International Baccalaureate®
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MARKSCHEME

May 2009

PHYSICS

Higher Level

Paper 2

General Marking Instructions

Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

Candidates are required to answer **ALL** questions in Section A **[45 marks]** and **TWO** questions in Section B **[2 × 25 marks]**. Maximum total = **[95 marks]**.

1. A markscheme often has more marking points than the total allows. This is intentional. Do **not** award more than the maximum marks allowed for part of a question.

2. Each marking point has a separate line and the end is signified by means of a semicolon (;).

3. An alternative answer or wording is indicated in the markscheme by a slash (/) either wording can be accepted.

4. Words in brackets ( ) in the markscheme are not necessary to gain the mark.

5. Words that are <u>underlined</u> are essential for the mark.

6. The order of marking points does not have to be as in the markscheme, unless stated otherwise.

7. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by writing ***OWTTE*** (or words to that effect).

8. Effective communication is more important than grammatical accuracy.

9. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded.

10. Only consider units at the end of a calculation. Unless directed otherwise in the mark scheme, unit errors should only be penalized once in the paper.

11. Significant digits should only be considered in the final answer. Deduct **1 mark in the paper** for an **error of 2 or more digits** unless directed otherwise in the markscheme.

e.g. if the answer is 1.63:

2	*reject*
1.6	accept
1.63	accept
1.631	accept
1.6314	*reject*

SECTION A

A1. (a) (i) no
the graph is not linear / not a straight line; ***[1]***

(ii) a straight horizontal line through the initial points along the T axis;
a smooth curve through the remaining points (T = 4.4 to 7.0 K); ***[2]***
The straight line and curve do not need to be joined.

(b) $R = 0\,\Omega$; ***[1]***
Do not apply unit mark.

(c) (i) 4.2 – 4.4 K; ***[1]***

(ii) 4.3 K;
± 0.1 (K); ***[2]***
allow ECF from (c)(i)

(iii) more sensitive thermometer / thermometer with a finer graduated scale / by taking resistance measurements at smaller temperature intervals; ***[1]***
*Award **[0]** for electronic digital thermometer **only**.*

(d) the data are for low temperatures well below room temperature;
no reason to assume the trend will continue to room temperature;
the data shows R varying sharply at T_C and another such transition might take place below room temperature;
mercury is a liquid at room temperature; ***[2 max]***
Award any other sensible answer.

A2. (a) $I = F\Delta t$ where Δt is the time for which the force acts/the change in momentum; ***[1]***

(b) (i) initial KE $= \left(\frac{0.075\times 2.20^2}{2}\right) = 0.182\,(\text{J})$;

rebound speed $= \sqrt{\left[\frac{2\times 0.8\times 0.182}{0.075}\right]}$;

$= 1.97\,\text{m s}^{-1}$ ***[2]***

(ii) $\Delta p = 0.075\times 2.20 + 0.075\times 1.97$;

$= 0.313\,\text{N s}$

$=$ impulse; ***[2]***

(c) some recognition that area under graph = impulse;

$\frac{1}{2}F_{\text{max}}T = 0.313$;

$F_{\text{max}} = 7.00\,\text{N}$;

average force $= \frac{1}{2}F_{\text{max}}$ = 3.50 N; ***[4]***

or

impulse $= F_{\text{ave}}\Delta t$;

$F_{\text{ave}} = \frac{impulse}{\Delta t}$;

$= \frac{0.313}{0.0894}$;

= 3.50 N;

Award ***[3 max]*** *if the candidate just writes impulse* $= F\Delta t$ *and not* $F_{ave}\Delta t$.

A3. (a) (i) *internal energy*:
the total (potential energy and) kinetic energy of the (copper) molecules/atoms/particles;

or

amount of stored energy in the copper;

heating:
the (non-mechanical) transfer of energy;
(from the surroundings/source) to the copper; ***[3]***

(ii) $c = \dfrac{\Delta Q}{m\Delta T}$;
$= \left[\dfrac{1.2\times10^3}{0.25\times20}\right] = 240\ \mathrm{J\,kg^{-1}\,K^{-1}}$; ***[2]***

(b) (i) $Q = \Delta U + W$
$Q = +623$;
$W = +249$;
$\Delta U = [623 - 249] = 374\ \mathrm{J}$; ***[3]***

(ii) $C = \dfrac{Q}{\Delta T}$;
$= 20.8\ \mathrm{J\,K^{-1}}$; ***[2]***

(c) less;
because (at constant volume) all the thermal energy supplied goes to increasing the internal energy;
and so the increase in temperature in the constant volume case is greater; ***[3]***

A4. (a) (i) $I_0 = \frac{100}{25} = 4.0\,(\text{A})$;

$I_{\text{rms}} = 2.8\text{ A}$; ***[2]***

or

$V_{\text{rms}} = \frac{100}{\sqrt{2}} = 70.7\,\text{V}$;

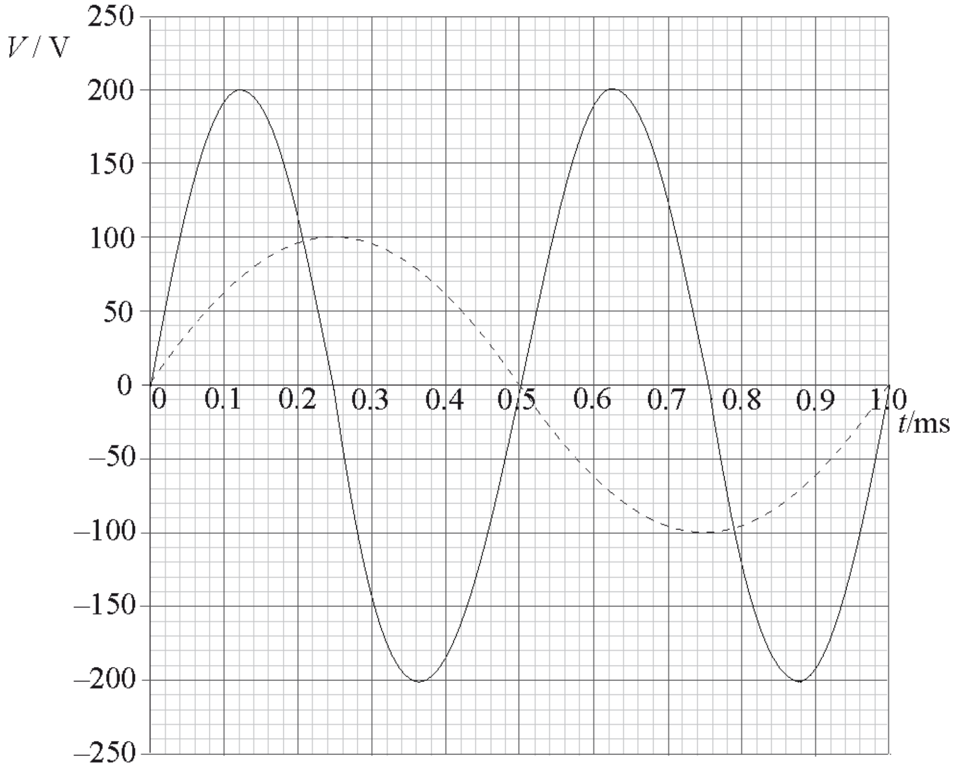
$I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{70.7}{25} = 2.8\,\text{A}$;

(ii) 200 W; ***[1]***

(iii) $V = 60(\pm 2.0)\,\text{V}$;

$P = \left[\frac{V^2}{R}\right] = \left[\frac{60^2}{25}\right] = 140(\pm 10)\,\text{W}$; ***[2]***

(b)



peak voltage of 200 V; *(allow 180 to 200 V)*
period = 0.50 ms; ***[2]***

A5. (a) thermal energy transferred to the surroundings / energy that is converted to thermal energy;
that is no longer available to produce useful work / *OWTTE*; ***[2]***

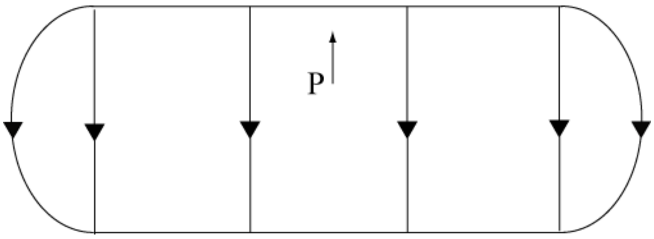
(b) (i) the energy/power available from the (combustion of the) coal; ***[1]***

(ii) $A \rightarrow$ hot gases from burning of coal/into chimney;
$B \rightarrow$ radiation and convection from the boiler;
$C \rightarrow$ friction at the bearings/in the mechanism of the dynamo; ***[3]***

SECTION B

B1. Part 1 Electric fields and electric circuits

(a) (i)



uniform field equal spacing of lines;
edge effect;
direction; ***[3]***

(ii) as shown; ***[1]***

(b) combine $F = qE$ and $F = ma$;

to get $E = \dfrac{ma}{q}$;

$E = 5.0 \times 10^{3}\,\text{N C}^{-1}$ / V m^{-1}; ***[3]***

(c) $V = \dfrac{1.9 \times 10^{-17}}{1.6 \times 10^{-19}}$;

$= 120\ \text{V}$ ***[1]***

(d) (i) 3.0 W; ***[1]***

(ii) power dissipated in battery $= \left(0.25^{2} \times 4.0\right) = 0.25\ \text{W}$;

power dissipated in circuit $= \left(3.0 - 0.25\right) = 2.8\,(2.75)\ \text{W}$; ***[2]***

(iii) power dissipated in lamp $= \left(3.0 \times 0.25\right) = 0.75\ \text{W}$;

power dissipated in resistor $= \left(2.75 - 0.75\right) = 2.0\ \text{W}$;

resistance $\left(= \dfrac{2.0}{0.25^{2}}\right) = 32\,\Omega$; ***[3]***

or

resistance of lamp $= 12\,\Omega$;
$12 = 0.25\,(R + 16)$;
$R = 32\ \Omega$;

or

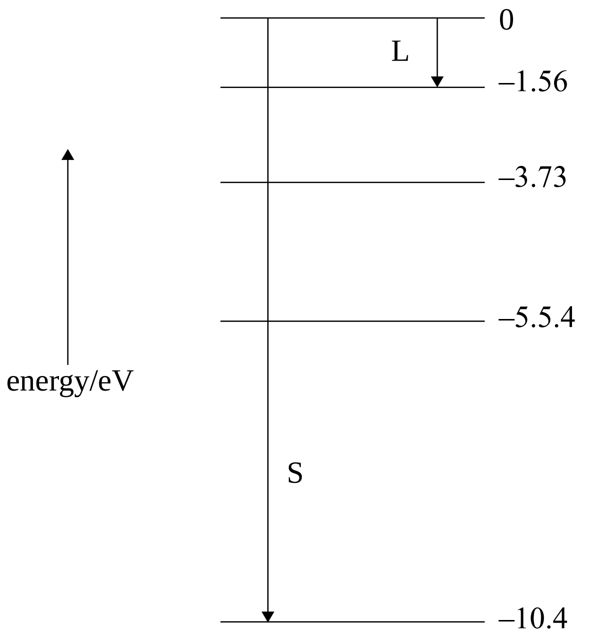
V across $R = 8.0\,\text{V}$;

$R = \dfrac{8.0}{0.25}$;

$= 32\,\Omega$;

Part 2 Atomic and nuclear spectra

(a)



(i) as shown; *(allow transition from –1.56 to –3.73)* ***[1]***

(ii) as shown; ***[1]***

*Award **[1 max]** if (i) and (ii) are labelled the wrong way round or if arrows in wrong direction.*

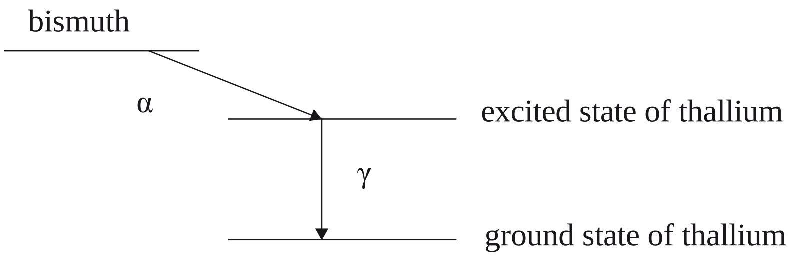
(b) $E = \frac{hc}{\lambda}$;

$\lambda = \frac{6.6\times10^{-34}\times3\times10^{8}}{10.4\times1.6\times10^{-19}}$;

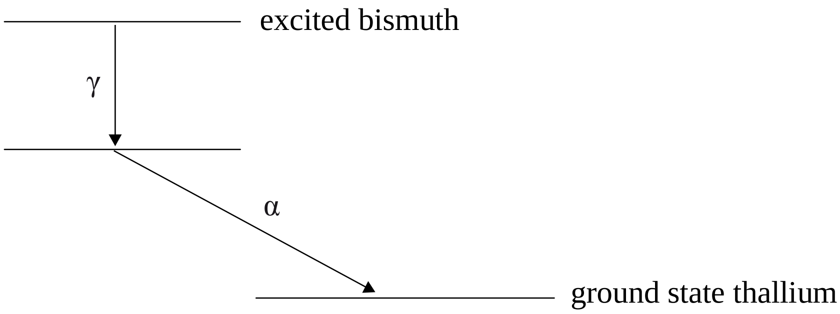
$= 1.20\times10^{-7}$ m; ***[3]***

ECF from (a): if 1.56 eV used, $\lambda = 7.93\times10^{-7}$ m.

(c)



or



labelled bismuth and thallium levels;
α and γ labels; ***[2]***

(d) use of $A = A_0 e^{-\lambda t}$

$\frac{1.13}{2.80} = e^{-80\lambda} = 0.404$;

$\lambda = 0.01134 \left(\text{min}^{-1}\right)$;

$T_{\frac{1}{2}} = \frac{0.693}{0.0113}$;

$\approx 61.1 \text{ min}$; ***[4]***

B2. Part 1 Greenhouse effect

(a) (i) infrared; ***[1]***

(ii) nitrogen dioxide in the atmosphere will readily absorb infrared radiation radiated from the surface of Earth / *OWTTE*;
and re-radiate the energy in random directions (so preventing the energy radiated from Earth escaping into space); ***[2]***

(b) *emissivity*:
the ratio of energy/power emitted (per unit area) of a body;
to the energy/power emitted (per unit area) of a black body of the same dimensions at the same temperature;

or

ratio of power emitted by a body;
to the power emitted if it were a black body;

albedo:
the fraction of energy/power incident in a surface that is reflected / *OWTTE*; ***[3]***
Allow answers that define in terms of the albedo of Earth.

(c) (i) power per unit area $= e\sigma T^4$;
$= 0.720 \times 5.67 \times 10^{-8} \times 242^4$;
$= 140\,\mathrm{W\,m^{-2}}$ ***[2]***

(ii) $= 0.720 \times 344$;
$= 248\,\mathrm{W\,m^{-2}}$ ***[1]***

(d) (i) new power radiated by atmosphere $= \left[0.720 \times 5.67 \times 10^{-8} \times 248^4\right]$
$= 154\,\mathrm{W\,m^{-2}}$; ***[1]***

(ii) new power absorbed by Earth $= (154 + 248) = 402\,\mathrm{W\,m^{-2}}$; ***[1]***

(e) $402 = 5.67 \times 10^{-8} \times T^4$;
$T = 290\ K$;
to give $\Delta T = 2\,\mathrm{K}$; ***[3]***

Part 2 Digital storage devices

(a) (i) 25 = 16 + 8 + 0 + 0 + 1 ;
=11001; ***[2]***

(ii) accuracy–each letter/symbol can be assigned a specific binary number/byte;
reproducibility–data can be retrieved many times without it becoming corrupted / *OWTTE*;
storage/portability–much less space required to store a great deal of data/*e.g.* a large amount of data can be stored on a CD/DVD which is easily carried around / *OWTTE*;
retrieval speed–some comparison *e.g.* internet with library; ***[2 max]***

(b) the pits and bumps / bits of information (on a DVD) are much closer together (than on a CD) / multi-layered data storage; ***[1]***

(c) <u>length of image (on CCD)</u>;
length of object; ***[2]***

(d) length of image of CD $=\left(2.0\times10^{-3}\times1.4\times10^{-2}\right)=2.8\times10^{-5}\,(\text{m})$;

minimum length of pixel $=1.4\times10^{-5}\,(\text{m})$;

minimum number of pixels $=\dfrac{4.0\times10^{-4}}{1.4^{2}\times10^{-10}}$;

$=2.0\times10^{6}$ ***or*** 2.1×10^{6}; *(accept 4.0×10^{6})* ***[4]***

B3. **Part 1** Simple harmonic motion and waves

(a) is proportional to the displacement/distance (of the particle) from its equilibrium position;
is directed towards the equilibrium position; ***[2]***

(b) (i) overall correct shape;
with max of 0.06 J at $x = \pm 0.05$ and zero at $x = 0$; ***[2]***

(ii) $E_{K_{max}} = \frac{1}{2} 4\pi^2 m f^2 x_0^2$;
from the graph $E_{K_{max}} = 0.06(\text{J})$;
and $x_0 = 0.050(\text{m})$;
$f = \sqrt{\frac{2E_{K_{max}}}{4\pi^2 m x_0^2}}$;
to give $f = 2.0$ Hz ***[4]***

or

$k = \frac{2E_{K_{max}}}{x_0^2}$;
$= \frac{2 \times 0.06}{0.05^2}$;
= 48;
use of $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$;
= 2.0 Hz

(c) (i) the energy of the wave is propagated in a direction at right angles;
to the direction of oscillation of the particles; ***[2]***

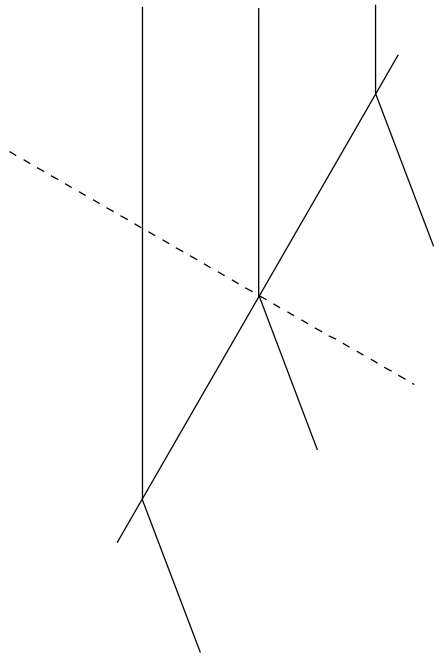
(ii) $\lambda = 0.40$ m; ***[1]***

(d) (i) use of $\sin\theta_2 = \frac{v_2}{v_1}\sin\theta_1$;

$\left.\frac{v_2}{v_1} = 1.5;\right\}$ *this marking point is not necessary to award full credit.*

$\theta_2 = \left[\sin^{-1} 0.75\right] = 49^\circ$; ***[3]***

(ii)



any two lines as shown bending in the correct direction; ***[1]***

Part 2 Gravitational fields and potential

(a) *definition*:
the force exerted per unit mass;
on a small/point/test mass;

relationship:
field strength = (negative) gradient of potential / formula with terms defined; ***[3]***

(b) (i) recognize that ΔV /change in potential energy is negative / potential energy of particle decreases;
therefore a gain in KE / KE is larger; ***[2]***

(ii) this corresponds to the point where the gradient is zero;
$= 4.8 \times 10^9\ m$; *(allow answers in the range of 4.5 to 5.0)* ***[2]***

(iii) field due to M_1 = field due to M_2 at $x = 4.8 \times 10^9$;
$\frac{M_1}{4.8^2} = \frac{M_2}{7.2^2}$;
$\frac{M_1}{M_2} = 0.44$; *(allow answers in the range of 0.36 to 0.48)* ***[3]***

B4. Part 1 Decay of radium-226

(a) (i) *proton number*: 86;
neutron number: 136; } *need both to award the mark.* ***[1]***

(ii) the equation shows a spontaneous change from an unstable state to a more stable state / *OWTTE*;
the less the binding energy per nucleon the more unstable a nucleus so binding energy per nucleon of Ra less than the binding energy per nucleon of Rn / so binding energy per nucleon of Rn greater than binding energy per nucleon of Ra; ***[2]***
Accept answers in terms of negative binding energy per nucleon e.g. the less negative the binding energy per nucleon etc.
Award ***[1]*** *for "number of protons less so (electrostatic) repulsion less and so nucleus more stable".*

(b) $226.0254 = 222.0175 + 4.0026 + Q$;
$Q = 0.0053 \times 931.5\text{ MeV}$;
$= 4.94\text{ MeV}$ ***[2]***

(c) (i) mass of $\alpha = \left(4.0026 \times 1.661 \times 10^{-27}\right) = 6.65 \times 10^{-27}\text{ (kg)}$;

$$v = \sqrt{\frac{2E_{\mathrm{K}}}{m}};$$

$$= \sqrt{\frac{2 \times 4.94 \times 10^{6} \times 1.6 \times 10^{-19}}{6.65 \times 10^{-27}}};$$

$= 1.54 \times 10^{7}\text{ m s}^{-1}$ ***[3]***

(ii) $F = \dfrac{\Delta E_{\mathrm{K}}}{d}$; ***[1]***

(iii) $\Delta E_{\mathrm{K}} = 7.89 \times 10^{-13}\text{ (J)}$;
$F = 1.88 \times 10^{-11}\text{ N}$; ***[2]***

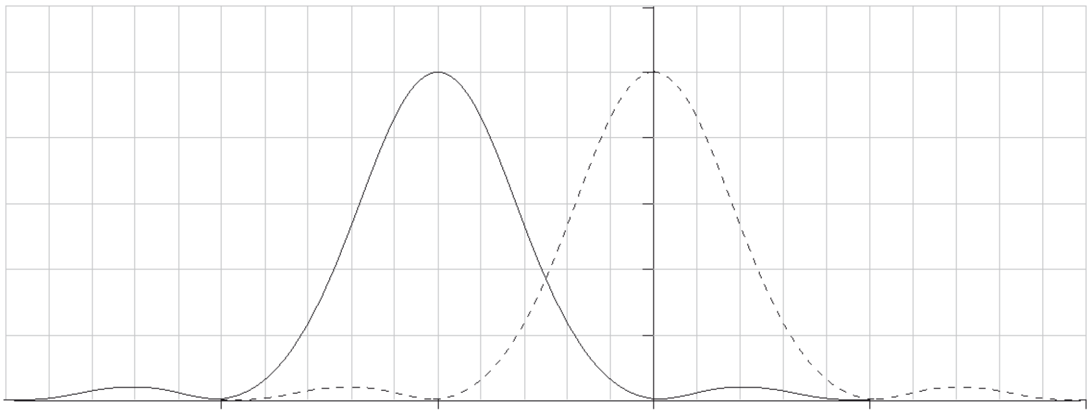
(iv) $a = \dfrac{F}{m}$ ***or*** $a = \dfrac{v^2}{2s}$;
$a = 2.82 \times 10^{15}\left(\text{m s}^{-2}\right)$;
$t = \dfrac{v}{a}$;
$= 5.46 \times 10^{-9}\text{ s} / \approx 5\text{ ns}$; ***[4]***

Part 2 Diffraction and resolution

(a) *Look for an argument that considers destructive interference between light from elements of the slit e.g.*

consider light from the top edge of the slit and light from X then for a destructive interference at M the path difference between them is $\frac{\lambda}{2}$;
this will be true for all elements of the slit that are paired with elements below X / *OWTTE*;
some conclusion *e.g.* for this to be true then l must equal λ; ***[3]***

(b)



same value maximum as maximum of S_2 coincides with minimum of S_1;
minimum of S_2 coincides with maximum of S_1;
*Deduct **[1]** if curve does not touch axis.* ***[2]***

(c) since the wavelength of radio waves is relatively large to get good resolution the aperture must be large / *OWTTE*;
this is achieved by having large dish-like receivers/by separating the receivers by large distances; ***[2]***

(d) angular separation of sources $=\left(\frac{2\times10^{12}}{3\times10^{16}}\right)=6.7\times10^{-5}$ (rad);

angle at which sources are resolved $=\left(1.22\frac{\lambda}{b}=\left(1.22\frac{0.21}{300}\right)\right)=8.5\times10^{-4}$ (rad);

some statement about angles to show that they cannot be resolved; ***[3]***