1)**

(ii) $= ½\ 3.5 \times 10^{-3} = 1.8 \times 10^{-3}$ m **(1)** (1.75×10^{-3} m) 2

[11]

83. (a) (i) 0, 2π or 4π [or 0, 360° or 720°] **(1)**

(ii) 4λ **(1)**

(iii) $\sin\theta = \frac{CE}{AC}$ **(1)**

[or $\sin\theta = \frac{BD}{AB}$]

CE = 4λ and AC = $2d$ **(1)** (hence result)
[or BD = 2λ and AB = d] max 3

(b) (limiting case is when θ = 90° or $\sin\theta = 1$)

$n\left(= \frac{d\sin\theta}{\lambda}\right) = \frac{2.22\times10^{-6}(\times1)}{486\times10^{-9}}$ **(1)** (= 4.6)

highest order is 4th **(1)** 2

[5]

84. (a) maximum force (from graph) = 1840 (N) (±100 N) **(1)**

max stress $\left(= \frac{\text{force}}{\text{contact area}}\right) = \frac{1840(\text{N})}{550\times10^{-6}(\text{m}^2)}$ **(1)**

(for correct denominator) **(1)**
$= 3.3 \times 10^6$ N m^{-2} **(1)** 4

(b) using shoes without cushioning:
impact time would be less **(1)**
maximum impact force would be greater **(1)**
area under the curve the same **(1)** 3

[7]

85. (a) $c_g \left(= \frac{c_a}{n}\right) = \frac{3\times10^8}{1.5}$ **(1)**

$= 2.0 \times 10^8$ m s^{-1} **(1)** 2

(b) (i) $\sin\theta_1$ ($= n\sin\theta_2$) $= 1.5 \times \sin 15$ **(1)**
$\theta_1 = 23°$ **(1)** (22.8°)

(ii) use of $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ **(1)** (or equivalent)

$n_2 = \frac{1.5 \times \sin 60}{(\sin 90)}$ **(1)**

$= 1.3$ **(1)** 5

(c) total internal reflection at A **(1)**
correct refraction out of glass at r.h. surface **(1)** (same angles as l.h. side) 2

[9]

86. (a) vector quantities have direction (as well as magnitude)
and scalar quantities do not **(1)** 1

(b) vector: e.g. velocity, acceleration, momentum **(1)**
scalar: e.g. mass, temperature, energy **(1)** 2

(c) (i) addition of forces (12 + 8) **(1)**

(use of $F = ma$ gives) $a = \frac{(12+8)}{6.5} = 3.1 \text{ m s}^{-2}$ **(1)** (3.08 m s^{-2})

(ii) subtraction of forces (12 – 8) **(1)**

$a = \frac{(12-8)}{6.5} = 0.62 \text{ m s}^{-2}$ **(1)** (0.615 m s^{-2}) 4

[7]

87. (a) resultant force on crate is zero **(1)**
forces must have equal magnitudes or size **(1)**
(but) act in opposite directions **(1)**
correct statement of 1st or 2nd law **(1)** max 3

QWC 1

(b) (i) work done = $F \times d = 640 \times 9.81 \times 8.0$ **(1)**
$= 5.0(2) \times 10^4$ J **(1)**

(ii) (use of $P = \frac{W}{t}$ gives) $P = \frac{5.02 \times 10^4}{4.5} = 1.1(2) \times 10^4$ W **(1)**
(allow C.E. for value of work done from (i)) 3

[6]

88. (a) (i) car A: travels at constant speed **(1)**

(ii) car B: accelerates for first 5 secs (or up to 18 m s^{-1}) **(1)**
then travels at constant speed **(1)** 3

(b) (i) car A: distance = 5.0 × 16 **(1)**
= 80 m **(1)**

(ii) car B: (distance = area under graph)
distance = [5.0 × ½ (18 + 14)] **(1)**
= 80 m **(1)** 4

(c) car B is initially slower than car A (for first 2.5 s) **(1)**
distance apart therefore increases **(1)**
cars have same speed at 2.5 s**(1)**
after 2.5 s, car B travels faster than car A (or separation decreases) **(1)** max 3

[10]

89. (a) (moment) force × perpendicular **(1)** distance (from the point) **(1)** 2

(b) (i) the point in a body where the resultant torque is zero
[or where the (resultant) force of gravity acts or where the weight acts through] **(1)**

(ii) $F \times 2.5 = 1800 \times 0.35$ **(1)**
$F = 250$ N **(1)** (252 N)

(iii) $F_R = (1800 - 252)$ **(1)**
$= 1500$ N **(1)** (1548) N
[use of $F = 250$ N gives $F_R = 1550$ N or 1600 N)
(allow C.E. for incorrect value of F from (ii)) 5

(c) force must have a horizontal component **(1)**
F (therefore) increases in magnitude **(1)**
and act at an angle (to the vertical) towards the car **(1)** 3

QWC 1

[10]

90. (a) tensile stress: force/tension per unit cross-sectional area or $\frac{F}{A}$ with F and A defined **(1)**

tensile strain: extension per unit length or $\frac{e}{l}$ with e and l defined **(1)**

the Young modulus: $\frac{\text{tensile stress}}{\text{tensile strain}}$ **(1)** 3

(b) (i) $E_S = \frac{F_s}{A}\frac{l}{e}$ **(1)** and $E_B = \frac{F_B}{A}\frac{l}{e}$ **(1)** hence $\frac{E_S}{E_B} = \frac{F_S}{F_B}$

(ii) $\frac{E_S}{E_B} = 2$ **(1)**

$\therefore F = 2F_B$ **(1)**

$F_S + F_B = 15$ N **(1)** gives $F_S = 10$ N

[or any alternative method]

(iii) $\left(E = \frac{F}{A}\frac{l}{e} \text{ gives}\right) \quad e = \left(\frac{F}{A}\frac{l}{E}\right) = \frac{10 \times 1.5}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ **(1)**

$= 5.36 \times 10^{-5}$ m **(1)** 6

[9]

91. (a) (i) particle vibration (or disturbance or oscillation) **(1)**
same as (or parallel to) direction of propagation (or energy transfer) **(1)**

(ii) (particle vibration)
perpendicular to direction of propagation (or energy transfer) **(1)** 3

(b) variation in intensity between max and min (or light and dark) **(1)**
two maxima (or two minima) in 360° rotation **(1)** 2

QWC 1

[5]

92. (a) diagram to show:
total internal reflection on side face **(1)**
ray emerging at base bent away from normal **(1)**
with ≈ correct angles **(1)** 3

(b) $n = \frac{1}{\sin\theta_c}$ **(1)**

$= \frac{1}{\sin 45}$ with calculation **(1)** (= 1.41) 2

(c) $\sin\theta_i = n \sin\theta r$ **(1)**
$\sin\theta_i = 1.41 \times \sin 40$ **(1)**
$\theta_i = 65°$ **(1)** 3

[8]

93. (a) (i) horizontal component = 850 × cos 42 **(1)**
= 630 N **(1)** (632 N)

(ii) vertical component = 850 × sin 42 = 570 N **(1)** (569 N)
(if mixed up sin and cos then CE in (ii))

(iii) weight of girder = 2 × 570 = 1100 N **(1)** (1142 N)
(use of 569 N gives weight = 1138 N)
(allow C.E. for value of vertical component in (ii)) 4

(b) arrow drawn vertically downwards at centre of girder **(1)** 1

[5]

94. (a) weight/gravity causes raindrop to accelerate/move faster (initially) **(1)**
resistive forces/friction **increase(s)** with **speed** **(1)**
resistive force (eventually) equals weight **(1)**
[or upward forces equal downward forces]
resultant force is now zero **(1)**
[or forces balance or in equilibrium]
no more acceleration **(1)**
[or correct application of Newton's Laws]
[if Newton's third law used, then may only score first two marks] Max 4

QWC 1

(b) (i) E_k (= ½mv^2) = ½ × 7.2 × 10^{-9} × 1.8^2 **(1)**
= 1.2 × 10^{-8} J **(1)** (1.17 × 10^{-8} J)

(ii) work done (= mgh) = 7.2 × 10^{-9} × 9.81 × 4.5 **(1)**
= 3.2 × 10^{-7} J **(1)** (3.18 × 10^{-7} J) 4

(c) $v_{\text{resultant}} = \sqrt{(1.8^2 + 1.4^2)}$ **(1)**
$= 2.2(8)$ m s^{-1} **(1)**
$\theta = \tan^{-1}(1.4/1.8) = 38°$ **(1)** (37.9°)
[or correct scale diagram] 3

[11]

95. (a) component (parallel to ramp) $= 7.2 \times 10^3 \times \sin 30$ **(1)** ($= 3.6 \times 10^3$ N) 1

(b) mass $= \dfrac{7.2 \times 10^3}{9.81} = 734$ (kg) **(1)**

$a = \dfrac{3600}{734} = 4.9(1)$ m s^{-2} **(1)** 2

(c) (use of $v^2 = u^2 + 2as$ gives) $0 = 18^2 - (2 \times 4.9 \times s)$ **(1)**
$s = 33(.1)$ m **(1)**
(allow C.E. for value of a from (b)) 2

(d) frictional forces are acting **(1)**
increasing resultant force [or opposing motion] **(1)**
hence higher deceleration [or car stops quicker] **(1)**
energy is lost as thermal energy/heat **(1)** Max 2

[7]

96. (a) Hooke's law: the extension is proportional to the force applied **(1)**
up to the limit of proportionality or elastic limit 2
[or for small extensions] **(1)**

(b) (i) (use of $E = \dfrac{F}{A}\dfrac{l}{e}$ gives) $e_s = \dfrac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}}$ **(1)**
$= 1.3 \times 10^{-4}$ (m) **(1)** (1.33×10^{-4} (m))

$e_b = \dfrac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}} = 4.7 \times 10^{-4}$ (m) **(1)** (4.66×10^{-4} (m))
total extension $= 6.0 \times 10^{-4}$ m **(1)**

(ii) $m = \rho \times V$ **(1)**
$m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3}$ (kg) **(1)**
$m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3}$ (kg) **(1)**
(to give total mass of 44 or 43.8×10^{-3} kg) 7

(c) (use of $m = \rho Al$ gives) $l = \dfrac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}}$ **(1)**
$= 2.2$ m **(1)** (2.16 m)
(use of mass $= 43.8 \times 10^{-3}$ kg gives 2.14 m) 2

[11]

97. (a) same wavelength or frequency **(1)**
(same phase or) constant phase difference **(1)** 2

(b) (i) narrow slit gives wide diffraction **(1)**
(to ensure that) both S_1 and S_2 are illuminated **(1)**

(ii) slit S acts as a point source **(1)**
S_1 and S_2 are illuminated from same source giving monochromatic/same λ **(1)**
paths to S_1 and S_2 are of constant length giving constant phase difference **(1)**
[or $SS_1 = SS_2$ so waves are in phase] Max 4
QWC 1

(c) graph to show:
maxima of similar intensity to central maximum **(1)**
[or some decrease in intensity outwards from centre]
all fringes same width as central fringe **(1)** 2

[8]

98. (a) (i) (use of $n = \dfrac{\sin\theta_1}{\sin\theta_2}$ gives) $1.45 = \dfrac{\sin\theta_1}{\sin 15.5°}$ **(1)**

$\theta 1 = 22.8°$ **(1)**

(ii) $n = \dfrac{1}{\sin\theta_c}$ **(1)**

$n = \left(\dfrac{1}{\sin 38.7^\circ}\right) = 1.6(0)$ **(1)**

use of ${}_1n_2 = \dfrac{\sin\theta_1}{\sin\theta_2}$ and ${}_1n_2 = \dfrac{n_2}{n_1}$ **(1)**

[or $n_1 \sin\theta_1 = n_2 \sin\theta_l$]

$1.45 \sin\theta_3 = 1.60 \sin 51.3$ **(1)**

$\theta_3 = 59.4°$ **(1)**

(allow C.E. for value of n from (ii)) 7

(b) block 1 **(1)**(requires some explanation)

reference to $\dfrac{\sin\theta_1}{\sin\theta_2} = \dfrac{c_1}{c_2}$ **(1)**

[or statement such as light refracts/bends towards normal as it enters a denser/higher refractive index material, or block 1 has lower refractive index] 2

(c) reflection at boundary with i = r **(1)**

refraction (at bottom surface) bending away from normal **(1)** 2

[11]

99. (a) scales **(1)**

six points correctly plotted **(1)**
trendline **(1)** 3

(b) average acceleration = $\dfrac{26}{25}$ **(1)**

$= 1.0(4)\ \text{m s}^{-2}$ **(1)**

(allow C.E. for incorrect values used in acceleration calculation) 2

(c) area under graph **(1)**
= 510 ± 30 m **(1)** 2

(d) (graph to show force starting from y-axis)
decreasing (not a straight line) **(1)**
to zero (at end of graph) **(1)** 2

(e) (since) gradient of a velocity-time graph gives acceleration **(1)**
first graph shows acceleration is decreasing **(1)** 2

[11]

100. (a) (i) (gravitational) potential energy **(1)**
to kinetic energy **(1)**

(ii) both trolley and mass have kinetic energy **(1)**
mention of thermal energy (due to friction) **(1)** 4

(b) masses of trolley and falling mass **(1)**
distance mass falls (or trolley moves) and time taken to fall (or speed) **(1)** 2

(c) calculate loss of gravitational pot. energy of falling mass (mgh) **(1)**
calculate speed of trolley (as mass hits floor),
with details of speed calculation **(1)**
calculate kinetic energy of trolley **(1)**
and mass **(1)**
compare (loss of) potential energy with (gain of) kinetic energy **(1)** Max 4

[10]

101.(a) the point (in a body) **(1)**
where the weight (or gravity) of the object appears to act
[or resultant torque zero] **(1)** 2

(b) (i) $P \times 0.90 = 160 \times 0.50$ **(1)**
$P = 89$ N (88.9 N)

(ii) $Q = (160 - 89) = 71$ N **(1)**
(allow C.E. for value of P from (i)) 3

(c) (minimum) force × 0.10 = 160 × 0.40 **(1)**
force = 640 N **(1)** 2

(d) force is less **(1)**
because distance to pivot is larger **(1)**
smaller force gives large enough moment **(1)** 3

[10]

102. (a) (i) (horizontal) force = zero **(1)**

(ii) (vertical) force = 2 × 15 sin 20 **(1)**
= 10(.3) N **(1)** 3

(b) (i) weight (of block) = 10(.3) N **(1)**
(allow C.E. for value from (a) (ii))

(ii) resultant force must be zero **(1)**
with reference to an appropriate law of motion **(1)** 3

[6]

103. (a) tensile stress: (normal) force per unit cross-sectional area **(1)**
tensile strain: ratio of extension to original length **(1)** 2

(b) (i) loading: obeys Hooke's law from A to B **(1)**
B is limit of proportionality **(1)**
beyond/at B elastic limit reached **(1)**
beyond elastic limit, undergoes plastic deformation **(1)**

unloading: at C load is removed
linear relation between stress and strain **(1)**
does not return to original length **(1)**

(ii) ductile **(1)**
permanently stretched **(1)**
[or undergoes plastic deformation or does not break]

(iii) AD: permanent strain (or extension) **(1)**

(iv) gradient of the (straight) line AB (or DC) **(1)**

(v) area under the graph ABC **(1)** Max 9

(c) $E = \frac{Fl}{Ae}$ **(1)**

$e = \frac{75 \times 3.0}{2.8 \times 10^{-7} \times 2.1 \times 10^{11}}$ =3.8(3) mm**(1)** 2

[13]

104. (a) $n = \left(\frac{\sin\theta_1}{\sin\theta_2}\right) = \frac{\sin 15.0°}{\sin 10.0°}$ **(1)** $(= 1.49)$ 1

(b) TIR on hypotenuse **and** refraction at top surface **(1)**
55°, 10° and 15° all marked correctly **(1)** 2

(c) (i) use of $_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} and _1n_2 = \frac{n_2}{n_1}$
[or $n_1 \sin\theta_1 = n_2 \sin\theta_2$] **(1)**
1.49 sin 55° = 1.37 sin θ_2 **(1)**
θ_2 = 63° **(1)**

(ii) (use of $n = \frac{c_1}{c_2}$) gives 1.37 = $\frac{3.0 \times 10^8}{c_2}$ **(1)**
c_2 = 2.2 ×10^8 ms^{-1} **(1)**
(2.19 × 10^8 ms^{-1})

(iii) refraction at boundary between prisms, refracted away from normal **(1)**
emerging ray (r.h. vertical face) refracting away from normal **(1)** 7

[10]

105. (a) potential energy to kinetic energy **(1)**
mention of thermal energy and friction **(1)** 2

(b) (use of ½ $mv^2 = mgh$ gives) ½ v_h^2 = 9.81 × 1.5 **(1)**
v_h = 5.4(2)ms^{-1} **(1)**
(assumption) energy converted to thermal energy is negligible **(1)** 3

(c) component of weight down the slope causes acceleration **(1)**
this component decreases as skateboard moves further down the slope **(1)**
air resistance/friction increases (with speed) **(1)** 2

(d) (i) distance (= 0.42 × 5.4) = 2.3m **(1)**
(2.27m)
(allow C.E. for value of v_h from (b))

(ii) v_v = 9.8 × 0.42 **(1)**
= 4.1(l) m s^{-1} **(1)**

(iii) $v^2 = 4.1^2 + 5.4^2$ **(1)**
v = 6.8 m s^{-1} **(1)**
(6.78 m s^{-1}) 5

(allow C.E. for value of v_h from (b))

[12]

106. (a) resultant force zero **(1)**
resultant torque about any point zero **(1)** 2

(b) (i) force due to wire P = 5.0 - 2.0 = 3.0 N **(1)**

(ii) (moments give) $5.0 \times d = 2.0 \times 0.90$ **(1)**
d= 0.36 m **(1)** 3

[5]

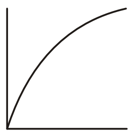
107. (a) (i) (use of $a = \frac{\Delta v}{\Delta t}$ gives) $a = \frac{4.5}{3600}$ **(1)**

$= 1.25 \times 10^{-3}\ \text{ms}^{-2}$ **(1)**

(ii) (use of $v^2 = u^2 + 2as$ gives) $0 = 4.5^2 - 2 \times 1.25 \times 10^{-3} \times s$ **(1)**

$s\left(= \frac{20.25}{2.5 \times 10^{-3}}\right) = 8.1 \times 10^3\ \text{m}$ **(1)** 4

(b) increasing curve **(1)**
correct curve **(1)** 2



(c) gradient (slope) of graph represents speed **(1)**
hence graph has decreasing gradient **(1)** 2

[8]

108. (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**
applies up to the limit of proportionality **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) **(1)**
[or correct use of permanent deformation]

(iii) the Young modulus: ratio of tensile stress to tensile strain **(1)**
unit: Pa or Nm^{-2} **(1)** 5

(b) (i) length of wire **(1)**
diameter (of wire) **(1)**

(ii) graph of force vs extension **(1)**
reference to gradient **(1)**

gradient = $E\frac{A}{l}$ **(1)**

[or graph of stress vs strain, with both defined
reference to gradient
gradient = *E]*

area under the line of F vs e **(1)**
[or energy per unit volume = area under graph of stress vs strain] 6

[11]

109. (a) $\lambda(= 2 \times 38) = 76(\text{m})$

$f\left(\frac{c}{\lambda} = \frac{3.0 \times 10^8}{76}\right) = 3.9(4)\ \text{MHz}$ **(1)** 1

(b) (i) angle between cable and horizontal $= \left(\sin^{-1}\frac{12}{14}\right) = 59^\circ$ **(1)**

$T = 110\cos 59° = 57\text{N}$ • (56.7N) **(1)**

(allow C.E. for value of angle)

(ii) cross-sectional area ($= \pi(2.0 \times 10^{-3})^2$)

$= 1.3 \times 10^{-5}$(m^2) **(1)**

(1.26×10^{-5}(m^2))

stress = $\left(=\frac{tension}{area}\right) = \frac{57}{1.3 \times 10^{-5}}$ **(1)**

$= 4.4 \times 10^6$Pa **(1)**

(4.38×10^6Pa)
(use of 56.7 and 1.26 gives 4.5×10^6 Pa)
(allow C.E. for values of T and area)

(iii) breaking stress is ≈ 65 × stress
copper is ductile
copper wire could extend much more before breaking
because of plastic deformation
extension to breaking point unlikely

any three **(1)(1)(1)** 7

[8]

110. (a) (moment) = 72 × 9.8 × 2.4 **(1)** penalise 1 mark for $g = 10$ m s^{-2}

= 1690 **(1)** Nm **(1)** 3

(b) ½ mv^2 = mgΔh **or** v^2 = u^2 + 2gs **(1)**

v^2 = 9.8 × 3.2 × 2 **(1)** *allow e.c.f. g = 10 m s^{-2}*

v = 7.92 m s^{-1} **(1)** (8.0 m s^{-1} with e.c.f.) 3

(c) from Δmgh or Δ½mv^2 = decelerating force × 1.6 m **(1)**

decelerating force = 1411N (**or** 1440N if g = 10 m s^{-2} used) **(1)**

total average upward force = 1411 + 706 = 2100 (2117)N **(1)** 3

[9]

111. (a) scales **(1)(1)** (one mark for each scale)

six points correctly plotted **(1)(1)**
(ignore 0,0 and lose one mark for each error)

trend line **(1)** (if misses more than two points then lose mark) 5

(b) average acceleration = 26/25 **(1)**

= 1.0(4) m s^{-2} **(1)** e.c.f. from correct values used 2

(c) area under graph **(1)** = 510 ± 30m **(1)** 2

(d) curve decreasing **(1)**

to zero at end of graph **(1)** and starting from vertical axis within 1mm **(1)** 3

(e) (since) gradient of a velocity-time graph gives acceleration **(1)**

(first graph shows) acceleration is decreasing **(1)**

or resistive force increases (with speed) **(1)**

so resultant force (or acceleration) decreases **(1)** 2

[14]

112. (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**

applies up to the limit of proportionality or elastic limit **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length when the force is removed **(1)**
(or correct use of permanent deformation)

(ii) the Young modulus: ratio of tensile stress to tensile strain **(1)**

unit: Pa or Nm^{-2} **(1)** 5

(b) (i) length of wire **(1)**

diameter (of wire) **(1)**

(ii) graph of force vs. extension **(1)**

reference to gradient **(1)** gradient = EA/l **(1)**

(or graph of stress vs. strain, with both defined and gradient = E)

area under the line of F vs. e **(1)** 6

[11]

113. (a) same wavelength or frequency **(1)**

same phase or constant phase difference **(1)** 2

(b) The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question.

Level	Descriptor an answer will be expected to meet most of the criteria in the level descriptor	Mark range
Good **3**	– answer includes a good attempt at the explanations required – answer makes good use of physics ideas including knowledge beyond that given in the question – explanation well structured with minimal repetition or irrelevant points and uses appropriate scientific language – accurate and logical expression of ideas with only minor/occasional errors of grammar, punctuation and spelling	**5-6**
Modest **2**	– answer includes some attempts at the explanations required – answer makes use of physics ideas referred to in the question but is limited to these – explanation has some structure but may not be complete – explanation has reasonable clarity but has a few errors of grammar and/or punctuation and spelling	**3-4**
Limited **1**	– answer includes some valid ideas but these are not organised in a logical or clear explanation – answer lacks structure – several errors in grammar, punctuation and spelling	**1-2**
0	– incorrect, inappropriate or no response	**0**

the explanations expected in a competent answer should include a coherent selection of the following physics ideas:

- narrow single slit gives wide diffraction
- to ensure that both S_1 and S_2 are illuminated
- slit S acts as a point source
- narrow single slit ensures it provides coherent sources of light at S_1 and S_2
- S_1 and S_2 are illuminated by same source giving same wavelength
- paths to S_1 and S_2 are of constant length giving constant phase difference or SS_1 and SS_2 so waves are in phase
- light is diffracted as it passes through S_1 and S_2 and the diffracted waves overlap and interfere
- where the path lengths from S_1 and S_2 to the screen differ by whole numbers, n of wavelengths, constructive interference occurs producing a bright fringe on the screen
- where the path lengths differ by (n + ½) wavelengths, destructive interference occurs producing a dark fringe on the screen

(c) graph to show: maxima of similar intensity to central maximum **(1)**
(**or** some decrease in intensity outwards from centre)

all fringes same width as central fringe **(1)** 2

[10]

114. (a)

property (of laser light)	**explanation**
monochromatic	waves of single frequency/wavelength
collimated	produces an approximately parallel beam
coherent	waves produced are in constant phase
polarised	vibrations in 1 plane only

two correct properties **(1)(1)**

each correct explanation **(1)(1)**
(if explanation contradicts property, no mark for explanation) 4

(b) (i) stepped graph: n = 1.5 A to B **(1)**

n lower and constant between 1.5 and 1.0 B to C **(1)**

n constant at 1.0: C to D **(1)**

(ii) $1.5 = \dfrac{\sin i}{\sin 10}$ **(1)** i = 15(.1)º **(1)**

(iii) light does not enter the cladding
so cannot pass across from one fibre to a neighbouring fibre **(1)**

fibres without cladding can allow light to pass between fibres when the surface of the fibre becomes scratched or moisture links two adjacent fibres optically **(1)**

personal data (such as bank account information) must be transmitted along fibres from which there is no danger of leakage of light resulting in a breach of security **(1)** 8

[12]

115. (a) reflection (or 2 waves travelling in opposite directions) **(1)**

waves have similar amplitudes **(1)**

waves have similar frequency **(1)**

reflected wave loses only a little energy at the wall **(1)** max 3

(b) displacement perpendicular to rest position of the string **(1)** 1

(c) **A** larger than **B** **(1)**

A 180° out of phase with **B** **(1)** 2

(d) $\lambda = 1.2$m **(1)**

$c = f\lambda$ **(1)**

$f = 6.2/1.2$ **(1)** 5.2Hz **(1)** 4

(e) (i) diagram correct: 6 loops **(1)**

(ii) Q and R correct **(1)** 2

[12]